Compendium of Representative Processing Techniques Investigated in Regulatory Studies for Pesticides

Version history

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13/09/2022	**Publication of the first update of the compendium on EFSA's Knowledge Junction** This update has been prepared by BfR in the framework of the project "First update of the EU database of processing factors for pesticide residues". From now on, the document is a stand-alone document and updated as needed. **Main changes** The following chapters have been added: • 2.1. Use of chlorinated water in various processing steps • 6.5. Rice wine • 7.5. Palm oil and palm kernel oil • 13.2.1. to 13.2.5. Production of sugar from sugar cane **Suggested citation**: Scholz R, Donkersgoed Gv, Herrmann M, Kittelmann A, Kraus C, Schledorn Mv, Mahieu CGK, Velde-Koerts Tvd, Anagnostopoulos C, Bempelou E and Michalski B, 2022. Compendium of Representative Processing Techniques Investigated in Regulatory Studies for Pesticides. Zenodo. https://doi.org/10.5281/zenodo.6564208 **Question number:** EFSA-Q-2021-00791 **Correspondence**: idata@efsa.europa.eu

Summary

This compendium of representative processing techniques describes the most important industrial processes in food production, both with respect to importance in consumption in the EU and production. It serves as a standard reference book, to which processing studies are compared to judge their representativeness. All processes covered by processing studies in the "EU database of processing factors for pesticide residues" are described in this compendium. As new processing studies are frequently submitted in the context of regulatory procedures, the EU database itself, but also the compendium of representative processing techniques require regular updates.

The following main processes have been identified as relevant in food processing:

- Cooking in water
- Steaming
- Canning of fruits and vegetables (including jam/jelly/marmalade production as well as purée and paste production)
- Dehydration/drying of fruits, vegetables, herbs and spices
- Frying and deep-frying
- Baking and roasting
- Microwaving
- Production of fruit and vegetable juices
- Wine manufacturing
- Fermentation and pickling
- Oil production including essential oils
- Soya drink and tofu production
- Beer brewing
- Milling processes
- Starch production
- Cocoa powder production
- Sugar production

For some of the processes the procedures vary for different raw products. These procedures are described individually in the compendium. For each process, a typical set of processing conditions is provided based on published literature and/or inquiry in the food processing industry. Detailed descriptions of processing conditions are given and the processes are visualised in flowcharts. Important intermediate products, products for direct human consumption and products used as feedstuffs are highlighted in the flowcharts by different colours. If yield factors could be retrieved, they are provided for processed products.

Processing studies are almost exclusively conducted on a very limited number of representative commodities. After having evaluated the various processing techniques, some extrapolation proposals are made based on the comparability of processing conditions, the plant anatomy and the similarity of plant parts to be processed. Suggestions for extrapolation are normally restricted to crop groups and are only provided at the level of sub crop groups when processing procedures were found to be closely comparable and differences in residue levels were not expected based on expert judgement.

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1. Introduction

1.1. History

This compendium of processing techniques was originally set up by a consortium that consisted of the German Federal Institute for Risk Assessment (BfR), the Dutch National Institute for Public Health and the Environment (RIVM) and the Greek Benaki Phytopathological Institute (BPI). It was first published as an EFSA Supporting publication in 2018 (Scholz Rebekka et al., 2018).

In the meantime, further processing studies became available in the framework of various regulatory procedures. In 2020, EFSA launched a further project called “First update of the EU database of processing factors for pesticide residues”. This project was executed by the BfR. As part of this project not only the EU database itself, but also the compendium of representative processing techniques was updated accordingly.

As updating the EU database and its accompanying documents is a continuous process, it was decided to publish the compendium from now on as a stand-alone document on EFSA’s Knowledge Junction and to regularly update the list and description of relevant representative processing techniques.

1.2. Representative set of processing studies underlying the compendium

The compendium is based on a representative set of valid and up-to-date regulatory processing studies conducted or contracted by agrochemical companies to elucidate the magnitude of residues in processed commodities according to OECD test guideline 508 (OECD, 2008b) and studies to specify the distribution of residues between inedible peel and pulp. The representativeness of study conditions is verified by current information from published literature and by inquiry in the food processing industry. It is noted that processing studies mainly cover industrial food processing.

The following aspects were considered when compiling the compendium:

- Studies covering processes for commodities of major importance in EU consumer diets and in production are preferred.
- Some by-products obtained during processing are used as feedstuffs. Only those feedstuffs were considered in the compendium, which are listed as relevant for the EU in the current OECD feeding table and in EFSA’s Animal Model calculator for feed (EC, 2017; 2020; EFSA, 2016e; OECD, 2013).
- When fruits or vegetables are canned, they are normally subject to a cooking process prior to canning. The final canned commodity is considered to be the representative end-product in industrial processing, while the cooking step covers household cooking. Where studies investigated the cooked food before and after canning, both are considered relevant end-products. If appropriate, in addition to a processing factor for canning also a processing factor for cooking is reported in the database.
- Slicing, chopping or any other purely mechanical treatment is not considered to have an impact on processing factors and is not considered to justify a separate (sub-)process. Although residues might be affected by enzymes when sliced samples are stored for a long time prior to further processing, it is difficult to retrieve information on this and it is concluded that in the majority of cases residues will not be impacted by slicing.
- Pasteurisation/sterilisation is not considered a separate process but a part of many industrial food processing operations. This step is not considered having a big influence on residue levels, except for residues that are unstable upon heating.
- As far as processing consists of a drying process, this is considered being widely independent of the commodity and the pesticide. Broad extrapolation across commodity groups based on a comparable loss of water is reasonable but literature data has to be further explored.
- Mechanical processes such as peeling are often reported in crop field trials and not in processing trials. Details of the process itself are often not reported and representativeness cannot be

assessed. Only when peeling is part of an industrial process (e.g. industrial peeling of potatoes), the representativeness of this processing technique is addressed.

For some processing operations just one or two studies were available. In such cases a suitable study was chosen on grounds of expert judgement. Vice versa, if a considerable amount of studies was available, this is taken as an indication of importance of the process and/or the processed commodity and is accounted for by selecting an adequate number of corresponding studies for the representative set of studies. They are chosen in order to reflect the anticipated range of processing conditions relevant in food industry.

1.2.1. Point in time when a study has been conducted

Processing studies mimic on laboratory scale the processes normally applied in food industry. Where several studies are available on the same processed product, the more recently conducted studies were preferred, as they are likely to better reflect contemporary technologies.

1.2.2. EU versus non-EU processing technologies

Both EU and non-EU production processes are considered relevant as long as the processed food item forms a relevant part of EU diets and on the other hand the import from third countries is relevant for the respective product. Representativeness regarding the most frequently applied and most up-to-date processing technology is based on expert judgement, including the one coming from experts in food industry.

1.2.3. General quality criteria

More general quality criteria also have to be fulfilled in a satisfactory manner by studies selected as “representative”: this is e.g. a study protocol including full and detailed documentation of all relevant processing parameters like heating regimes (temperature, duration), employment of a fully validated analytical method and sample storage conditions for which storage stability has been demonstrated. In addition, the availability of a full mass balance was preferred. A high number of replicates in a study does not necessarily mean that a study is more reliable, but when two studies were performed according to the same methodology and quality criteria, the study with the higher number of replicates was usually selected for the representative set of studies.

1.2.4. Degree of conservatism of results

In case more than one study is available on the same process/active substance, but they result in clearly different processing factors, the study providing the more conservative factor (“worst case”) was preferentially chosen unless information was available that another process was more representative for European consumers (e.g. based on the market penetration of processed products from a certain country of origin) or that certain aspects of the study were not appropriate.

Whenever conflicts arise on the representativeness of a study regarding the economical relevance of the food processing technology used compared to the conservatism of the technology (higher transfer of residues to the processed product), the first criterion is in principle the most relevant. The study reporting conditions more representative of EU diets was preferred over the study providing more conservative data. However, if two processes are equally relevant from an economical perspective, both are described in the compendium.

1.3. Major features of the compendium of processing techniques

For each process, a typical set of processing conditions is provided based on published literature and/or inquiry in the food processing industry. Detailed descriptions of processing conditions are given and the processes are visualised in flowcharts. The flowcharts contain the most important information on typical processing conditions. Important intermediate products, products for direct human consumption and products used as feedstuffs are highlighted in the flowcharts by different colours (product for direct consumption: blue; important intermediate product: orange; product used as feedstuff: grey).

If yield factors could be retrieved, they are provided. Yield factors are based on the amount of the RAC required for the production of the processed product in question (in weight %).

The yield factor is defined as: $\frac{\text{Mass of processed commodity (kg)}}{\text{Mass of RAC (kg)}} * 100\%$

Usually, yield factors are smaller than 100%. This is due to the removal of non-edible parts like stones or peels, to a loss of water upon concentration or drying (e.g. tomato paste production) or to the separation of certain fractions (e.g. separation of bran and flour).

If the processed product has a higher weight than the RAC because of dilution by addition of water (e.g. beer) or sugar (e.g. jam), an indication is given on how much RAC was used to make the final product.

Proposals for extrapolation to other processed commodities are made (see also chapter 1.5). For each process one or more studies are referenced as being representative of this particular process. A short overview of the processing conditions in each of these representative studies is given to allow comparison with the set of typical processing conditions. The selected studies normally

- were evaluated and considered acceptable in a Reasoned Opinion or Conclusion issued by EFSA;
- were, as far as possible, of recent date (after the year 2000) with more up-to-date processing techniques having been employed;
- fully met the general quality criteria (see chapter 1.2.3).

1.4. Influence of processing conditions on the nature and level of pesticide residues

The nature and level of pesticide residues in food may be affected by the processing conditions.

Heating processes such as cooking in water, pasteurisation, sterilisation or baking may affect the nature of the residue in food through hydrolysis and other break-down processes. Degradation products may be formed or conjugates may get released. During cooking in water or deep-frying in oil, pesticide residues can migrate from the RAC into the cooking water or the oil. The extent of this migration is driven by water or fat solubility of the substance, the liquid/food ratio, the duration of the heating step, the strength of adhesion of residues to plant structures (conjugates), the change in food structure during cooking and the temperature applied during the process.

Heating in open systems (including drying processes) may reduce the level of residues in food through volatilisation of highly volatile compounds of the residue. On the other hand it may increase the level of residues through concentration (evaporation of water from the food).

Furthermore, pH labile residue components may be affected by alkaline or acidic processing conditions, which are widespread in food industry.

Non-systemic pesticides may concentrate on the outer surface of a harvested product. Surface residues may be mechanically removed together with withered leaves, peels, husks, pods or shells. Especially when this separation is done manually, cross-contamination is possible, i.e. residues residing on outer layers may contaminate inner parts of the harvested product by direct contact.

Surface residues may also get removed by washing with water and/or detergents. The extent of residue removal mainly depends on the water solubility of the residue and the strength of its adhesion to plant structures.

1.5. Extrapolation

Processing studies are almost exclusively conducted on a very limited number of representative commodities. Data for comparison of the effect of processing on the magnitude of residues in RACs from the same commodity subgroup are therefore scarce and in many cases not sufficient to underpin extrapolation proposals.

The Guidance Document on magnitude of pesticide residues in processed commodities (OECD, 2008a) indicates that for commodities belonging to the same commodity group and undergoing the same processing operation, the study results obtained on one commodity can be extrapolated to the other, similarly processed commodities of this group. For example, results from studies on the processing of oranges into orange juice can be extrapolated to other citrus fruit juices. Nevertheless, even this apparently clear rule should be cautiously applied and not without closer scrutiny of the processed fraction. For example, rather divergent factors were found in juices originating from pome fruit, but referring to either clear or turbid final products. With a view to the large variety of processed products, an extension of the existing rules for extrapolation would be desirable, but is suffering from a lack of side-by-side processing data for commodities belonging to the same group.

After having evaluated the various processing techniques, some extrapolation proposals have been made. On the one hand, the comparability of the processing conditions was considered, on the other hand the plant anatomy of the crop as well as of the plant part to be processed (e.g. fruit body, root, or seed) was taken into account. Suggestions for extrapolation are normally restricted to crop groups and are only provided at the level of sub crop groups as listed in Regulation (EU) No 2018/62[1] when processing procedures are closely comparable and significant differences in residue levels were not expected based on expert judgement. Although single processing steps may often be comparable, this is normally not the case for the whole process. Extrapolations should therefore be made with care.

Possible extrapolations are suggested in the text describing the representative processes and are summarised in tabular form (Appendix A).

Likewise, it might be worthwhile to explore possibilities of extrapolating processing factors from one substance to another, if closely related in terms of structure and/or physicochemical properties. However, based on the restricted set of representative studies selected for the compendium, which did not aim on a broad coverage of active substances, no such extrapolation proposal was made within the scope of this Compendium.

1.6. Processing codes for representative processes

The Guidance Document on magnitude of pesticide residues in processed commodities (OECD, 2008a) attributes code numbers to all major general processing procedures. These codes consist of Roman numerals. OECD’s coding system has been extended in the framework of the current project. Processing codes are now provided for all representative processes. They consist of the OECD code for the general process, e.g. “preparation of fruit juice” (II) and are complemented by an Arabic numeral, e.g. -001 for the preparation of citrus juice (II-001). A detailed list of all processing codes is provided in Appendix C. The processing codes are also referenced in the figure titles to the processing flowcharts and – if no such flowchart was available for the respective process – in the text.

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[1] Regulation (EU) No 2018/62 of 17 January 2018 replacing Annex I to Regulation (EC) No 396/2005 of the European Parliament and of the Council of 23 February 2005 on maximum residue levels of pesticides in or on food and feed of plant and animal origin and amending Council Directive 91/414/EEC. OJ L 18, 23.01.2018, p. 1-73.

2. Preparatory steps before consuming or processing a raw commodity

For the wide variety of fruits and vegetables, various techniques and machineries are in use to prepare the RAC for further steps such as thermal processing (pasteurisation, sterilisation, dehydration, cooking, canning, etc.), juicing, wine production or fermentation.

It has to be noted, that first cleaning and sorting of agricultural commodities is normally not part of the actual process but of obtaining the RAC as such. For specification of the RACs it is referred to Regulation No 2018/62.

Cleaning

Agricultural commodities may be contaminated with soil particles. The way of cleaning depends on the agriculture commodity and the further processing steps envisaged.

Generally two processes can be distinguished and are often connected (Heiss, 2004):

Dry cleaning

- air to remove rough impurities such as stones,
- vibrating sieve and cleaning drum (e.g. for peas),
- magnet grate

Wet cleaning (usually water)

- washing bath with/without water circulation and brushes
- moving of agriculture commodity through belt washers, drum washers or spiral conveyors
- induced air flotation

Sorting

Damaged items or withered leaves are removed to obtain the RAC as such. The RACs are sorted for different criteria such as size, weight, colour or degree of maturity.

Peeling

Regulation No 2018/62 always defines the RAC as commodity with peel.

Several methods are used to peel fruits or vegetables (Brennan, 2006; Heiss, 2004). An overview is given below. Standard methods for several RACs are explained in the respective chapters. In general, peeling may lead to 5-20% peeling loss (Heiss, 2004). Several RACs contain edible peels and may be processed with or without peel. For example, tomatoes are used with peel for tomato juice and without peel for canned tomatoes.

Steam peeling	During a thermal treatment with a vapor pressure of 4-15 bar in 30-90 s the cell layer under the peel is reached. Because of an abrupt pressure stop peel loosens. Especially root and tuber vegetables and tropical fruits are steam peeled.
Lye peeling	The RAC is transported through a lye bath with a concentration of 0.5-20% alkaline lye. The exposure time ranges from 2 min (90-100°C) to 15 min (50-70°C) depending on the RAC. The lye can be neutralised with 1-2% citric acid. Lye peeling is applied for root and tuber vegetables as well as fruiting vegetables (tomato). For pome fruit a combined treatment with high pressure steam is applied.
Mechanical peeling	The RAC rotates in carborundum-lined bowls or carborundum rollers (with different granulation). Furthermore mechanical peeling knives are applied.

Loosened peel is washed away with water.

Destemming and pitting

Berry fruits are mechanically destemmed. For grapes, combined destemmer-crushers are used prior to wine or juice production. Regulation No 2018/62 defines whether the RAC includes stems or not.

Inedible stones are always considered being part of the RAC according to this Regulation. Though for practical reasons the stones are often removed before homogenization and analysis in surveillance laboratories, the results are recalculated for the RAC to which the MRL applies (fruit with stone). In food processing, fruit pitting machines are in use to remove stones from stone fruits such as cherries, plums or apricots. Plungers are inserted into the RAC to push the stone out. With regard to plums or apricots the plungers are fitted with blades to cut the fruits in halves while pitting. Stone fruits such as cherries are both destemmed and pitted.

Inedible parts of commodities

The following Table 1 gives an overview about the percentage of inedible parts for various commodities, which are always removed before consumption. The inedible parts consist of stones or peel.

Table 1: Percentage of inedible parts for commodities. The data are referenced in the SFK database (SFK, online).

Commodity	Inedible part (weight ∅)	Inedible part
Apricots	9%	stone
Avocados	25%	stone and peel
Bananas	33%	peel
Cherries (sour)	11%	stone
Cherries (sweet)	12%	stone
Kiwis	13%	peel
Mangos	31%	stone and peel
Melons	38%	peel
Papayas	28%	seeds and peel
Passions fruits	39%	peel
Peaches	8%	stone
Pineapples	46%	peel
Plums	6%	stone
Pumpkins	30%	seeds and peel (depending on variety)
Table olives	20%	stone

Crushing and cutting

Fruits and vegetables are crushed or cut prior to processing them into juice, jam or purée. Depending on the RAC different machineries such as roller mills, pin mills or graters are used. Normally these processes do not influence pesticide residue levels.

2.1 Use of chlorinated water in various processing steps

Water is used during preparatory steps (such as wet cleaning or sorting), but also as part of many processes in food industry. It serves as cleaning or transport medium or even as food ingredient (e.g. when it is used for glazing to prevent deep-frozen food from dehydration). This water may have previously been treated with disinfectants according to applicable law. In the European Union, disinfectants are classified as biocidal active substances. Though not allowed for direct treatment of food, they are allowed for treatment of water (Product type 5) or machinery used in food processing (Product type 4) and can cause residues in food. Among others, a couple of chlorinated substances are employed for this purpose, leaving stable disinfection by-products such as chlorate behind. Chlorate is frequently found in processed food (EFSA, 2015h).

The system of processing factors is, however, not applicable to residues in processed products, which are not present in the RAC, but enter the food chain during various steps in food processing. Chlorate residues in food are therefore not covered by entries in the European database of processing factors for pesticides in food.

3. Thermal processes

Information on the effects of heating on the nature of pesticide residues is frequently available from studies according to OECD guideline 507 (OECD, 2007) simulating commonly used processing conditions in terms of temperature, pH and duration of heating. As this information is gained from just model experiments carried out in buffered aqueous solutions, the results are only indicative of which kind of breakdown products may be formed under real processing conditions. When it is known from such experiments that toxicologically relevant breakdown products are formed in relevant amounts, they are usually included in the residue definition for dietary risk assessment. Any study on the magnitude of residues according to OECD guideline 508 (OECD (2008b) which involves heating steps then has to take into account parent and the relevant degradation products in order to obtain processing factors meaningful for both enforcement and dietary risk assessment purposes (OECD, 2008a).

It has to be noted that hydrolysis studies carried out according to OECD 507 may not cover the various thermal processes, which are presented below in more detail, especially not the high temperature processes.

Despite of a broad variety of cooking technologies applied in practice, processing studies normally focus on rather simple water cooking procedures. However for potatoes the effect of frying, baking or microwaving is also reported in some studies. As no stringent conditions are prescribed by OECD 508, important parameters such as heating period, ratio of RAC/water or the size (contact surface) of the RAC, inter-comparison of study results may be difficult even for such a rather easy process.

Heating operations form integral parts of quite a number of food processing procedures. They come in a wide variety of different types and are basically undertaken for two purposes:

- To substantially reduce the number of bacteria and other microorganisms in/on the material for food preservation (e.g. canning of fruit or vegetables),
- To break down the tough connective tissue of otherwise inedible foods, i.e. exerting a desired softening effect on the texture of raw material (e.g. cooking vegetables).

Furthermore, thermal processes such as frying or roasting are conducted to produce flavouring aromas.

The following part gives a short overview of different heat treatments being part of several processes. Some of the processes are described in more detail in subsequent chapters.

Dehydration

During dehydration (drying) the content of water is decreased by different methods such as sun drying or by contact with hot air or heated surfaces. In consequence the amount of water is reduced and microbial growth inhibited. Thus the shelf-life of foods is extended. Such dehydration steps are used e.g. for drying fruits and vegetables (e.g. apples, tomatoes), spices and herbs. Dehydration processes are described in detail in chapter 3.1.

Cooking in water/steaming

Most frequently heating of the RAC is done in cooking liquid (mostly water), serving as a transfer medium for thermal energy flow from the heat source to the raw commodity. The process of cooking is described in detail in chapter 3.1.

Simple cooking of e.g. vegetables without a finishing step such as canning (see chapter 3.3) or other forms of packaging is normally limited to the fresh preparation of daily meals on domestic scale. In this context cooking is predominantly aiming on affecting the texture of the material. Heating of food in water or water-based liquids is normally limited to the boiling point of water under atmospheric pressure.

For steaming, the water is boiled until it vaporises. RACs are not cooked in direct contact with the boiling water but in contact with steam. The steam carries heat to the food, thereby inducing the cooking process. Unlike for cooking in water pesticide residues contained in the food are not solubilised in a surrounding aqueous phase. In order to accelerate the process (shortening of heating period duration), heating to beyond the boiling point can be achieved by pressure cooking which uses a sealed vessel with the trapped steam increasing the internal pressure and allowing the temperature to rise. Steaming is described in chapter 3.2.

Blanching

Blanching is a heat treatment of unpacked raw products used prior to further processing such as pasteurisation and sterilisation, but also canning or freezing. Two basic methods, depending on the RAC, are applied: water blanching and steam blanching. In general the blanching temperature ranges from 70 to 100°C and is hold for 1-15 min (Brennan, 2006; Heiss and Eichner, 2002). The minimum temperature and blanching time depends on the RAC and its size. Table 2 gives an overview. Blanching mainly inactivates food enzymes, removes gases from plant tissues and destroys some microorganisms. Water soluble pesticides can be solubilised by blanching.

Table 2: Water blanching of several commodities (VI-004) - common temperatures and durations (Schuchmann and Schuchmann, 2005).

RAC	Water temperature (°C)	Treatment duration (min)
Cauliflower	95-100	2-3
Green beans with pod	90-100	1.5-3
Carrots	90-100	3-4
Spinach	90-95	1-3
Potatoes	80-95	10-30

Pasteurisation

Pasteurisation is a heat treatment at elevated temperatures below 100°C (Fellows, 2016). Pasteurisation affects the microbial and enzymatic processes and extends the product shelf-life. It does not kill spores or heat resistant bacteria. Pasteurisation can be combined with other preservation processes such as concentration or acidification. Pathogenic spores cannot grow in acidic foods (pH < 4.5) such as yoghurt, fermented products (sauerkraut), beer or acid fruit juices (see Table 3). Hence no sterilisation is necessary.

Depending on the RAC and the pH, the pasteurisation temperature and time differ. Three methods are distinguished: Long-term heating, short-term heating and high temperature heating. In general, the trend in food industry is towards higher temperatures and shorter times (HTST pasteurisation). To achieve higher quality products and/or longer shelf-lives, industry uses novel pasteurisation methods such as high-pressure processing, which involves pressure between 100 and >800 MPa for a millisecond pulse up to several minutes. During this pressure treatment the temperature ranges from below 0°C to above 100°C (Fellows, 2016).

Table 3: Classification of food according to its pH value (Heiss and Eichner, 2002).

pH value	Acidity	Example
pH < 3.7	high-acid	Citrus juice, Sauerkraut
3.7 < pH < 4.5	acid	Tomatoes, Apricots
pH > 4.5	medium to low-acid	Carrots, Peas (without pods) and Beans (with pods)

Sterilisation

The purpose of sterilisation is a complete destruction of microorganisms. Depending on the RAC, temperature and time differ. Sterilisation is usually required for RACs with a pH > 4.5 (see Table 3). The core of the treated food must receive the required heat. Sterilisation is operated in autoclaves at a temperature of at least 120°C. One relevant heat resistant bacterium is Clostridium botulinum, which does not grow below pH 4.5 and at high temperatures. Its destruction requires heating at 121°C. This is a reference temperature for sterilisation processes. Several modes of operation are available. The trend is towards higher temperatures and shorter times such as ultrahigh-temperature (UHT) processing. During UHT processing the food is heated to 130-150°C for a few seconds and finally filled in pre-sterilised containers (Fellows, 2016).

Heating in oil or fat (frying and deep-frying)

Other matrices like oils or fats of vegetable or animal origin may also serve as a heating environment for mostly watery raw materials. Unlike for heating in water, oils and fats allow for considerably high temperatures. Further to thermal disinfection and the cooking effect on the commodities texture, roast aromas and a crunchy food surface are desired effects to achieve. Frying is conducted at temperatures of about 160-190°C (Fellows, 2016). The surface temperature quickly reaches around 100°C. It is emphasised that such extreme thermal conditions are not reflected in studies on the nature of pesticide residues according to OECD 507 (OECD, 2007). The process of frying is described in detail in chapter 3.4.

Baking, roasting, grilling and toasting

Baking, roasting, grilling and toasting are processes which use heated air to change the nature of foods. The main purpose is to destroy micro-organisms and to reduce the water content, but also to achieve a typical aroma in the product.

The terms baking, roasting, grilling and toasting often intermingle, as specific terms exist for specific commodities, but the heating process behind the term may differ.

- The term baking is commonly applied to dough to obtain various pastries and bread by heating in an oven. Baking may also refer to baked potatoes and other roots and tubers (e.g. sweet potatoes).
- The term roasting is commonly applied to coffee beans, cocoa beans, tree nuts or peanuts and refers to dry heating on a heated plate or heated surface. Roasting may also refer to roasted vegetables (e.g. root vegetables, corn-on-the-cob, fruiting vegetables). Sometimes the term toasting is used in the context of nuts. In the framework of this report, the term roasting is used for both, the processing of tree nuts or peanuts and the roasting of coffee or cocoa beans.
- The term grilling is commonly applied to vegetables or animal commodities like meat and fish when heated on a grill plate. Grilling may be done with or without the addition of a little oil to prevent burning.

The process of baking and roasting is described in detail in chapter 3.6.

Microwaving

Microwave heating is applied to induce processes such as cooking, frying, pasteurisation or sterilisation. The microwave operates in a frequency range of 300 MHz to 300 GHz (Fellows, 2016). The process of microwaving is described in detail in chapter 3.7.

3.1. Cooking in water

Cooking is a common process in food production and means that the raw commodity is heated in water at temperatures around the boiling point.

Several vegetables are cooked prior to consumption. The cooking process is comparable for most of the commodities. Table 4 gives an overview of different subgroups of vegetables, which are partially (e.g. carrot) or in almost all cases (e.g. fresh beans with pods) cooked. Cooking is necessary for preservation, softening the texture or even to generate edible food.

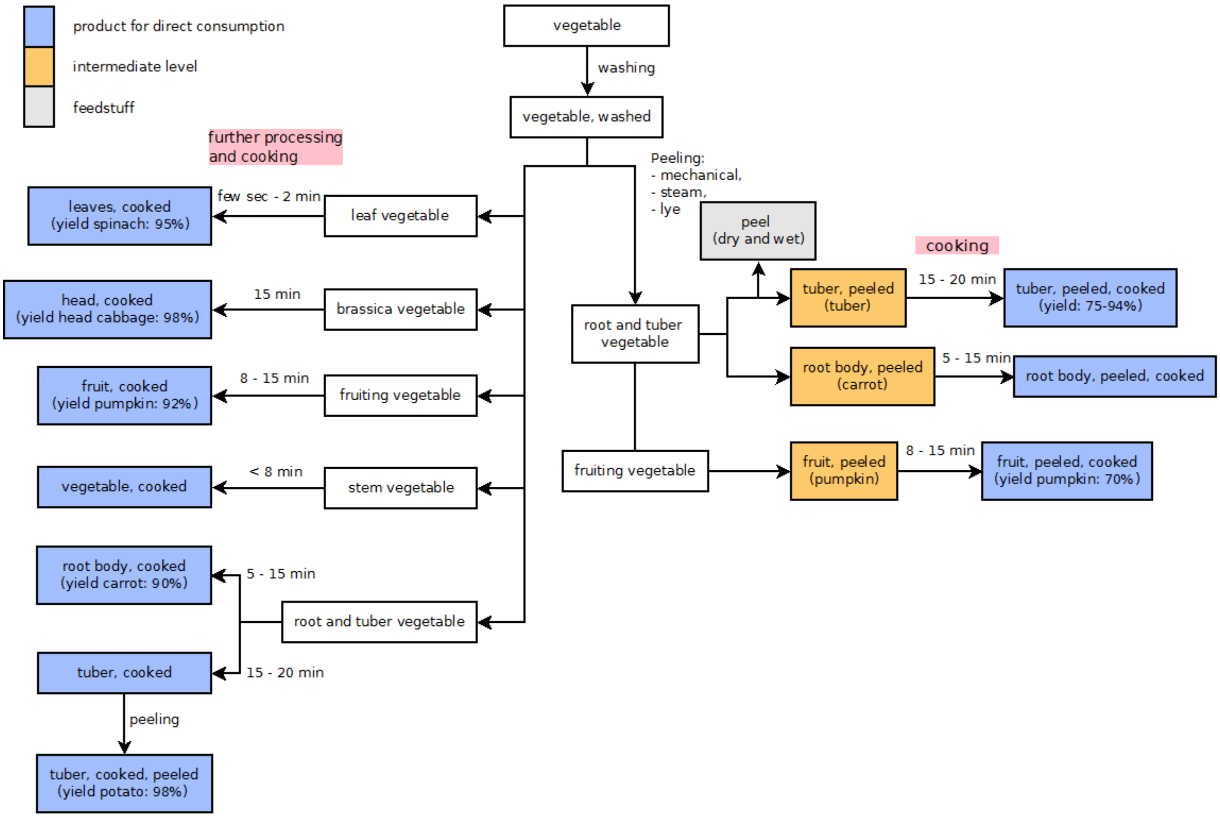
Table 4: Overview of commodities listed in Regulation No 2018/62, which are typically cooked. For italicised commodities processing studies were reported in various EFSA Reasoned Opinions or EFSA Conclusions.

Vegetable subgroup	**Commodity**
Root and tuber vegetables	*Potatoes,* beetroots, *carrots*
Fruiting vegetables	*Sweet peppers, Pumpkins*
Brassica vegetables	*Broccoli, cauliflower, head cabbage, kale*
Leaf vegetables, herbs and edible flowers	*Spinach*
Legume vegetables	*Green beans* (with and without pods), *green peas* (with and without pods),
Stem vegetable	*Celeries, leeks*
Pulses	*Beans, chickpeas, peas, lentils*
Cereals	Rice

3.1.1. Processing details

Several commodities are typically cooked in water. The processing details and the definition of the RAC according to Regulation No 2018/62 may differ in these commodities. In general the RAC is the whole product after removal of tops (if any) and adhering soil (root and tuber vegetables), stems (fruiting vegetables), roots and decayed outer leaves (leaf and brassica vegetables). Damaged or spoiled parts are generally removed. After preparation, the RAC is further processed.

Figure 1 gives an overview of different ways of preparing the major commodities according to (EC, 2020) for cooking and of typical cooking durations.



The final product is the cooked, drained commodity. With regard to spinach, cabbage, pumpkin and carrot, the yield factors refer to the unprocessed RAC, which is prepared and cooked. For processing of pulses see chapter 3.1.5 and for peas with and without pods see chapter 3.1.4. Concerning potatoes the range is due to the range of peeling losses of 6-25%, depending on the peeling method (BLS, 2009; Bognár, 2002; Heiss, 2004).

Figure 1: Overview of cooking processes in water at approximately 100°C (VI-001)

Preparation before cooking in water

The remaining RAC is subsequently rinsed with water to remove undesired soil particles and other pollutants. Detergents and/or disinfectants like chlorine or ozone are sometimes added to the washing water for enhancing the cleaning effect and/or reducing the microbial contamination. The cleaning effect can be further boosted by mechanical brushing.

As a side effect, thorough washing of the RAC may also reduce pesticide remainders, in particular of compounds exhibiting high or even moderate water solubility. As the location of the pesticide residue (e.g. on the surface) is crucial for washing-off effects, it varies from only marginal amounts of residues in washing solutions when substances have passed the epidermis into the interior of a commodity, up to considerable amounts of non-systemic substances which are located on the commodity surface and are easily accessible by the washing solution (Hamilton and Crossley, 2004). Lipophilic pesticide residues are not significantly removed by washing because they are sticking to natural waxy surfaces of fruits (e.g. apples) or vegetables (e.g. cabbages). Warm water and surfactants were shown to be more effective to remove pesticide residues than cold water (Holland et al., 1994).

Several root and tuber vegetables may be peeled before cooking such as sweet potatoes, carrots, beetroots, celeriac or turnips. Three main peeling processes are applied in industry: Steam peeling, lye peeling and mechanical peeling. More details on these techniques are outlined in chapter 2 and for potato in chapter 3.1.2. Pesticide residues located in or on the peel may be reduced by up to 50% upon peeling (Hamilton and Crossley, 2004).

For brassica vegetables such as head brassicas or flowering brassicas the RAC is defined as commodity after removal of roots and decayed outer leaves (different for Brussels sprouts and kohlrabies). Remaining leaves can be removed during processing. Further processing is discussed in chapter 3.1.3.

The stems of legume vegetables with pods are removed prior to further processing. As outlined before, such preparatory steps may reduce the pesticide amount remaining on the prepared RAC. Further processing see 3.1.3.

Cooking in water

The term "cooking" generally refers to the preparation of a RAC in boiling water. Due to the boiling temperature of water the cooking process occurs at approximately 100°C at ambient pressure. The cooking period required for achieving the desired texture strongly depends on the nature of the commodity to be cooked (resistance to softening), but also on shape and size of pieces (e.g. chopped into fine particles or cooked as a whole), as well as the mass ratio of commodity and water. The cooking times shown in Figure 1 should therefore be taken as indicative figures only. RACs with a high water content (e.g. fresh beans) are generally more rapidly cooked compared to drier ones requiring an initial soaking phase (e.g. pulses) and longer times for tissues to disintegrate consequent to solubilisation of binders. Differences of varieties and maturity of the commodity also impact cooking time. The final product is the cooked and drained vegetable. The cooking liquid is not taken into account when deriving the processing factor. On domestic scale the cooking liquid is discarded or retained for soup preparation.

Apart from removing commodity parts, processing factors for cooked vegetables are driven by

- the hydrolytic stability of the pesticide residue
- the volatility of the pesticide
- the tendency of the pesticide residue to migrate from the RAC into the cooking water, which is driven by water solubility, the liquid/food ratio, the strength of adhesion to plant structures (conjugates) and the change in structure of the food during cooking.

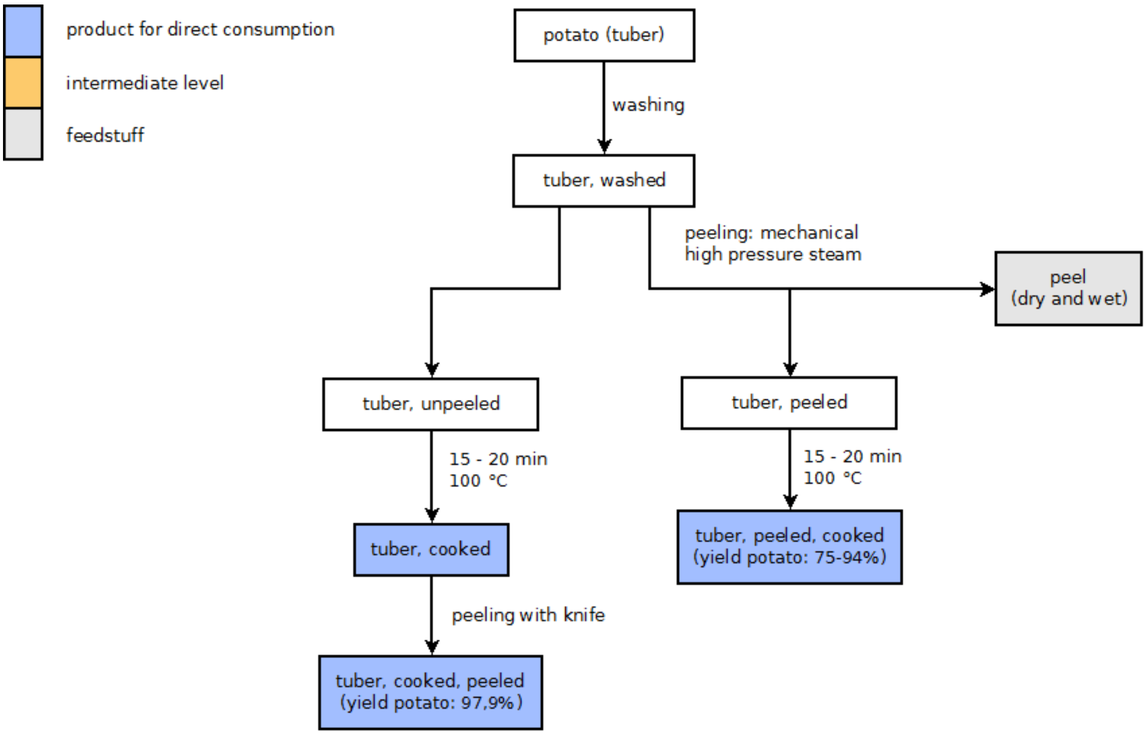
Steam assisted cooking is not uncommonly practised but such conditions are hardly simulated in the laboratory processing studies and data were only sporadically reported for potatoes.

In the following, the cooking process is described in more detail for several representative commodities.

3.1.2. Cooked root and tuber vegetables

Processing code VI-001 is assigned to the cooking root and tuber vegetables.

For the subgroup "root and tuber vegetables" potato was selected as a representative commodity due to a high intake and a large number of adequate processing studies. Potatoes can be processed into a wide variety of products and are among the most consumed commodities in Europe. The process of potato cooking is visualised in Figure 2. At industrial scale the peeled tubers are only pre-cooked. The final cooking is done at consumer level.



The final product is the cooked, drained commodity. The peeled cooked potato contains 94-75% of the raw potato (RAC). The yield range is due to a large range of peeling losses of 6-25% depending on the peeling method, which is referenced in Heiss (2004).

Figure 2: Process of cooking potatoes (VI-001)

Sorting and Washing

Prior to processing, the potatoes are inspected for rut, green or damaged ones and stones. Adhering soil can be removed with dry cleaning methods. The remaining RAC is washed with fresh tab water to remove remaining soil.

Peeling

The washed potatoes can be processed as peeled or unpeeled tubers. Two typical processes are applied for peeling:

- *Steam peeling:* Steam peeling is particularly suited to root crops. The potatoes are exposed to high pressure steam for an exposure time of 10 to 90 s. When the skin is loosening it can be removed with a water spray or an abrasive peeler (Brennan, 2006; Heiss, 2004). The peeling loss is about 6 to 15% of the total weight (Heiss, 2004). Industry reports a peeling loss of 5-30% (BOGK, 2018).
- *Mechanical peeling:* Raw potatoes can be peeled mechanically with an abrasion peeler. The peel is removed with carborundum rollers or rotated in a carborundum-lined bowl. Mechanical knives can be used as well. The rubbed-off peel is washed away with water. The peeling loss is normally in a range of about 15 to 25% of the total weight and higher than for steam peeler treatment (Heiss, 2004). Industry reports a peeling loss of 5-30% (BOGK, 2018). On domestic level, a peeling knife or peeler is normally used.

Finally the potatoes are checked for peeling rests which are removed before cooking. Whilst on industrial scale optoelectronic equipment is used, in laboratory studies this is made by hand. If potatoes are cooked with peel, they can be peeled afterwards with a knife. As the skin can be selectively removed, the overall peeling loss is less compared to potatoes which are peeled before cooking.

Cooking

The cooking time depends on size and variety of the potato (Heiss, 2004). The unpeeled or peeled potatoes are cooked for approximately 15 - 20 min at approximately 100°C, sometimes sodium chloride is added. The final product is the cooked, drained commodity. At industrial scale the peeled tubers are only pre-cooked. The final cooking is done at consumer level.

3.1.2.1. By-products of potato cooking

Cooked potatoes as well as potato culls (unpeeled) and by-products from potato processing operations, e.g. wet and dry peel, can serve as component in diets of various livestock animals (OECD, 2013).

3.1.2.2. Scientific studies reflecting typical processing operations

The peeling process is an important key step, because the amount of removed peel affects the level of pesticide residue in the remaining peeled and cooked potatoes. The available processing studies do not always provide details about the peeling process. Three studies, cited by EFSA, were chosen as representative. The studies describe different peeling processes. The majority of studies reports potato peeling by hand with a vegetable peeler, which does not represent industrial processing. Only the third study (Rice, 2009) describes a common industrial peeling method (and further processing to potato flakes). Peeling by hand with a vegetable peeler leads to a higher weight loss and reduction of pesticide residues than steam peeling.

The peeling of potatoes by hand with a vegetable peeler is reported by Hoven and Nixon (2012), cited by EFSA (2014g) and acceptable according to the quality criteria. Two subgroups were analysed: Peeled and unpeeled cooked potatoes. The tubers were rinsed in tab water to remove soil, any eyes were removed too. One half was peeled by hand with a vegetable peeler and lightly rinsed with tab water. The other group remained unpeeled. The subgroups were placed in boiling water and cooked for 20 min.

In contrast Melrose and Eberhardt (2006) describe the peeling of potatoes after cooking. The study is cited by EFSA (2005) and acceptable according to the quality criteria. The potatoes were sorted and washed in tab water. The washed and unpeeled potatoes were boiled in water at approximately 100°C for about 25 min, sodium chloride was added. After cooking the tubers were peeled thinly with a knife.

The study of Rice (2009) is cited by EFSA (2012d) and is acceptable according to the quality criteria. It represents a third possibility of peeling potatoes, the steam peeling. First the potatoes were washed in water. The potatoes were peeled with 6,9-8,3 bar pressure steam peeler for 45-60 s. To remove loosened skin, the potatoes were scrubbed in batches using a restaurant style fitted with a rubber scrubber for 15-30 s. The peeled potatoes were further processed to potato flakes.

3.1.2.3. Extrapolation to other commodities

Noting widely comparable conditions, the extrapolation of results gained in processing studies on cooking of potatoes to other root and tuber vegetables e.g. carrots, seems justified. Also carrots can be cooked in boiling water, processed in microwave ovens or pressure cookers or be steam cooked.

Carrots are first washed in tap water and sorted for damaged or rotten ones. Then the washed carrots are peeled manually or with industrial food processors. In household processes, carrots may also remain unpeeled. Depending on the size (half carrot or chopped) the carrots are cooked in water for 5-15 min at approximately 100°C. If only blanched, carrots can be further processed to canned carrots (see 3.3.1).

Reported differences in cooking time of 5-15 min for carrots compared to 15-20 min for potatoes are assumed being caused by different size of pieces.

3.1.2.4. Comparison to industrial and/or household processing techniques

In food manufacturing industry peeling is practised with steam pressure as well as mechanically with abrasive peeler or mechanical knifes. In household preparation, root and tuber vegetables are peeled by hand with vegetable peelers or knife, though electric fruit and vegetable peelers are sometimes also available. Depending on the method, peeling losses are in a range of 6-25% (see 3.1.2). Quite obviously the thickness of removed outer layers significantly affects the remaining amount of pesticide and thus the peeling factor.

Irrespective of scale, cooking in water proceeds more or less at the boiling point of water and no significant differences are anticipated between industrial and household preparation. Cooking times are typically seen between 5 and 20 min, depending on variety, size of the pieces and desired degree of softness. At industrial scale the peeled tubers are only pre-cooked. The final cooking is done at consumer level.

When potatoes are peeled after cooking, peeling losses are considerably lower, as the thin ultimate layer can easily be removed in a selective manner. Differences between industrial and household preparation are only small in this case.

At domestic level the cooking liquid may be used for sauces or soups, but not at industrial scale.

3.1.3. Cooked brassica vegetables

Processing code VI-001 is assigned to the processing of cooking brassica vegetables.

The RAC definition depends on the brassica subgroup. Flowering and leafy brassicas and head cabbage are defined as the whole plant after removal of roots and decayed leaves. Brussels sprouts are defined as the cabbage buttons and kohlrabies as the whole product after removal of roots, tops and adhering soil (if any). Remaining leaves can be processed.

The outer leaves or upper parts of the crops are predominantly exposed to pesticide spraying. As a consequence the pesticide residues may be reduced when these parts are removed and discarded. This effect is very pronounced for head forming species, where the outer leaves are wrapping, thus protecting the interior heart/curd of the crop from getting exposed. There is evidence from quite a number of crop field trials on brassica vegetables that discarding upper/outer protective leaves substantially lowers the residue concentration of the trimmed commodity. The remaining RAC is washed in water and cooked for up to one hour, again depending on the desired bite strength, size and age of the commodity.

Unlike for outer/upper leaves, the removal of stalks (e.g. head cabbage) is not anticipated to further reduce the residue level.

3.1.3.1. Scientific studies reflecting typical processing operations

EFSA has reported processing studies on cabbage. One of these studies was chosen as representative for the cooking of cabbage (Gardinal, 2006). The study is cited by EFSA (2012c) and is acceptable according to the quality criteria. For the cooking process head cabbage was washed with water sprayed from constant gas pressure sprayer and strained afterwards. The cores and external leaves were removed. The trimmed cabbages were cut into portions and cooked in boiling water for about 15 min.

3.1.3.2. Extrapolation to other commodities

For most brassica vegetables heating is necessary to achieve a better digestibility. The cooking process is in principle comparable for different brassica species. Depending on the RAC the cooking time can differ. Extrapolation should be restricted to the respective subgroup of brassica vegetables due to different RAC definitions and consequently different preparatory steps.

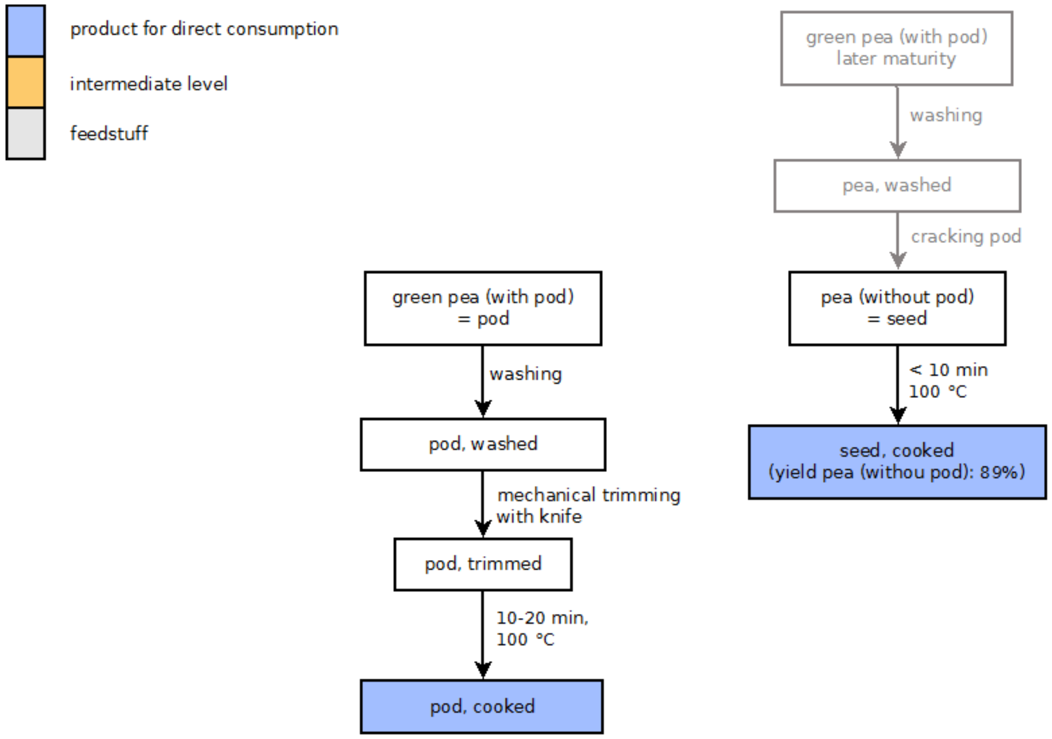
3.1.4. Cooked legume vegetables

Processing code VI-002 is assigned to the processing of cooking legume vegetables.

Regarding the subgroup of legume vegetables, beans and peas are selected as representative commodities. Raw beans contain harmful substances which need to be inactivated by cooking prior to human consumption.

To differentiate phenological stages of legume vegetables, the BBCH scale is used (Feller et al., 1995; Weber and Bleiholder, 1990). Green beans/peas with pods are harvested young at about BBCH 75 and are consumed along with a tender pod and rudimentarily developed seeds. Green peas without pods are harvested at a later BBCH stage of about 79 when the green pea seeds are further developed and can be separated from the pods.

For green beans and peas with or without pods the whole commodity is defined as the RAC. They are consumed after having been cooked. The processing is shown in Figure 3 and is described below.



Both peas with pods and peas without pods are defined as RACs. Preparatory steps (pre-RAC) are shown in grey. Note: The yield factor refers to the green peas with pod (not to the respective RAC) and is referenced in Bognár (2002). The final products are cooked and drained.

Figure 3: The process of cooking green peas with and without pod (VI-002)

Preparatory steps

The process starts with sorting by sieves and air to remove foreign material, damaged, broken or non-standard size beans. Optoelectronic systems can be used to support the selection. The sorted RACs are subjected to a washing step prior to further processing.

Trimming and cracking the pods

Prior to cooking fresh beans/peas with pod are trimmed with mechanical knifes. The stems are always removed, the other ends are sometimes but not necessarily removed.

In order to separate the green seeds from the pods, the closed pods are mechanically cracked. However it has to be noted that beans and peas without pods are defined as RACs themselves. Therefore the processing of RAC starts after separating beans/peas from pods.

Pesticides which are located in or on the stems/ends of beans are removed/reduced by trimming.

Cooking

Depending on the variety and size, the cooking time of green beans with pod is 10-20 min and for separated green seeds without pod 5-10 min. The cooking temperature is approximately 100°C, sodium chloride can be added to the boiling water.

The cooking time depends on the commodity. The translocation of the pesticides or metabolites from the RAC into cooking water depends on their water solubility.

3.1.4.1. Scientific studies reflecting typical processing operations

Processing studies available to EFSA have been submitted for the process of cooking beans/peas with/without pods and for the cooking of pulses. In the case of green beans with pods the cooking time was 10 to 20 min.

The study of Weir (2011) was chosen as representative of the process of cooking beans with pod. It is cited by EFSA (2014e) and acceptable according to the quality criteria. Beans with pods were washed and sorted, then trimmed and cooked in water for approximately 20 min, sodium chloride was added.

Several studies are available reporting the cooking of beans/peas without pods (green seeds). The study of Langridge (2013) was chosen as representative, is cited by EFSA (2015c) and is acceptable according to the quality criteria. The peas without pods were washed in tap water and cooked for 8 min.

3.1.4.2. Extrapolation to other commodities

An extrapolation from green beans/peas with pod and fresh seeds without pod to other legume vegetables is possible. Surface residues can be washed off before cooking and residues can transfer into the cooking liquid during cooking. The processing factor is therefore assumed to be comparable for legumes with pod and without pod.

An extrapolation from legume vegetables to pulses (dried seeds) and vice versa is not recommended due to different water contents in the RAC and cooking durations.

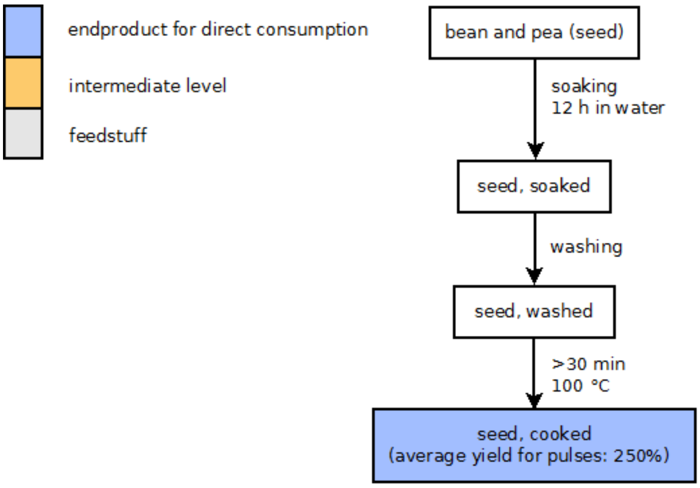
3.1.4.3. Comparison to industrial and/or household processing techniques

Apart from automated cutting of tips which is done by hand at household scale, no difference of industrial and household processing techniques is anticipated which has a significant impact on pesticide levels and processing factors.

3.1.5. Cooked pulses

Processing code VI-003 is assigned to the cooking of pulses.

Pulses are the fully ripe, dry seeds of legume crops (e.g. beans, peas, lentils). They are harvested at optimal seed moisture content of 15-17% which is reached at BBCH 87-89 (Feller et al., 1995; LLG, online; Weber and Bleiholder, 1990). Depending on the weather conditions during harvesting, pulses may require additional drying with warm air. This is part of the harvesting process. The dry seed is defined as the RAC. Processing of pulses is shown in Figure 4 and is described below.



The yield factor refers to the RAC "dry pulses" and includes the soaking step (USDA, 2016). The final product is cooked and drained.

Figure 4: The procedure of cooking pulses (VI-003)

Soaking and washing

In an initial step pulses are sorted for damaged or otherwise spoiled specimens. The remaining RAC is washed with water. Prior to cooking, dried beans and peas have to soak for typically 12 h in water, which is discarded afterwards. When removing the hull of dried peas mechanically, no soaking is necessary. Split peas and lentils do not require soaking.

Cooking

The cooking time depends on the variety and the duration of soaking. The cooking time decreases with the duration of soaking. It ranges from 10 min (lentils) to up to 1.5 hours (whole peas). During cooking, water is absorbed by pulses. The yield factors of pulses range from 273% (lentils) to up to 460% (green beans) (Bognár, 2002). When the hull of dried peas is removed mechanically, no soaking is necessary and cooking time is only 45 to 60 min (compared to otherwise up to 120 min) (BZfE, online). The processing factor refers to the cooked and drained commodity. The cooking liquid is not taken into account when deriving the processing factor. On domestic scale the cooking liquid is discarded or retained for soup preparation.

3.1.5.1. Scientific studies reflecting typical processing operations

Regarding the process of cooking pulses, several EFSA cited studies are available. The study by Devine (2013) was chosen as representative, is cited by EFSA (2015c) and is acceptable according to the quality criteria. The dry peas were cleaned with a rubber roller peeler and soaked in water overnight. After soaking they were washed with tap water and cooked for 27-68 min.

3.1.5.2. Extrapolation to other commodities

An extrapolation from peas or beans to other pulses is principally possible. While several dried pulses such as beans need to be soaked in water before cooking, this is not necessary for others (e.g. lentils). Therefore it is recommended to extrapolate within the group of commodities with long swelling and cooking times (unpeeled peas, beans and soya beans) and commodities with short cooking times and no swelling (peeled peas, lentils).

Pulses requiring short cooking times (e.g. lentils) and being consumed together with the cooking liquid (for soups) exhibit the worst case for setting a processing factor.

3.1.6. Further cooked vegetables

The procedure of cooking the following vegetables is visualised in Figure 1 and the processing code VI-001 is assigned to it.

Leaf vegetables

The RAC is defined as the whole product after removal of roots, decayed outer leaves and soil (if any). Spinach as a representative commodity of this group and can be consumed with stems. Spinaches are washed in water and then cooked for a view minutes with only very little addition of water. Furthermore spinach can be blanched (90-95°C for 1-3 min).

Fruiting vegetables

The RAC pumpkin is defined as the whole product after removal of stems. Depending on the variety (edible or inedible peel), mechanical peeling is necessary. The cooking process itself is comparable to that of carrots and potatoes (see 3.1.2).

Stem vegetables

The RAC is defined as the whole product after removal of decayed tissues, soil and roots. Leeks require the cutting of roots as a preparatory step (pre-RAC processing). Washing would be part of the processing. Cooking of leeks takes less than 8 minutes.

3.1.6.1. Scientific studies reflecting typical processing operations

EFSA has reported processing studies on spinach. One of these studies was chosen as representative for the process of cooking spinach (Old et al., 2002). The study is cited by EFSA (2014e) and is acceptable according to the quality criteria. The spinach was sorted to remove damaged or wilted leaves, then washed with tab water and sorted again for stalks and ribs. The washed spinach was boiled in water for 6 min.

3.1.6.2. Extrapolation to other commodities

Leaf vegetables such as spinach can be blanched or boiled in water. Extrapolation to other leaf vegetables, such as chard, is possible as long as the process is conducted in a comparable way.

Regarding pumpkins, an extrapolation to root and tuber vegetables is possible with respect to the cooking process itself, because the cooking conditions are comparable (see 3.1.2). Depending on the variety, pumpkins may be peeled before cooking to remove inedible peels, which is also recommended for potatoes. The peeling loss might however differ significantly between pumpkins and root and tuber vegetables, which need to be taken into account when extrapolating.

3.2. Steaming

Steaming of vegetables is particularly a household process, but is sporadically also used in industrial processing. It saves nutrients and is an alternative to cooking in water.

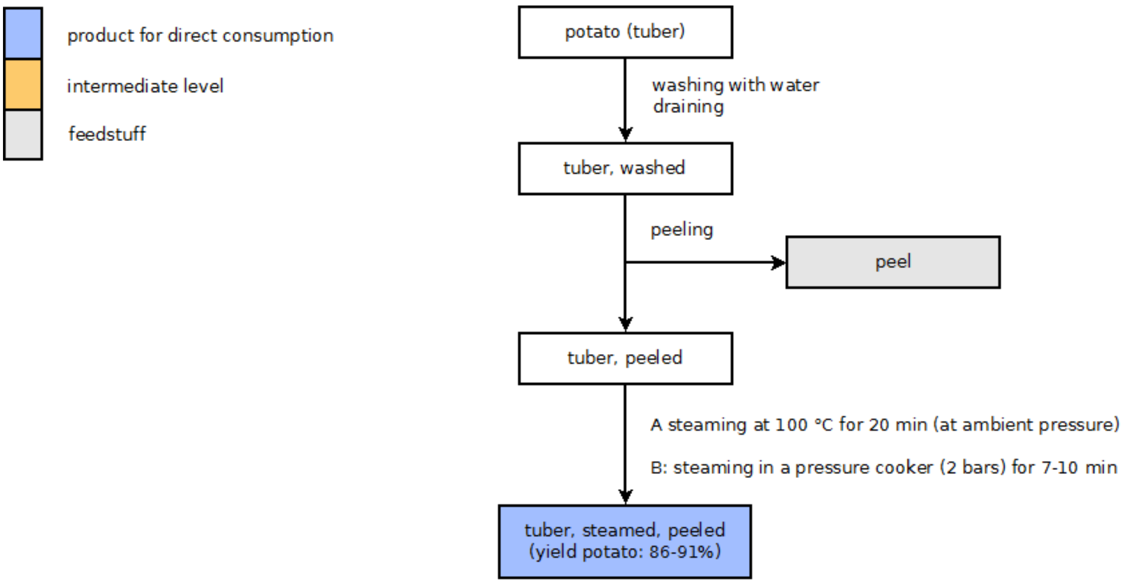
In principle, a distinction must be made between steam generation at ambient pressure (so-called unpressurised steaming) and the pressure steaming. In the case of unpressurised steaming, the food to be cooked is exposed to the steam of boiling water at ambient pressure. The cooking temperature is 100°C. In pressurised steaming, boiling water and food form a closed system. The boiling water leads to an increasing pressure in the system. Generally, the pressure is limited to 2 bars, at which water begins to boil at 120°C. The higher steam temperature is the reason for shorter cooking times during pressure steaming compared to steaming at ambient pressure.

Compared to cooking in water, less transfer of pesticides into the surrounding medium is expected during steaming. Diffusion of pesticide residues into steam is much lower. Residues tend to remain in/on the finished product.

Only for potatoes processing studies for steam cooking have been reported. However, steam cooking processes also play a role in other processing sequences. For example in food industry oat groats are steamed before flaking or rolling (chapter 10.3). Furthermore pasteurisation and sterilisation are carried out under water steam atmosphere. Likewise, steam peeling is a way to remove non-edible peels from fruits and vegetables.

3.2.1. Processing details

In the following the steaming of potatoes is explained exemplary. The preparation is carried out by means of washing, sorting and, if necessary, peeling. Both possibilities of the steaming process are described below. Figure 5 illustrates the processing of potatoes by steaming, which is mostly done in household processing. Potatoes can be steamed with peel and afterwards peeled with a knife.



Yield factors for the product for direct consumption are referenced in Bognár (2002). Potatoes can be steamed with peel and peeled afterwards with a knife.

Figure 5: Processing of steamed potatoes (VI-005)

Unpressurised steaming

Washed and peeled potatoes are placed in a steamer at 100°C for 15-20 min. The cooking time depends on the quantity and the size of the potatoes.

Pressure steaming

The washed and peeled potatoes are placed in the basket of a pressure cooker. The pressure cooker is filled with water. The water level should remain beneath the basket so that potatoes do not soak in water. According to typical recipes, potatoes are cooked for about 7-10 min. The cooking time depends on the quantity and the size of the potatoes.

3.2.2. Scientific studies reflecting typical processing operations

No studies regarding steam cooking have been cited in any EFSA Conclusion or Reasoned Opinion, but three processing studies are available from authorisation procedures. One of these studies is considered to reflect the steaming process under pressure well (Bastiani, 2013). The washed potatoes were placed in the basket of a pressure cooker. The pressure cooker was filled with water. The water level remained beneath the basket so that the potatoes did not soak in water. 3 kg potatoes were cooked for about 17-19 min (according to their size) from the onset of the valve. The study of Bastiani (2013) is acceptable according to the quality criteria.

3.2.3. Extrapolation to other commodities

Concerning steam cooking, processing studies have been submitted exclusively for potatoes. An extrapolation to further root and tuber vegetables like carrots or sweet potatoes is proposed.

3.2.4. Comparison to industrial and/or household processing techniques

In principle, available studies describe the process of steam cooking on household scale rather than on industrial scale. If large quantities of potatoes are processed in industry, longer cooking times are required in order to reach the boiling point. Different equipment is used in industry (e.g. steam blanchers with large tunnels), but no information is available on the impact on residue levels in the processed product. Overall, steaming of potatoes is not a common industrial process.

3.3. Canning

Canning is a process to preserve a wide range of vegetable or fruit products (whole fruits or fruit sections). Table 5 summarises typically canned commodities, most of which have been repeatedly reported in processing studies.

Table 5: Overview of typically canned commodities. *Italicised* canned commodities were reported by EFSA in Reasoned Opinions or Conclusions.

Main crop group	Sub crop group	Commodity
Fruits	Citrus fruits	*Mandarins, lemons,* grapefruit*, oranges*
	Pome fruits	*Apples, pears*
	Stone fruits	*Apricots, cherries, peaches, plums*
	Berries and small fruits	*Strawberries,* cane fruits, other small fruits and berries such as *currants*
	Miscellaneous fruits with edible peel	Table olives
	Miscellaneous fruits with inedible peel	Pineapples
Vegetables	Root and tuber vegetables	*Carrots,* potatoes, beetroot
	Bulb vegetables	Onions
	Fruiting vegetables	*Tomatoes, sweet peppers, gherkins, chili peppers,* sweet corn
	Brassica vegetables	Head cabbage, kale
	Legume vegetables	*Beans (with/without pod), peas (with/without pod)*
	Stem vegetables	Asparagus, *leeks*
	Fungi	Cultivated fungi (Mushrooms)
	Pulses	*Beans, peas*

In addition to the preservation of fruits and vegetables, the production of purée and paste, as well as the preparation of marmalade, jam or jelly are examples of the canning process. Several processing steps are the same, such as cleaning, separation of inedible and edible parts, size reduction, pre-cooking or blanching, filling, closing, followed by sterilisation or pasteurisation and final cooling. For explanation of sterilisation and pasteurisation see introduction to chapter 3.

An increase of the residue level is to be expected along with a concentration step (as in tomato paste or purée production). On the other hand, a dilution of the residue is to be expected upon canning of fruits and vegetables in jars. The canning liquid is often not consumed and therefore not considered when deriving processing factors, i.e. the factors refer to the drained commodities, while a certain amount of the residue might have transferred into the liquid. Nevertheless, canning liquid can be consumed.

Thermal processes like pasteurisation or sterilisation can also lead to a reduction of residue levels.

3.3.1. Canned vegetables

Processing codes VIII-001, VIII-002 and VIII-003 are assigned to the canning of tomatoes and various vegetables.

Canning is one of the most important processes to preserve vegetables. Most of the vegetables have a low–acid pH value and need a sterilisation step for preservation, unless they are acidified during the process (see Table 6).

The definition of the RAC according to Regulation No 2018/62 differs between types of vegetables. In general the RAC is the whole product after removal of tops (if any) and adhering soil (root and tuber vegetables), detachable skin and soil (bulb vegetables), stems (fruiting vegetables), roots and decayed outer leaves (brassica vegetables), decayed tissues and soil on root (stem vegetables) and after removal of soil or growing medium (fungi). Damaged or spoiled parts are generally removed.

The processing of RAC includes washing with water and further preparing, cutting, blanching and filling in jars or cans. Additives like brine, sugar, citric acid, calcium salts or monosodium glutamate are used. It is important to adjust the pH to an acidic level to avoid spoilage. The filled jars are sealed and pasteurised or sterilised in autoclaves. This process tends towards higher temperatures and shorter times since this ensures a better quality. Overall, the temperatures and heating times depend on commodity, size and canning materials (Belitz et al., 2009). The canning liquid is not taken into account when deriving the processing factor, i.e. the factors refer to the drained commodities. Nevertheless canning liquid can be used.

One of the most important canning processes is that of tomatoes. Regarding the world production, Europe is the third largest producer of tomatoes with a share of 13.3% in 2014 (FAO, online-c). Consequently, most of the canning studies conducted refer to tomatoes. Other vegetables such as gherkins, sweet corn, carrots, beans with or without pods, peas without pods, pulses or mushrooms are also commonly canned. For mushrooms, there is no representative processing study available. Information on the production of canned mushrooms is obtained from published literature and is described further below. Canning of gherkins is described in Chapter 6.3.

Table 6: Inedible parts and pH of fresh vegetables (Featherstone, 2015; SFK, online).

Commodity	Inedible part (weight ∅)	pH
Beetroots	22%	5.30 – 6.60
Carrots	19%	5.90 – 6.40
Onions	8%	5.30 – 5.85
Tomatoes	4%	4.00 – 4.70
Beans with pod	6%	5.60 – 6.50
Asparagus	26%	6.00 – 6.70
Cultivated fungi	2%	6.00 – 6.70

3.3.1.1. Canning process of tomatoes

The canning of whole tomatoes is shown in Figure 6 and is described below.

Sorting and washing

The tomatoes are first sorted for damaged or unripe ones and the remaining RAC is then washed with water. The washed tomatoes are sorted again for unevenly ripe, overripe and defect fruits.

Coring and peeling

Depending on variety and size of stems coring of tomatoes is necessary. This can be done by hand or machine.

For tomatoes two peeling methods are common:

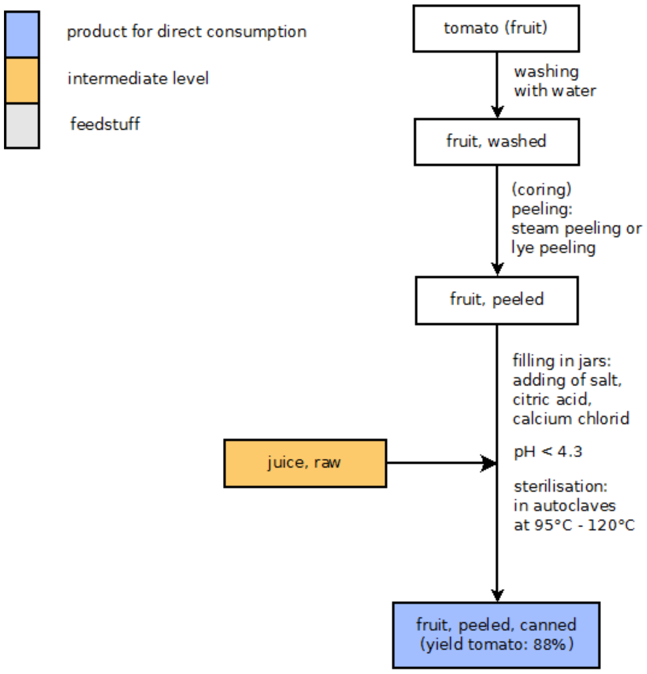
- *Steam peeling:* Is mainly used. Tomatoes are scalded in steam to loosen the skin. Steaming should be done as briefly as possible to prevent a loss of quality. After steaming the tomatoes are immediately cold sprayed to crack the skin. Depending on variety, fruit size and stage of maturity, scalding is done at 98-100°C for 30-60 s or longer (Featherstone, 2015).
- *Lye peeling:* Tomatoes are dipped into or sprayed with sodium hydroxide (8-25 g/100 g water) at temperatures from 60 to above 100°C for a short time (20-30 s), drained, held for 45-60 s and finally washed with cold water (citric acid may be added) to remove lye and peel. A second rinse with up to 10% citric acid solution is possible (Ayvaz et al., 2016).

Further peeling methods are blanching in hot water, followed by immediate plunging in cold water to crack the peel, as well as superheated steam at 149°C and infrared peeling. (Ayvaz et al., 2016; Featherstone, 2015; Heiss, 2004).

Filling and sterilising

Generally, peeled tomatoes are filled in jars cold. Tomato juice or paste, sodium chloride, calcium chloride and/or calcium sulfate are added. To adjust the pH to lower than 4.3 an acidification with citric acid is necessary. Sweeteners, spices and flavourings may be added. Cans are typically exhausted and filled at the same time (Sinha et al., 2011).

Four methods for exhausting are available: Thermal exhausting, mechanical vacuum, hot filling and steam flow closing (Sinha et al., 2011). At industrial scale the closed jars are pasteurised at 95°C in autoclaves or flow heater, followed by cooling (Heiss, 2004). Overall the processing time and temperature depends on type of equipment and can size.



Canned tomatoes can be consumed drained or with the canning liquid. A yield factor for the final product for direct consumption is referenced in BLS (2009).

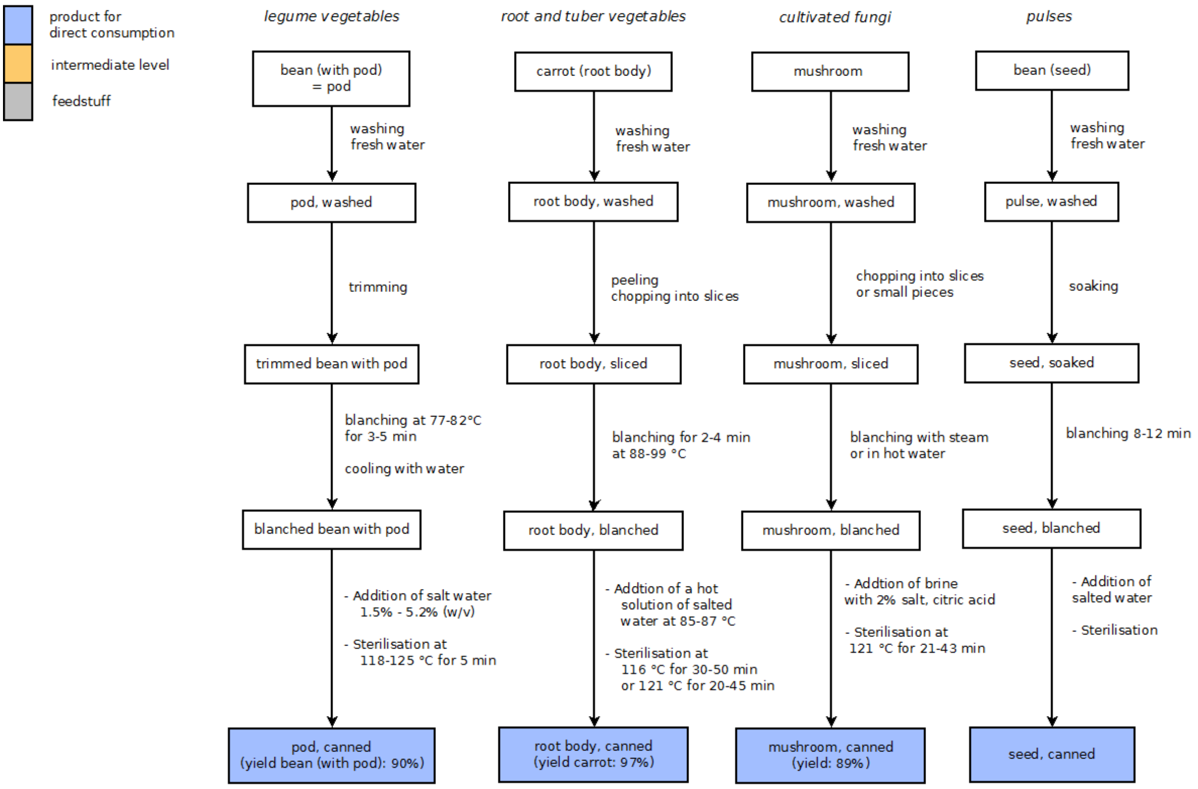
Figure 6: Canning of tomatoes (VIII-001)

3.3.1.2. Canning of further vegetables

Canning of tomatoes is the most common canning process, but several other vegetables can be canned, too. The processing is shown in Figure 7.

Preparatory steps

Pre-processing is comparable to the techniques described in the processing of cooked vegetables. For preparation of beans/peas with and without pods see chapter 3.1.4, for pulses see chapter 3.1.5 and for root and tuber vegetables chapter 3.1.2. Depending on their size, vegetables may be cut into smaller pieces.



The canned commodity is consumed drained. Yield factors for products for direct consumption are referenced in BLS (2009); Bognár (2002).

Figure 7: Canning procedure for various vegetables (VIII-002) (Featherstone, 2015)

Blanching

Vegetables are blanched before canning to achieve a better texture and to remove occluded air. The prepared vegetables are blanched for a few minutes (1 to 5 min). Soaked pulses may require a blanching time of 8-12 min (Featherstone, 2015). Duration and temperature depends on size and structure of the vegetables. Several examples are given in the introduction to chapter 3.

Pasteurisation and sterilisation

Vegetables are filled into glass jars or cans. Salted water solutions as well as other additives like sugar, citric acid, vinegar and spices (depending on the recipe) are added. Sometimes hot brine with a temperature of about 85-95°C is added. Some commodities require an exhausting step. Depending on the pH, pasteurisation or sterilisation takes place after sealing. Acidic foods with a pH below 4.5 only need to be pasteurised, while less acidic foods are normally sterilised to prevent microbial decomposition. Thermal processing depends on whether a whole or cut vegetable is canned, as well as on the initial temperature, filling weight and can size. Regarding beans with pods, the brine is added at 93°C, followed by a retort temperature of 116°C (20-60 min) or at 121°C (10-50 min) depending on the can size. In contrast carrots require an exhausting step at 66°C and a retort temperature of 116°C (30-50 min) or 121°C (23-35 min), while cultivated mushrooms are processed at 121°C for 21-43 min (Featherstone, 2015).

The canning liquid is not taken into account when deriving the processing factor, i.e. the factors refer to the drained commodities. On domestic scale the canning liquid might be used (e.g. beans with pod).

3.3.1.3. Scientific studies reflecting typical processing operations

Several processing studies are available for canning of vegetables. Concerning tomatoes, the procedure is consistent, except for the peeling method. The majority of studies describe peeling by blanching, while a few studies describe peeling by steaming. No further peeling methods were reported.

The following study was chosen as representative for the process of canning whole tomatoes including peeling by blanching (Gemrot, 2012). The study is cited by EFSA (2015d) and is acceptable according to the quality criteria. The unwashed tomatoes were blanched in boiling water for 1 min at maximum and immediately plunged in cold water to crack the peel. Blanched tomatoes were peeled. The peeling method was not reported, but in laboratory this is mostly done with a knife. Alongside tomato juice was prepared: Unwashed tomatoes were crushed and sieved. The Brix and pH of the remaining juice was measured and adjusted with sodium chloride and citric acid to pH 3.5. The juice was pasteurised at 82-85°C for 1 min. Canned tomatoes consist of two parts of peeled tomatoes, filled up with one part of tomato juice. Tomatoes and tomato juice were placed in jars and the jars were closed and sterilised at 115-120°C for 10 min.

A representative study for the canning of beans (with pods) was investigated by Weir (2011). The study is acceptable according to the quality criteria and is referenced in a conclusion by EFSA (2014b). After washing and trimming, green beans (with pods) were blanched in boiling water for 2 min. They were placed into jars, salted water was added and sterilisation was made at 118-125°C for 5 min.

Furthermore, the study of Scharm (2001b) which reports the canning process of carrots was selected as representative. The study is acceptable according to the quality criteria and is referenced by EFSA (2014d) in a Reasoned Opinion according to article 12. Washed and peeled carrots were chopped into 3 to 5 mm thick slices and blanched in water for 5 min. After blanching, carrot slices were filled into jars. A hot solution of salted water was added and the jars sealed. Sterilisation took place in an autoclave while heating up to 120°C for 20 min, keeping the temperature for 18 min and cooling down to 70 - 80°C for 30 - 82 min.

3.3.1.4. Extrapolation to other commodities

Extrapolation is normally possible within a subgroup as defined by Regulation No 2018/62.

In contrast the processing of canned tomatoes is quite different from other common canning procedures due to addition of tomato juice instead of salted water. An extrapolation from tomatoes to other fruiting vegetables is not recommended.

3.3.1.5. Comparison to industrial and/or household processing techniques

Industrial and domestic processing of canning vegetables is comparable. The peeling method may be different at industrial scale e.g. tomatoes are commonly peeled by steam, while in household processing this may be done by blanching of tomatoes. At industrial scale jars are filled under aseptic conditions, while in a typical household process jars are only inverted to pasteurise the cover. In domestic processing, longer heating periods are often indicated. This can have an effect on the residue level for heat-sensitive pesticides.

3.3.2. Canned fruits

Processing codes III-001 and III-003 are assigned to the canning of various fruits and to the canning of table olives, respectively.

The preservation of fruits by canning has a long tradition both in household and industry. Fruits have usually a pH of <4.6, rendering a heating step for preservation not necessary. If the fruit is acidified, a pasteurisation step is sufficient. Overall the pH of canned fruit should be below 4.2 to ensure a save product (Featherstone, 2015).

In principle, the canning process is comparable for different fruits. Depending on the fruit structure, peel and/or stones are removed before the actual canning (see Table 7).

Table olives are also canned, which corresponds to the "California style". In general, table olives can be fermented as well. See chapter 6.2 for the processing of pickling olives.

Table 7: Percentage of inedible parts removed prior to fruit canning. The data are referenced in an online database (SFK, online).

Commodity	**Inedible part (∅)**
Mandarins	35%
Apple	8%
Pears	7%
Apricots	9%
Cherries sweet	12%
Cherries sour	11%
Peaches	8%
Plums	6%
Strawberries	3%
Table olives	20%
Pineapples	46%

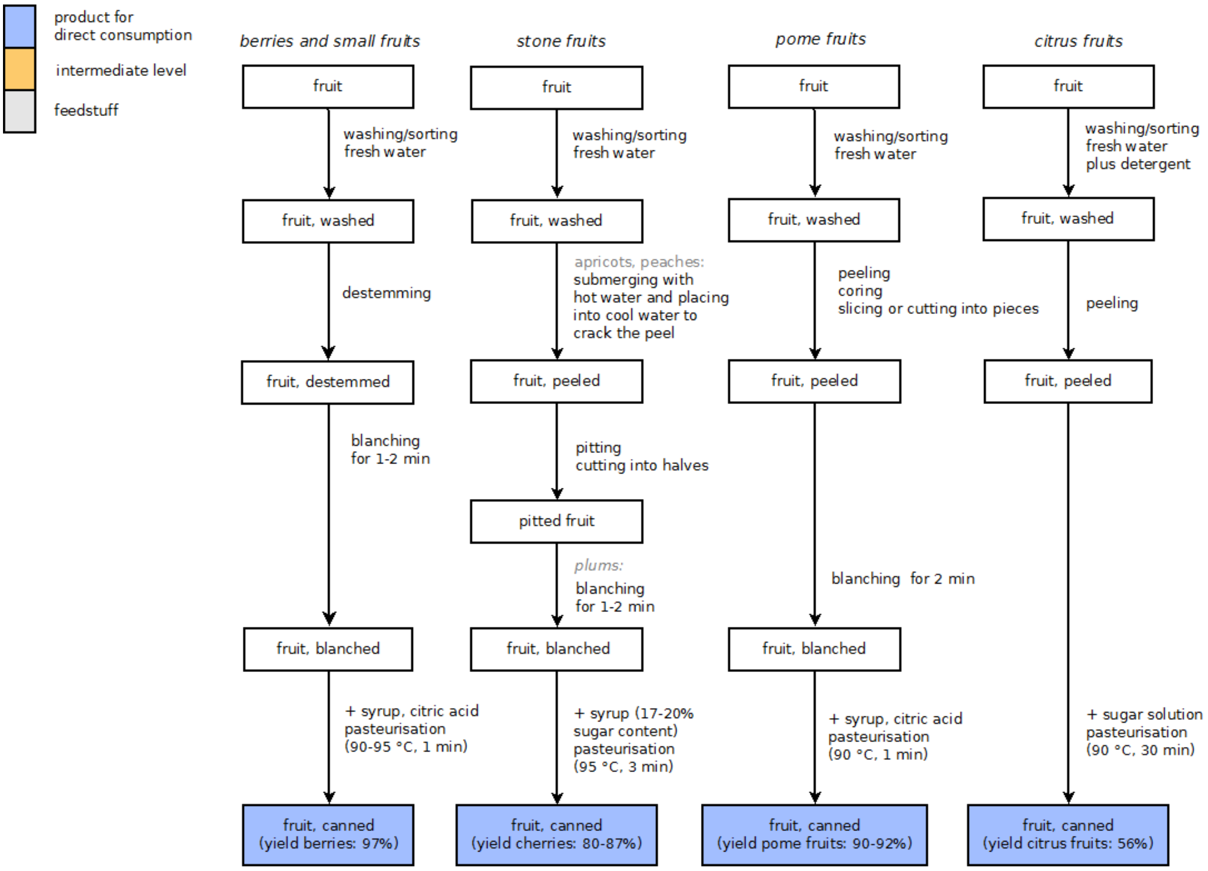
3.3.2.1. Processing details

According to Regulation No 2018/62 the RAC is defined as the whole product after removal of stems (citrus, pome and stone fruits), furthermore caps, stems (except currants) and crowns (berries and small fruits). Damaged or spoiled parts are generally removed.

Overall the process of canning is divided into the following stages: washing, if necessary peeling and pitting, blanching and finally pasteurising. The flowchart (Figure 8) gives an overview of the canning process for fruits.

Washing

Washing of the raw fruits in water is a common initial step for all canning operations to ensure effective removal of adhering dirt. Sometimes chlorine dioxide, hypochlorite or other chlorine compounds are added to control microbial build-up in re-circulated water. For citrus fruits, additives such as detergents and foam inhibitors are often added to assist removal of soil residues and microbial impurities. Washing may include physical scrubbers, which can actually reduce the washing time. In addition, on industrial scale water is commonly used as a flotation medium to the masher (Fellows, 2016).



Yield factors for products for direct consumption are referenced in BLS (2009).

Figure 8: Canning procedure of various fruits (III-001)

Preparatory steps

Some stone fruits like plums can be canned without having been peeled or pitted. Apricots and peaches may be peeled by steam peeling or lye treatment. For lye peeling procedure, whole fruits are either immersed in or sprayed with lye solution (1.5% to 2% sodium hydroxide) at a temperature around the boiling point (Featherstone, 2015). Depending on fruit type and size, the treatment duration ranges from 0.5 to 1.5 min. Finally, the fruits are rinsed with water to remove lye and loosened peel. Another technique places fruits into boiled water for approximately 5 min, and then immediately puts them into cold water for 20 s to crack the peel. A special feature is the removal of the segment peel (endocarp) from citrus fruits. For this purpose, the fruit segments are bathed in a 0.5-0.9% hydrochloric acid solution that peels off the segment the surrounding endocarp. Without removing the endocarp, the produce turns bitter (Berk, 2016).

Stones are usually removed industrially by means of a pitting machine and in domestic procedures by hand. Large fruits are cut into halves or pieces before final canning. Berries and small fruits such as table grapes or currants are destemmed prior to canning.

Blanching

Fruits are blanched in boiling water for 1 to 2 min. This step serves primarily for deactivating enzymes and thereby preventing unwanted product changes (further maturation, enzymatic browning, degradation of valuable ingredients, and development of false aromas). In addition, oxygen is exhausted from the tissue by the blanching process, the cell structure is loosened (solution or degradation of pectins) and the microbial load is reduced.

Pasteurisation and cooling

A syrup is prepared (proportion of sugar depends on fructose content of the fruit) and, if necessary, the pH is adjusted to about 3.5 by using citric acid. Prepared fruits and syrup are filled into jars or cans and sealed. The cans require an exhaust to remove air from the can. Depending on the desired sweetness the following syrup concentrations can be used: 20 to 40° Brix (sweet cherries), 35 to 50° Brix (grapefruit) or 20 to 55° Brix (strawberries). During pasteurisation the can centre should reach temperatures of at least 82°C (apples, cherries), 80°C (grapefruit), or approximately 100°C (strawberries). The duration depends on the fruit and can size. Since citrus fruits are not blanched before pasteurising, the pasteurisation takes longer (up to 30 min) (Featherstone, 2015).

Immediately after processing the cans are cooled to about 30-40°C.

During canning a reduction of surface residues is to be expected due to removal of peel, treatment with reactive agents and washing with detergents and/or water. Furthermore pH labile residues may be reduced by the peeling method (lye solution) or the addition of citric acid. A dilution is expected because of the adding of canning liquid. The canning liquid is not taken into account when deriving the processing factor. The factors refer to the drained commodities.

3.3.2.2. By-products of fruit canning

No other by-products than peels and cores of pome fruit are derived, which can be used as feedstuff (OECD, 2013). Intermediate products such as washed and peeled fruits can be subjected to other processing operations such as juicing.

3.3.2.3. Scientific studies reflecting typical processing operations

EFSA made reference to several studies where fruit were subjected to canning. Processing studies for canning of strawberries, plums, peaches, mandarins and apples were selected as representative and were briefly described.

The processing of small fruits and berries is represented by the study of Goodband and Volle (2002) using strawberries. The study is acceptable according to the quality criteria and is referenced by EFSA (2014e) in a Reasoned Opinion according to Article 12. The strawberries were washed and blanched in boiling water for 1 min. Syrup was prepared from water and sugar (20% sugar content) and the pH was adjusted to approximately 3.5. The syrup was added to the blanched strawberries in sterilised glass jars. After sealing, the jars were pasteurised at 90-95°C for 1 min.

In the sub crop group of stone fruits peaches and apricots have to be peeled before canning, while plums and cherries are canned without any peeling process. Two studies illustrate the different procedures.

The study of Simek (2007) describes the canning of peaches and is acceptable according to the quality criteria. It is referenced by EFSA (2013d) in a Reasoned Opinion according to article 10. After washing by soaking in cold water, whole fruits were submerged into boiling water for approximately 5 min, and then placed into cold water for 20 s to crack the peels. The fruits were peeled, cut into halves and pitted. The peeled and pitted fruits were placed into glass jars with syrup (17-20% sugar content). The jars were pasteurised at 95°C for 3 min.

The study of Wieser and Klimmek (2009) reports the canning of plums and is acceptable according to the quality criteria. It is referenced by EFSA (2013d) in a Reasoned Opinion according to article 10. The plums were blanched in boiling water for 1 min followed by pitting. Syrup was prepared (40% sugar content), the pH was adjusted to 3.5 using citric acid. The blanched and pitted plums and syrup were put into glass jars, sealed and pasteurised at 90-95°C for 1 min.

The canning of pome fruits is represented by the study of Grolleau (2003). The study is acceptable according to the quality criteria and was referenced by EFSA (2012a) in a Reasoned Opinion according to Article 10. The apples were peeled and blanched in boiling water for 2 min to avoid enzymatic browning. After blanching, cores were removed with a knife. Cored apples were sliced. Syrup (20%

sugar) was prepared and the pH was adjusted to 3.5 by addition of citric acid. Syrup and apples were added to glass jars and pasteurised at 90-95°C for 1 min.

Another study on canning refers to citrus fruits. The study of Pollmann (2007) is acceptable according to the quality criteria and is referenced by EFSA (2014f) in a Reasoned Opinion according to Article 12. The processing starts with the sorting out of damaged fruits. Intact mandarins are peeled by hand and separated into segments. The segments were bathed in 0.5-0.9% hydrochloric acid twice and subsequently washed. Furthermore, mandarin segments were put into cans filled with syrup (25% sugar content) and sealed airtight. Pasteurisation took place at 80-90°C for 30 min.

3.3.2.4. Extrapolation to other commodities

Extrapolation of the canning process is possible within sub crop groups as defined by Regulation No 2018/62, except for stone fruits. This allows extrapolating the canning of strawberries to further berry varieties (like currants or gooseberries). Similarly, in the case of pome fruits apple canning can be extrapolated to pears and quinces and in the group of citrus fruits mandarin canning can be extrapolated to other citrus fruits. In the group of stone fruits it must be considered whether or not peeling takes place. This means that processing factors for plums and cherries can be extrapolated between each other and processing factors for apricots, peaches and nectarines can be extrapolated between each other, but processing factors for plums or cherries cannot be extrapolated to apricots, peaches or nectarines. Pesticide residues can be higher on the peel so that peeling can have an influence on the residue level.

3.3.2.5. Comparison to industrial and/or household processing techniques

Canning is used in industry as well as household applications. The processing studies represent industrial processing.

In domestic processing, longer heating periods of about 30 min are often indicated. This could have an effect on the residue level for heat-sensitive pesticides.

3.3.3. Jam, Jelly and Marmalade

Processing code IV-001 is assigned to the manufacturing of jam, jelly and marmalade.

Numerous fruits can be preserved as marmalade, jam or jelly. The composition and labelling is defined in Council Directive 2001/113/EC[2] regarding the fruit and sugar content, residual content of sulphur dioxide and other permitted additives (e.g. pectin, citric acid). The Directive covers the products jam, extra jam, jelly, extra jelly, marmalade and jelly marmalade, which are explained below. These products must have a Brix (soluble dry matter content) of 60% or more, except for those where sugar is replaced by sweeteners and some other permitted exceptions apply. The mixtures are distinguished by their gelled consistency. Depending on the pectin and acid content of the processed fruits the used pectin and acid quantity needs to be adjusted. The use of different kinds of sugar is permitted and defined in the Directive.

Jam, jelly and marmalade are composite foods. Meaningful processing factors can be derived after recalculation to the fruit part only, considering the percentage of sugar.

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[2] Council Directive 2001/113/EC of 20 December 2001 relating to fruit jams, jellies and marmalades and sweetened chestnut purée intended for human consumption. OJ L 10, 12.1.2002, p. 67–72.

Definition of jam, jelly and marmalade according to Council Directive 2001/113/EC:

- Jam is a mixture of sugars, the pulp and/or purée of one or more kinds of fruit and water. Apart from that, citrus jam may include the whole fruit, cut into strips and/or sliced. Furthermore it is specified that 1000 g of jam must contain a quantity of pulp and/or purée not less than:

  - 350 g as a general rule,

  - 250 g for currants (red, black and white), rosehips and quinces.

- Extra jam is a mixture of sugars, the unconcentrated pulp of one or more types of fruits and water. Furthermore, rosehip, seedless raspberry, blackberry, currant and blueberry extra jams may contain entirely or in parts unconcentrated purée of the mentioned fruits. Citrus extra jam is produced from the whole fruit, cut into strips and/or sliced. The following fruits and fruiting vegetables may not be used prepared with others in the production of extra jam: Apples, pears, melons, watermelons, table grapes, pumpkins, cucumbers and tomatoes. The quantity of pulp used for 1000 g of extra jam must not be less than:

  - 450 g as a general rule,

  - 350 g for currants (red, black and white), rosehips and quinces.

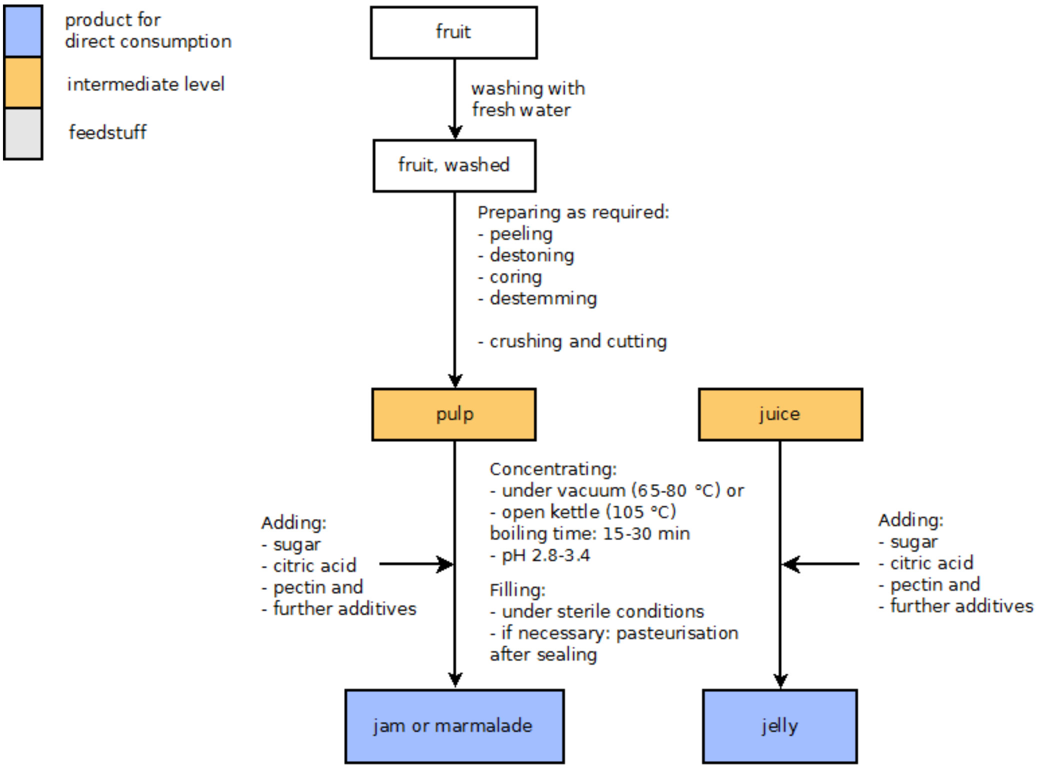
- Jelly is a gelled mixture of sugars, the juice and/or aqueous extracts of one or more kinds of fruit. The quantity of juice and/or aqueous extracts used for 1000 g of jelly must not be less than as laid down for jam.

- Relating to extra jelly the quantity of fruit juice and/or aqueous extracts used for 1000 g must not be less than that laid down for extra jam. These fruits and fruiting vegetables may not be used with others in the production of extra jelly: apples, pears, melons, watermelons, table grapes, pumpkins, cucumbers and tomatoes.

- Marmalade is a mixture of water, sugars and one or more products obtained from citrus fruit: purée, pulp, peel, juice and aqueous extracts. It is defined that 1000 g marmalade must contain not less than 200 g of citrus fruit, while at least 75 g must be contained of the endocarp (fruity pulp of citrus fruits). In contrast jelly marmalade contains no insoluble parts except possibly for small quantities of finely sliced peel. Commodities such as mandarins, oranges or lemons can be used for marmalade processing.

3.3.3.1. Processing details

The general procedure for the preparation of jam, jelly and marmalade is visualised in Figure 9 and is described further below.



Recipes differ depending on the fruit (pectin content) and the desired sweetness and acidity. A basic jam recipe for fruits with low pectin content would be 10 kg fruit, 10 kg sugar, 60 g pectin and 55 g citric acid, with a desired Brix of 68%. The recipe is referenced in FAO (1995). The final yield depends on the used amount of fruit and sugar. The cooking process lasts until enough water has evaporated and the desired Brix been reached. To calculate the desired amount of ingredients the dry solid mass of each ingredient needs to be known.

Figure 9: Processing of jam, jelly and marmalade (IV-001)

Preparation of fruits

The fruits are first washed with water, drained and sorted for damaged ones. Inedible parts are removed, i.e. stone fruits such as peaches or cherries are pitted, pome fruits such as apples are cored and berries such as currants are destemmed. Depending on the fruit and the desired concentration of the final product the used amount of fruit varies.

Peeling can be achieved by blanching in water for a few minutes, followed by immediate cooling in cold water for a few seconds to crack the peel. The loosened peel can be removed with a knife. Peeling of citrus fruits for marmalade can be done mechanically without heating.

The remaining edible fruit parts are crushed or cut into pieces (called pulp) for further processing.

For jelly production clarified juice is required. The process of juice production is explained in detail in chapter 4.

Processing of jam, jelly and marmalade

The prepared fruits or the juices are combined with a known amount of sugar and water if necessary. Depending on the fruit variety, the initial weight and the final desired concentration, the used quantity of sugar varies. This mixture is heated while constantly stirring in closed vacuum boilers at reduced pressure at 65-80°C or in open kettles at atmospheric pressure at up to 105°C (Belitz et al., 2009; Heiss, 2004). During boiling the pectin is added. The pH is measured and adjusted with lactic, citric or tartaric acid to the optimum pH of 2.8-3.2 (depending on the fruit) (Featherstone, 2015). Finally the Brix (total soluble solids) is measured with a refractometer and the boiling process ends. The final product must have a Brix of at least 60%, except for those products where sugar is replaced.

Filling

Finally the jam is filled in jars, which are closed and can be pasteurised if required. Depending on the temperature and sterility during filling pasteurisation may not be necessary. The closed jars are immediately cooled for retaining an optimum consistency.

3.3.3.2. By-products of marmalade, jam and jelly production

By-products occur only during preparation of fruits. This contains peel or pomace from juice extraction. According to OECD (2013), apple pomace (containing remaining stems, cores and peel) can be fed to livestock. Other remaining parts of fruit preparation are not foreseen for animal feeding in the EU.

3.3.3.3. Scientific studies reflecting typical processing operations

Regarding the preparation of jam, commonly pome fruits, stone fruits and berries and small fruits are used. Several studies on jam production from apple, apricot, black currant, cherry, peach, plum and strawberry are available. A few studies do not report the added amount of sugar. The preparation is consistent except for the fact that a few studies report a sterilising step after filling and closing the jars. This is not needed if the jam reached a temperature above 70°C and conditions were aseptic (Heiss, 2004).

The study of Ryan and Richards (2004) is cited by EFSA (2014e) and is acceptable according to the quality criteria. Black currants were first washed, spin-dried and sorted. After crushing, the Brix was measured and sugar was added. The mixture was heated and reduced until 62% Brix. The pH was measured, too. Finally the jam was filled in jars, closed with a lid and sterilised at 115°C for 10 min.

Only a few studies on jelly production from apples, table grapes (red and white) and black currants are available and the following one was selected.

The study of Mackie (2008) is cited by EFSA (2013b) and describes a representative manufacturing of jelly. The study is acceptable according to the quality criteria. Grapes were washed with water and passed through a crusher/destemmer. For depectination the crush was transferred to a kettle and pectinase enzymes added. The mixture was heated for 2-3 h at 50-60°C. For extraction the slurry was passed through a screw press. The extracted, unclarified juice was transferred to a steam-jacketed kettle for clarification. The unclarified juice was heated to about 90°C to inactivate the pectinase enzymes and was subsequently cooled for argol settling. The process was completed by filtration to prepare a clarified juice for jelly making.

For jelly preparation the filtered juice was transferred into a steam-jacketed kettle. Sugar, pectin and citric acid were added. The mixture was concentrated and filled into jars. The closed jars were held inverted and finally cooled under water.

Several studies report the preparation of marmalade from oranges and one also from mandarins.

The study of Pollmann (2007) is cited by EFSA (2014f) and is acceptable according to the quality criteria. Oranges were first washed with water. They were peeled manually and the pulp was cut into small pieces. The peel was cut into extra fine pieces. Afterwards pulp (85% w/w) and peel (15% w/w) were mixed with sugar and pectin and heated to 95°C until jelled. Acid was added until pH 3 was reached. The final sugar content was 59 to 64% Brix. The hot marmalade was filled in jars, closed and cooled.

3.3.3.4. Extrapolation to other commodities

Assuming that jam, marmalade and jelly usually exhibit at least a soluble solid content of 60% and pH 3, the extrapolation within a sub crop group is justified. Differences might occur during preparation of fruits. The level of pesticide residues remaining is mainly affected by removing parts of the fruit (which is not done for all fruits).

For jams, jellies and marmalades processing factors can in principle be derived in parallel for jam/marmalade and for cooked fruit purée or for jelly and (heated) fruit juice, as long as the sugar content of jam/marmalade and jelly is reported in the processing study. The processing factor for cooked fruit can then be calculated. Depending on the fruit variety, the initial weight and the final desired concentration the used quantity of sugar varies.

3.3.3.5. Comparison to industrial and/or household processing techniques

Industrial and domestic processing of fruits to marmalade, jam or jelly is comparable.

At industrial scale the fruits are already prepared and delivered frozen and are warmed up for the further process. For household processing open kettles are normally used, while industry additionally uses closed vacuum kettles (Heiss, 2004). For household production of jams etc., ready mixtures of sugar, pectin and citric acid or other ready to use gelling agents are available. While at industrial scale Brix and pH are measured during processing, this is usually not done in households. To prevent foam, industry uses cooking oil. After filling jars under aseptic conditions, at industrial scale they are cooled to obtain an optimum consistency. This is not done in a typical household process, where jars are only inverted to pasteurise the cover.

3.3.4. Purée and Paste

Processing codes IV-002 and IV-003 are assigned to the fruit purée production. Furthermore, processing codes VII-001 and VII-005 are assigned to the production of vegetable purées and pastes.

Several fruits and vegetables are manufactured into purée. Thus purée is made of the edible part of the whole fruit or vegetable, after peel, skin, seeds, pips or stones have been removed if necessary and the remaining pulp has been reduced to purée by sieving and evaporation.

Several processing studies are available for purée made from apples, apricots, peaches and vegetables such as carrots or tomatoes. Furthermore other vegetable purées are important primarily as baby food. They are often combined with fruit purées.

Overall the production follows the principle that the edible part of the whole fruit or vegetable is prepared and heated, sieved and concentrated to the required consistency and desired Brix (content of soluble solids). Depending on the commodity, sugar, sodium chloride or spices are added. Apple sauce (apple purée) and tomato purée are exemplary explained below and have been selected because of their high consumption quantities.

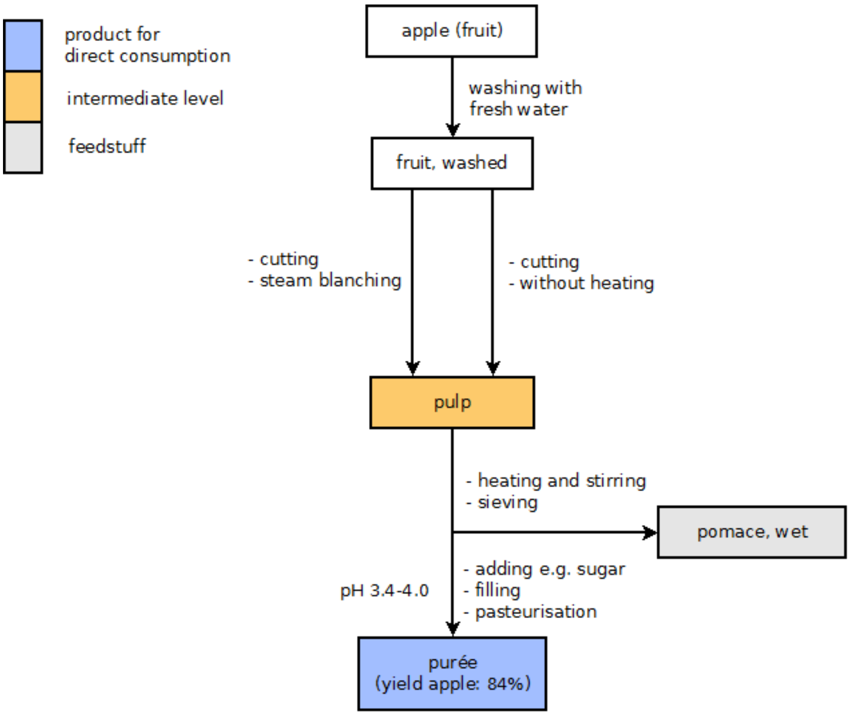
Furthermore tomato paste is defined as the thick paste made from tomatoes, in which skin and seeds are removed, i.e. tomato paste is the finally concentrated tomato purée. It can be processed further into ketchup. Since tomato ketchup is a multi-ingredient commodity, its production will not be discussed in this compendium. The processing factor for tomato paste applies to the fraction of tomato paste present in tomato ketchup.

Potatoes are processed industrially to flakes or granules using mashed potatoes as starting material. The process is described in chapter 3.4.3.

3.3.4.1. Processing of apples to apple sauce

Apple sauce can contain sugar, other sweeteners and spices. The sugar and acid ratio depends on the apple variety. The fruits are either blanched before sieving or heated afterwards. The Brix of unsweetened apple sauce is about 9%, while sweetened apple sauce has a Brix of about 16%. Furthermore the apple sauce has approximately a pH of 3.4 to 4.0 (Hui et al., 2006). To derive a processing factor no recalculation is done.

The processing steps are shown in Figure 10 and are described below.



A yield factor for the product for direct consumption is referenced in BLS (2009).

Figure 10: Processing of apples to apple sauce (IV-002)

Washing and sorting

The process starts with washing of apples in water and sorting. The sorted apples can be processed peeled or unpeeled. For further processing they are cut into pieces or crushed.

Apple sauce manufacturing

The apple pulp is blanched in steam and stirred. Further the pulp is passed through a sieve. Remaining parts such as seeds and peel are removed as wet pomace. During the process the pH and Brix is measured and sugar or other ingredients can be added. Finally the hot apple sauce is filled in jars and sealed. The closed jars are pasteurised and immediately cooled down.

3.3.4.2. Processing of tomatoes to tomato purée

Tomatoes can be processed into a wide range of products such as juice, purée or paste. Tomato purée is defined as the tomato concentrate that contains between 7% and 24% of total soluble solids and has a pH lower than 4.5 (FAO, 2013). The basic step of tomato purée production is evaporation. The procedure is described as reported in the literature and is shown in Figure 11.

Washing and crushing

The process begins with washing of fresh tomatoes in water and sorting. The tomatoes are further chopped and crushed in a pulper. The tomato pulp can be processed by either a hot-break or a cold-break method (Sinha et al., 2011). With the hot-break method the crushed tomatoes are heated rapidly to temperatures above 77°C (Featherstone, 2015; Sinha et al., 2011). The heat inhibits pectolytic enzymes and leads to a higher viscosity. In cold-break systems the tomatoes are chopped at 60-66°C and the temperature is hold for some time.

Extraction and evaporation

The preheated tomato pulp is sieved by extractors to separate juice and pomace. For a higher yield centrifuges may be used. The wet pomace contains seeds, skin and any other impurities.

The raw tomato juice is concentrated in vacuum evaporators at a typical temperature range of about 50-80°C (FAO, 2009; Smith and Hui, 2004), until a content of soluble solids of at least 8% but less than 24% is achieved (FAO, 2013; Smith and Hui, 2004). Final pH should be less than 4.5 and can be adjusted with citric acid.

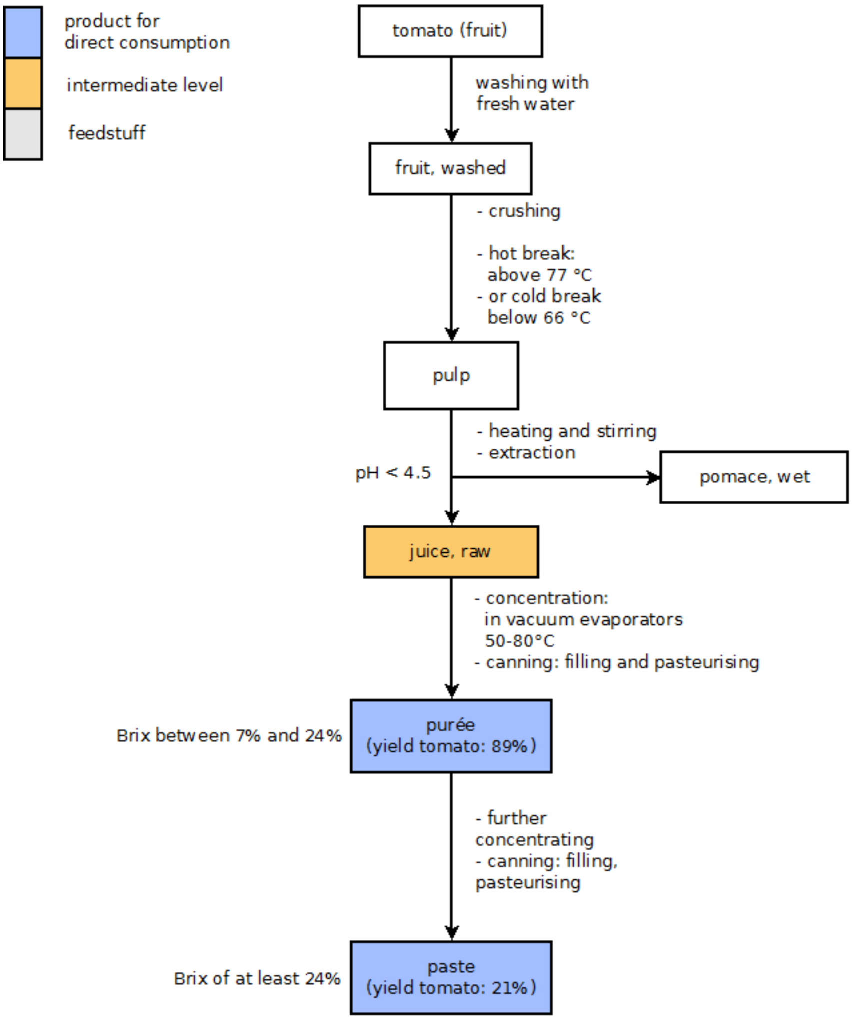
Filling and sterilisation

The tomato purée can be pasteurised at a temperature of 90°C and filled into jars or jars can be filled and sterilised afterwards. The closed jars are cooled in water.

3.3.4.3. Processing of tomatoes to tomato paste

The processing of tomatoes to tomato paste is similar to tomato purée production (see 3.3.4.2) except for the fact that the tomato purée is further concentrated in vacuum evaporators until the desired concentration of at least 24% natural total soluble solids and a pH below 4.6 is obtained (FAO, 2013). Adding of sodium chloride or acid is permitted. Filling of paste into cans should be done at a temperature of at least 90°C (Featherstone, 2015).

The process of tomato paste production is shown in Figure 11.



The yield factor for tomato products depends on the variety and its water content. Yield factors for products for direct consumption are referenced in BLS (2009).

Figure 11: Processing of purée and paste from tomatoes (VII-001)

3.3.4.4. By-products of purée and paste production

During apple purée production the pulp is sieved. The remaining wet pomace includes stems, cores and peel. According to OECD (2013) it can in principle be used for feeding purposes.

During tomato purée and paste production wet pomace is separated, but not used for animal feeding in Europe (OECD, 2013).

3.3.4.5. Scientific studies reflecting typical processing operations

Apple sauce

Several processing studies are available on apple sauce production, which follow widely comparable procedures. Main difference is the heating process: Either the apples are blanched before crushing or they are crushed raw. In general blanching inactivates enzymes and prevents apple browning, but is not necessary if the manufacturing system is closed and low in oxygen. The following study is chosen as representative for the process of apple sauce preparation.

The study Oppilliart (2009) is cited by EFSA (2013e) and is acceptable according to the quality criteria. The apples were first washed with water and strained. To avoid enzymatic browning the washed apples were blanched in boiling water for 2 min. Afterwards the blanched apples were crushed with an electric crusher and were sieved. Sugar was added (20 %) and purée was reduced by heating at 70°C to 25% Brix and a final pH of 3.5. Finally the hot purée was filled in jars, which were sealed and sterilised at 115-120°C for 10 min.

Tomato purée and paste

For the processing of tomato purée and paste two variations are in use in industry. Either the crushed tomatoes are heated (hot break), followed by sieving and evaporation or the crushed tomatoes are evaporated first until the desired Brix is reached and finally sieved.

The following study was chosen as representative for the process of tomato purée and paste production including the hot break step.

The study of Mäyer (2012e) was performed in the United States. It is cited by EFSA (2015b) and is acceptable according to the quality criteria. The whole tomatoes were first washed with fresh water. Further they were chopped in a Hobart bowl chopper and heated rapidly in a heat exchanger to 90-97°C (hot break). The heated pulp was further sieved to separate wet pomace. The acidity was adjusted with citric acid to pH 4.5 or less. The purée was evaporated under heat and vacuum until a solid range of 8-24% was reached and further concentrated until 24-30% for tomato paste. Both were heated to 85-90°C, filled in bottles and sealed. The bottles were cooled in water at 15-27°C for 28-32 min.

A second study was selected to cover the other variation: Concentrating of crushed tomatoes followed by sieving.

The study of Foster et al. (2006) is cited by EFSA (2013a) and is acceptable according to the quality criteria. First the washed tomatoes were crushed with an electric crusher and put in double jacketed saucepans for reduction at 60-75°C. The process was stopped when the desired Brix of 12-14% for tomato purée and 24-25% for tomato paste was reached. Furthermore both were sieved to remove seeds and peel. Sodium chloride was added and the pH adjusted to 3.5. Finally purée and paste were filled in jars, which were sealed and sterilised at 115°C for 10 min.

3.3.4.6. Extrapolation to other commodities

Apple sauce

An extrapolation from apple purée to other pome fruit purées is reasonable due to a comparable production. It should be noted that sugar can be added to fruit purées thus further diluting pesticide residues. Water is not commonly added.

Other fruit purées can be extrapolated within their subgroups (e.g. apricot purée, raspberry purée).

Tomato purée and paste

Tomato is the most important fruiting vegetable processed into purée. Due to its unique processing, no extrapolation to other crops is recommended. Other vegetable purées can be extrapolated within their subgroups.

Tomatoes are the only relevant vegetable commodity processed into paste. No extrapolation is recommended.

3.3.4.7. Comparison to industrial and/or household processing techniques

Apple sauce

At industrial scale the apple sauce production is conducted in closed and oxygen deficient atmosphere. The whole apples are chopped, steamed and sieved through a 1 mm sieve. The pulp is heated and sugar can be added. The hot purée is filled in containers, which are then closed and pasteurised. Heating temperature is as low as possible for a gentle preservation. For household processing open kettles are normally used. While at industrial scale Brix and pH are measured during processing, this is usually not done in households. In a typical household process jars are filled and inverted to pasteurise the cover.

Tomato purée and paste

The industrial tomato purée and paste production is conducted under vacuum which minimises oxidation. The process is monitored and the pH and Brix is measured at certain times and automatically adjusted. In contrast the household process is done with normal cooking pots and usually without measuring any parameters.

3.4. Dehydration (drying)

The terms "dehydration" and "drying" are used synonymously in this chapter to describe the removal of water, naturally present in foodstuff, by either evaporation (impact of heat) or sublimation (freeze-drying). Dehydration of fresh produce is a widely used method for preservation of perishable food materials by reducing the moisture to a level which inhibits the growth and development of spoilage and pathogenic microorganisms, reducing the activity of enzymes and the rate at which undesirable chemical changes occur (Brennan, 2006). Nevertheless it can be assumed that a certain degree of dryness is inherently attained in order to avoid microbial spoiling and to meet general quality criteria and trade standards for the dried produce.

Dehydration is usually described as a simultaneous heat and mass transfer operation. The removal of water can be achieved either in a purely passive manner (e.g. using sun drying) or actively (and more expeditiously) by running a gentle air steam at mostly moderately elevated temperatures (ca. 40 to 60°C) over and/or through the bulk material. The heat is transferred by convection from the air to the surface of the food and by conduction inside the food. Alternatively, the food may be placed in contact with a heated surface. Albeit higher temperatures may accelerate the drying process they may negatively impact the quality of the final product. For large scale production various combined engineering solutions are in place; e.g. flow convection dryers are widely used, occasionally assisted by infrared radiating systems and/or vacuum components (Brennan, 2006).

Further to heat-drying processes, freeze-drying (lyophilisation) is also commonly applied in rendering certain end products stable against microbial and chemical spoiling in an aroma preserving way (e.g. instant coffee, fruit components of mueslis). Freeze drying works by freezing the material to -50°C to -80°C, and subsequently reducing the surrounding pressure to allow the frozen water in the material to sublime directly from the solid phase to the gas phase. In osmotic drying, food pieces are immersed in a hypertonic solution. Water moves from the food into the solution, under influence of osmotic pressure (Brennan, 2006).

Generic drying factors can be derived as follows: The dry matter content of the dried product is compared to the dry matter content of the unprocessed product (EC, 2022). The loss of water entails a relative increase of pesticide concentrations due to the fact that the dry matter content is increasing. Only for rather volatile pesticides substantial loss is to be anticipated in such drying operations due to evaporation. With a view to the moderate temperatures involved in air-drying, the nature of the residue is anticipated to be affected in only rare cases (and if so to only a minor extent). In case of sun-drying residue decline may occur for photolytic sensitive substances particularly on the surface of the produce, thus causing countervailing effects from accumulation of the residue due to water loss of the raw commodity on one side and photolytic depletion of the residue on the other. Implausibly low ´drying´ factors may therefore be checked for potential effects of volatility, photolytic breakdown or washing prior to starting the drying process.

For some commodities parts of the fresh RAC to which the MRL applies do not show up in the processed product but are removed before drying (e.g. stones, peels). This should be kept in mind in the interpretation of processing factors. Residue data for fresh and dried herbs and spices are normally reported in crop field trials rather than in processing studies.

3.4.1. Dried fruits

Processing code XVI-001 is assigned to drying of fruits.

Studies on processing of fresh into dried fruit containing residual moisture contents between approximately 15 and 25% are available on representative RACs of the pome fruits group (apples, pears) which are normally sliced and have core parts removed prior to undergoing the final dehydration step (FAO, online-b).

Some studies are also available on certain stone fruit representatives, in particular plums/prunes, but also apricots and peaches. Prior to initiating the (final) drying, fruits were pitted. That loss of mass needs be taken into account when deriving a processing factor. Unlike for pome fruits and stone fruits no parts of the fresh commodity are removed in the case of various other fruits like table grapes, cranberries, goji berries or dates and figs. Most of the studies on berries have been done on table grapes to produce raisins. No processing studies whatsoever were available for that fresh fruit which are peeled before drying, such as banana or papaya. As a makeshift approach, peeling factors and generic drying factors may be combined in such cases in a modular manner.

In industry small amounts of food additives like sorbic acid, antioxidants (e.g. sulfites) and surfactants are commonly added, which is normally not reflected in the lab-scale processing studies. This is no harm as the quantities are not anticipated to significantly impact overall processing factors (FAO, online-b). Raisins are sometimes bleached and/or treated with oil.

3.4.1.1. Processing details

Fruits are commonly sorted and washed. Inedible parts of the fruit like stones (for stone fruits) and peels are removed but fruits with edible peel may nevertheless also be peeled before drying in certain cases. E. g. dried apples are manufactured both in peeled and unpeeled form. Bigger fruits are typically sliced in smaller pieces, the thickness of which depending on the water content of the fruit. Small berries do not need to be chopped to enhance drying. Occasionally agents are added to the fruits in order to speed up transfer of water through membranes (potassium carbonate, olive oil in the case of sultanas). Small quantities of sulphite, citric acid and sucrose syrup may also be employed either for preservative reasons or/and to achieve a balanced sugar/acid ratio.

Any such additives or pre-drying of fruits in the field are not reflected in lab processing studies but are also not anticipated to have a significant effect on the eventual processing factors.

3.4.1.2. Scientific studies reflecting typical processing operations

Processing studies for dried fruits are mainly done on either plums to yield prunes or on grapes to yield raisins. Studies on the drying of apple slices have also been reported.

The study of Shepard (2008) reports on the drying of plums. Fresh plums were pitted by hand and sorted to remove leaves, stems and rotten or otherwise damaged fruits. After washing in water, the fruits were dried in a tray air dryer at 68-79°C until a moisture content of 32-38% was achieved. The study is acceptable according to the quality criteria and was referenced in an EFSA Reasoned Opinion according to Article 10 (EFSA, 2012d).

The study of Mäyer (2012b) reports the processing of grapes into raisins. Grapes were de-stemmed and stored on a tray (single layers of grapes). Grapes were dried at 55-60°C to a moisture content of 15-18%. The study is acceptable according to the quality criteria and was referenced in an EFSA Conclusion (EFSA, 2015b).

Reported studies use predominantly table grape varieties for production of raisins. Only in a few cases wine grape varieties were used.

The study of Mackie (2006) describes the processing of apples to dried apple pieces. After washing, apples were peeled, cored and sliced. The peeled and cored apples were placed in cold water containing sodium chloride to prevent enzymatic browning. Furthermore, the pieces were dipped in sulphite solution and citric acid solution. Drying was proceeded by an air dryer until a target moisture content of 2.5% was obtained. The study of Mackie is acceptable according to the quality criteria and was referenced in a Conclusion (EFSA, 2013c).

3.4.2. Dried vegetables

Processing code XVI-002 is assigned to drying of vegetables.

In principle, the same considerations as outlined in section 3.4.1 for dried fruits equally apply to dried vegetables. A limited number of studies on the magnitude of residues due to processing of fresh produce into dried vegetables are available for commodities representative of the bulb vegetables (onions) and root and tuber vegetables (potatoes), fungi (mushrooms), and the fruiting vegetable group (tomatoes).

At a first glance, water extraction under mild conditions appears being a rather simple process with dehydration factors depending almost completely on the water content of the matrix. However, the factors reported in processing studies on e.g. sun-dried tomatoes are seen in an unexpectedly wide range, starting as low as 3.5 (EFSA, 2014a) up to about 11 (EFSA, 2015d). When taking into account initial water contents of the fruits of around 90%, the lower factor of 3.5 appears implausible. In this specific case, the figure may easily be explained by photo-transformation of the concerned active substance cyantraniliprole in the sun-dried product during exposure to solar radiation. In case of overlooking such specific effects they may constitute a considerable source of error when generalising from specific conditions of an experiment (e.g. sun dried tomatoes) to all kind of dried tomatoes. But not only photolytic decomposition can lead to unexpected lowering of processing factors. If the raw commodity is washed before drying and (non-edible) parts are removed, this can also result in a reduction of the residue level in the dried products. This explains the sometimes larger scope of processing factors.

3.4.2.1. Scientific studies reflecting typical processing operations

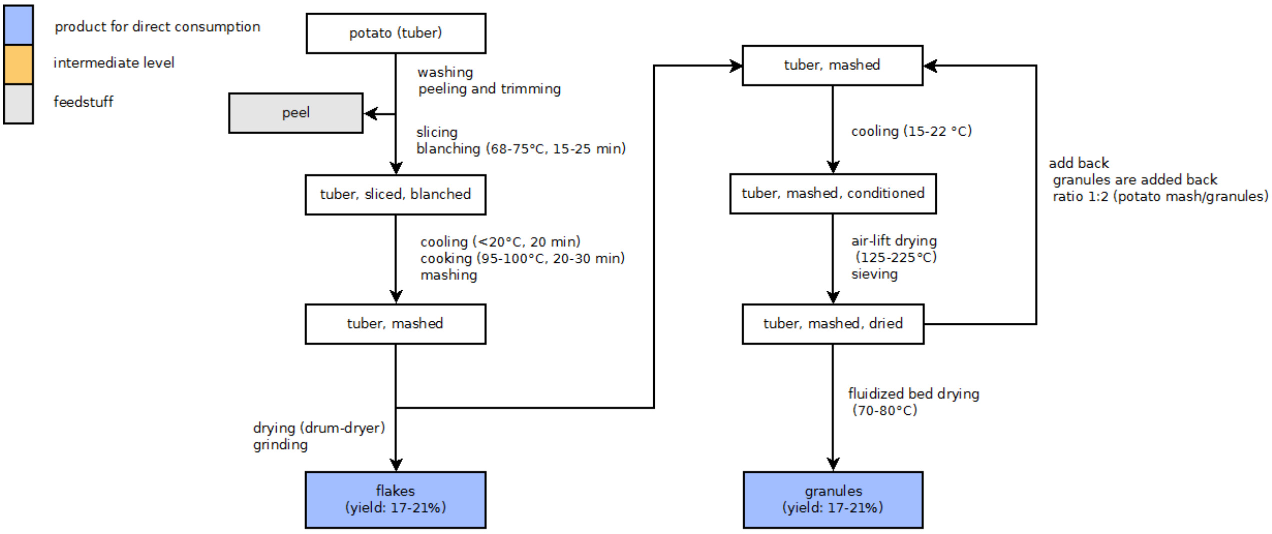
A processing study for dried tomatoes has been scrutinised by EFSA in the framework of MRL setting according to Article 10 and the results were reported in the corresponding Reasoned Opinion (EFSA, 2015d). The study is acceptable according to the set quality criteria.

The study of Gemrot (2012) reports on processing of sun-dried tomatoes. Unwashed tomatoes were cut in quarters and subsequently pressed to remove the majority of the water before drying. The pressed tomatoes were placed on a plate to dry. The plates were put out in the sun during the day and brought into a glasshouse overnight. The process was stopped when the tomatoes were visually dry. The residual moisture content was reported between 4 and 6%.

3.4.3. Processing of potatoes to flakes and granules

At industrial scale potato flakes and potato granules are obtained from cooked, mashed and dehydrated potatoes. They can be reconstituted in hot water for use as mashed potatoes. The use as an ingredient in baking products or snack products is possible as well.

The production of potato flakes and potato granules is very similar and differs only in the drying step. Both processes are depicted in Figure 12 and are explained below.



Yield factors are referenced in Heiss (2004).

Figure 12: Processing of potatoes to potato flakes and granules (XVI-004)

Washing, peeling and slicing

Potatoes are washed and peeled in a comparable way as described in chapter 3.1.2 on potato cooking. The washed potatoes are sliced in 1.2-1.5 cm thick slices. Subsequently, the slices are washed with water to remove free starch (Heiss, 2004).

Blanching

Sliced potatoes are heated to a temperature between 64 and 80°C (BOGK, 2018). At this temperature starch gelatinisation takes place but intercellular bonds are not softened. After blanching, the sliced potatoes are cooled to 20-25°C for 6-8 min (BOGK, 2018; Heiss, 2004). Blanching and cooling is not always conducted at industrial scale.

Cooking and mashing

Sliced potatoes are steam cooked. Cooking time depends on the potato variety and is usually between 15 and 40 min (BOGK, 2018). The cooked potatoes are then gently mashed. Addition of monoglycerides and antioxidants to improve texture and stability is possible.

Drying (potato flakes)

The potato mash is drum dried and subsequently grinded into flakes.

Drying (potato granules)

The hot potato mash is mixed with a large quantity of previously dried potato granules. The ratio is approximately one part potato mash to two parts of potato granules. The moisture content of the mix is approximately 30%. The mixture is cooled down to temperatures between 15 and 22°C and rests until the water content is evenly distributed. The mix is then dried in a preliminary drying step to a moisture content of 12-15% with an airlift dryer. About two-thirds of the mix is added back to the hot potato mash. The remaining mix is further dried with a fluidised bed dryer at temperatures between 70 and 80°C to a moisture content of 6-7% (Heiss, 2004; Salunkhe and Kadam, 1998).

The processing of potatoes into flakes or granules includes several steps which might lead to a decrease of pesticide residues. Peeling removes part of non-systemic pesticides. Several heating steps decrease the concentration and/or change the nature of residues of heat-labile pesticides. Though the dehydration of the potato mash can lead to a higher concentration of pesticides in the end product, it should be taken into account that the end product is rehydrated before consumption, so no significant influence is expected from dehydration and rehydration.

3.4.3.1. By-products of potato flakes and granules

The main by-product of the potato flakes and granules production is potato peel, which can be used as feedstuff (OECD, 2013).

3.4.3.2. Scientific studies reflecting typical processing operations

Several studies are available which describe the processing of potatoes into potato flakes. However, in studies describing the production of potato granules as well as potato flakes, both products are only differentiated by size and not by the production method. For both products the potato flaking method is used and the resulting product is separated into potato flakes and granules by screening.

The study of Mäyer (2012d) was selected as representative. The study is acceptable according to the quality criteria and is cited by EFSA (2015b) in a Reasoned Opinion. The study describes the processing of potatoes into potato flakes and potato granules. Potatoes were washed and peeled. The peeled potatoes were sliced in 0.63 cm thick slices and subsequently washed to remove free starch. The potato slices were blanched for 19 to 21 min in water at temperatures between 71 and 73°C. Afterwards, the potato slices were drained and then steamed for 35-45 min at temperatures between 95 and 100°C. The cooked potatoes were mashed and subsequently flash dried with a steam heated drum dryer. The dried product was roller milled and then separated with 30 and 62 mesh screens. Material less than 62 mesh was granules and material greater than 62 mesh but less than 30 mesh was flakes. Material above 30 mesh was milled again and then screened once more.

3.4.3.3. Extrapolation to other commodities

Extrapolation between potato flakes and potato granules is possible. No extrapolation to other commodities is recommended.

Home-made mashed potatoes can be extrapolated to other mashed root and tuber vegetables, like carrots or parsnips.

3.4.3.4. Comparison to industrial and/or household processing techniques

The household production of potato mash mainly consists of cooking peeled potatoes and mashing them afterwards. Dilution by addition of other ingredients, e.g. milk, is possible. Despite of additional steps in the industrial process, the processing factor is expected to be similar for the industrial and household methods as far as the ready-to-use end product is concerned. The increase of the pesticide concentration caused by dehydration is reversed when water is added again prior to consumption.

3.4.4. Herbs and spices

Processing code XVI-003 is assigned to drying of herbs and spices.

Consumption of herbs, spices and herbal infusions is a rather small part of the human diet.

No processing study on the magnitude of the residue was available for any kind of fresh herbs. It is noted that in some of the crop field trials residues were reported for fresh and dried samples in parallel – however without much detail on the drying process. Very few processing studies on the magnitude of residues were available for dried onions. In the absence of specific data, generic figures on water content of fresh and dried end-products may be used as a surrogate. Based on data retrieved from public literature and data gained in laboratories of its member companies the European Spice Association (ESA) has published a list of empirical dehydration factors which may be used to estimate concentration of pesticide residues in the final products (refer to Table 8).

For plant parts which may get processed into dried herbal infusions or dried spices, hardly any processing studies were available, but none are required due to the fact that MRLs for RAC of both spices and herbal infusions apply already to the dried products entering the market.

Table 8: Recommended generic dehydration factors for selected commodities used as dried herbs and spices according to ESA (ESA, online).

Plant parts (Code according to Annex I to Reg (EC) No 396/2005)	**Product to which MRLs apply**	**Commodity**	**Generic dehydration factor**
Herbs and edible flowers (0256000)	MRL applies to fresh product	Chervil	5
	MRL applies to fresh product	Oregano, parsley	6
	MRL applies to fresh product	Basil, chives, dill, laurel, lovage, marjoram, mint, rosemary, sage, savory, tarragon, thyme	7
	MRL applies to fresh product	Celery leaves	10
	MRL applies to fresh product	Coriander leaves	13
Bulb vegetables (0220000)	MRL applies to fresh product	Garlic	3
	MRL applies to fresh product	Onion	9
Fruiting vegetable (0230000)	MRL applies to fresh product	Sweet pepper	10
Herbal infusions from flowers (0631000)	MRL applies to dried product		n.a.[#]
Herbal infusions from leaves and herbs (0632000)	MRL applies to dried product		n.a.[#]
Herbal infusions from roots (0633000)	MRL applies to dried product		n.a.[#]
Herbal infusions from any other parts of the plant (0639000)	MRL applies to dried product		n.a.[#]
Seed spices (0810000)	MRL applies to dried product		n.a.[#]
Fruit spices (0820000)	MRL applies to dried product		n.a.[#]
Bark spices (0830000)	MRL applies to dried product		n.a.[#]
Root and rhizome spices (0840000)	MRL applies to dried product		n.a.[#]
Bud spices (0850000)	MRL applies to dried product		n.a.[#]
Flower pistil spices (0860000)	MRL applies to dried product		n.a.[#]
Aril spices (0870000)	MRL applies to dried product		n.a.[#]

[#] A dehydration factor is not applicable as monitoring data already refer to the dried product.

3.4.5. Further dehydration processes

In the preceding chapters, reference is made to the drying of fruits and vegetables which, after drying, could be directly consumed. However, the drying of various commodities is an intermediate step during processing. Thus, for example, cereal grains are prepared for storage by reducing the moisture content to a maximum water content of 14% (Schuchmann and Schuchmann, 2005).

Certain commodities further to herbal infusions and spices are defined as RAC in EU residue legislation in their dried state (Reg. (EU) No 2018/62), for example hops and (black) tea leaves. However, both commodities are not consumed as such, but as composite foods: Tea as an infusion with hot water, hops after further processing to beer (see chapter 9.2).

Processing code XIII-003 is assigned to the preparation of tea infusions. The difference between black and green tea leaves is the fermentation. Leaves for black tea production undergo a fermentation process. About 8 g of tea leaves are used per litre water. Black tea infusions are prepared with boiling water and leaves are steeped for about 3 min. For green tea the water temperature is around 70-80°C and steeping time about 2 min (Teakampagne, online).

During processing of barley to malt, the malt is also dried in a multi-stage process. The detailed descriptions of the drying as part of multi-step processes are reported in the respective chapters.

Similar to food for human consumption, animal feed may also be preserved by water extraction in order to control decay. Feedstuffs include mainly grass (hay) and dried by-products of food manufacturing such as dried pomace, dried pulp and molasses, and peels. Processing studies focussing on those feed commodities are not available but factors for these secondary spin-off products are commonly reported on grounds of mass balance, and also in some residue field studies, e.g. on grass.

3.5. Frying and deep-frying

Frying is a heating process in which water-containing foods are completely immersed in edible oil or fat at temperatures of 140 to 180°C. Oils and fats have a high heat capacity and can transmit heat at temperatures above the boiling point of water to the food. The water bound in the food is gradually transferred to the surface layer from the interior as a result of the evaporation at the surface, and is finally released into the surrounding oil more or less quickly depending on the structure of the crust. The shelf-life of fried foods is mostly determined by the moisture content after frying. Foods that are more thoroughly dried by frying (e.g. potato crisps (*potato chips* in the United States) and other potato or maize snack foods) have a long shelf-life at ambient temperature. When water is no longer transferred to the surface, the temperature rises from the outside to the inside to above 100°C. Now, the typical frying flavour as well as the golden yellow colour develops (DGF, online; Fellows, 2016).

Many types of frying are used in processing operations, including:

- *Deep(-fat) frying:* This is the main frying method. Food is submerged in hot fat, most commonly oil, rather than the shallow oil used in conventional frying in a frying pan. Normally, a deep fryer or chip pan is used for deep-frying. Industrially, a pressure fryer or vacuum fryer may be used (Thornes, 1996).
- *Sautéing:* A method of cooking food that uses a small amount of oil or fat in a shallow pan over relatively high heat.
- *Stir frying:* A Chinese cooking technique in which ingredients are fried in a small amount of very hot oil while being stirred in a wok (Liley, 2007).
- *Pan frying:* A form of frying characterised by the use of minimal cooking oil or fat, but typically using just enough oil to lubricate the pan.
- *Shallow frying:* Shallow-fried foods are often batter coated. It is a high-heat process, promoting browning and, in some cases, a Maillard reaction.

Several types of foods are fried, like cereal, fruits (apple slices, batter coated) and vegetables (slices from onion, carrot, sweet potato, beetroot and especially various potato products) (Fellows, 2016).

Processing studies are only available on the production of potato crisps (from peeled and unpeeled potatoes) as well as French fries (from peeled and unpeeled potatoes) (*potato chips* in the UK).

Oils that are suitable for frying should remain stable during the process. Other criteria are:

- Stability against oxidation during both frying and product storage
- A fatty acid profile that is low in saturated and *trans*-fatty acids
- Low tendency to foam, or polymerise and produce gums
- High smoke point
- Low viscosity
- Neutral or bland flavour

Suitable are refined frying oils made from cottonseed, peanut, maize, olive, rape seed, palm fruits, safflower, soya bean and sunflower (Fellows, 2016).

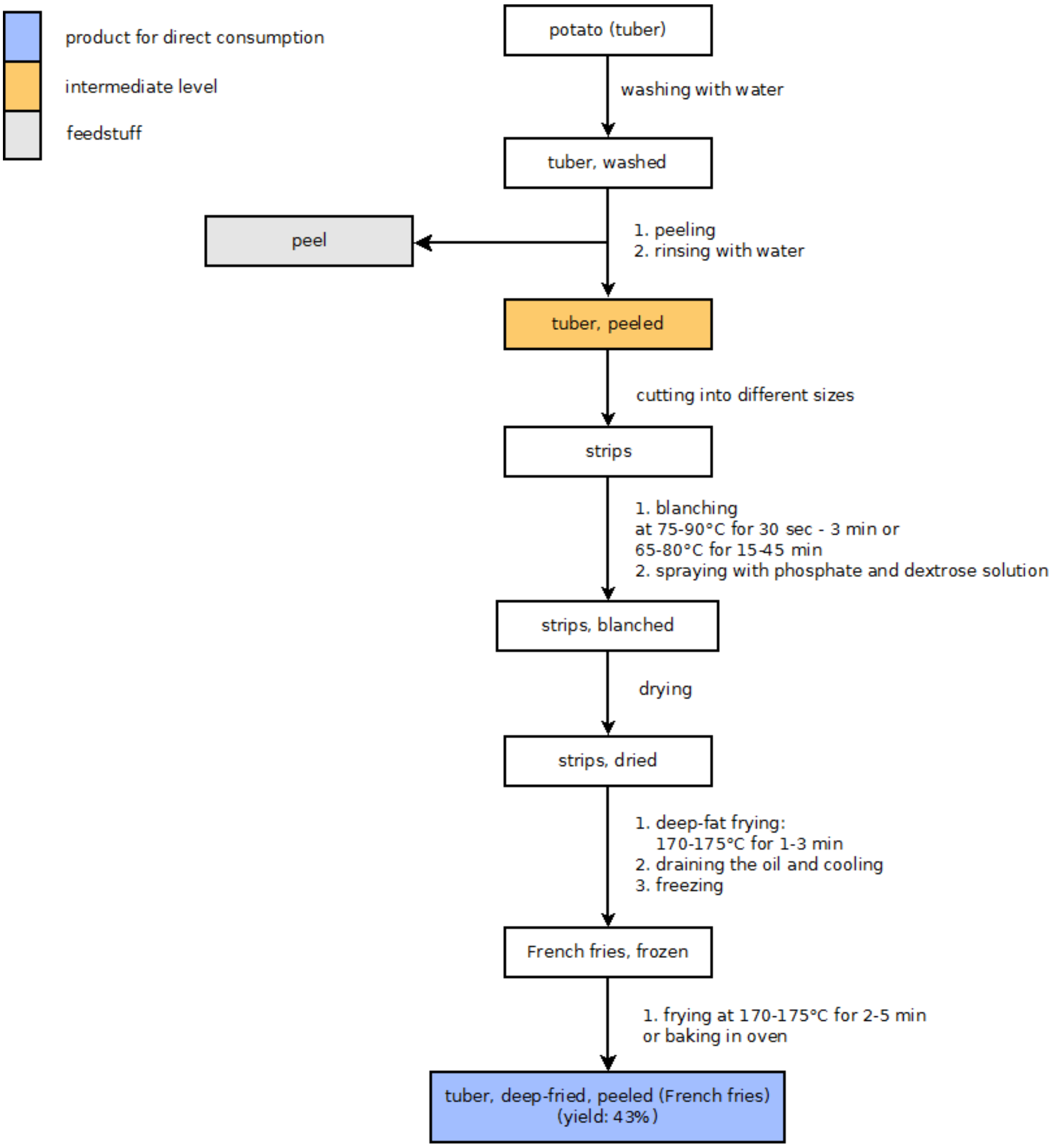
If pesticide residues are found in French fries, they may stem from the potato or from the frying oil which has been absorbed to a considerable extent. The range of processing factors reported for fried potatoes is relatively large. On the one hand, the frying process leads to water loss at very high temperatures, which leads to a concentration of the residue. On the other hand, residues are often removed by washing and peeling. Some active ingredients decompose at the employed temperatures around 190°C.

For the different types of frying, temperatures are similar, which is the main parameter influencing the nature of pesticide residues. The absorbed amount of oil depends on the method and commodity. For example the oil content of potato crisps is around 35% and of French fries around 15% (both deep-fat fried) (Pedreschi and Enrione, 2014).

Both French fries and crisps are considered to be composite foods. Meaningful processing factors can be derived after recalculation to the potato fraction in the fries and crisps.

3.5.1. Processing of potatoes to potato chips (French fries)

French fries are produced both in household and in industry. The industrial production includes peeling, cutting, blanching, drying, pre-frying and freezing. As a frozen product, pre-fried French fries are of great importance. The following Figure 13 presents the processing of potatoes to French fries on industrial scale.



A yield factor for the product for direct consumption is referenced in BLS (2009). If frozen French fries are fried again, a water content of 39.5% and an oil content of 14.8% are typical (Pedreschi and Enrione, 2014). These percentages range depending on the cut size and frying conditions.

Figure 13: Processing of potatoes to French fries on industrial scale (IX-001)

Washing, sorting and peeling

Potatoes are washed and peeled as described in chapter 3.2.2 on potato cooking. At industrial scale steam peeling is usually conducted. Peeled potatoes are inspected and sorted.

Cutting and Blanching

The peeled potatoes are chopped by cutters into different sizes: 6x6 mm to 15x15 mm and 10x20 mm (BOGK, 2018). Afterwards they are blanched. This is done either at higher temperature and shorter time (between 75 - 90°C for about 30 s to 3 min) or at lower temperature and longer time (between 65 - 80°C for about 15 - 45 min) (BOGK, 2018; Brennan, 2006; Fellows, 2016). This removes excess sugars and ensures a consistent texture and colour of the fries. The blanched stripes may be dipped into or sprayed with a solution of 0.5% disodiumdiphosphate (as a processing aid to prevent darkening of the fries) and optionally approx. 0.5% dextrose (to maintain an even golden colour)(Ellinger, 1972) at temperatures of about 70°C (Sumnu and Sahin, 2008).

Drying

After blanching and dipping, the strips are dried in an air dryer to a moisture content of about 75-80% (BOGK, 2018).

Deep-fat frying, cooling and freezing

The dried strips are tempered at room temperature and then pre--fried in vegetable oil for 1-3 min at 160-180°C (BOGK, 2018; Brennan, 2006). After frying, the fried strips are drained to remove excess oil, cooled down and finally placed in the freezer for rapid freezing (at about -30°C for 5-10 min) (Heiss, 2004).

French fries are sold pre-fried in chilled or frozen form as commercial goods. The ready-to-eat final product is prepared by re-frying at 170-175°C for 2-5 min (BOGK, 2018). In household preparation the temperature usually not exceeds 175°C. French fries are salted and seasoned after frying (Fellows, 2016).

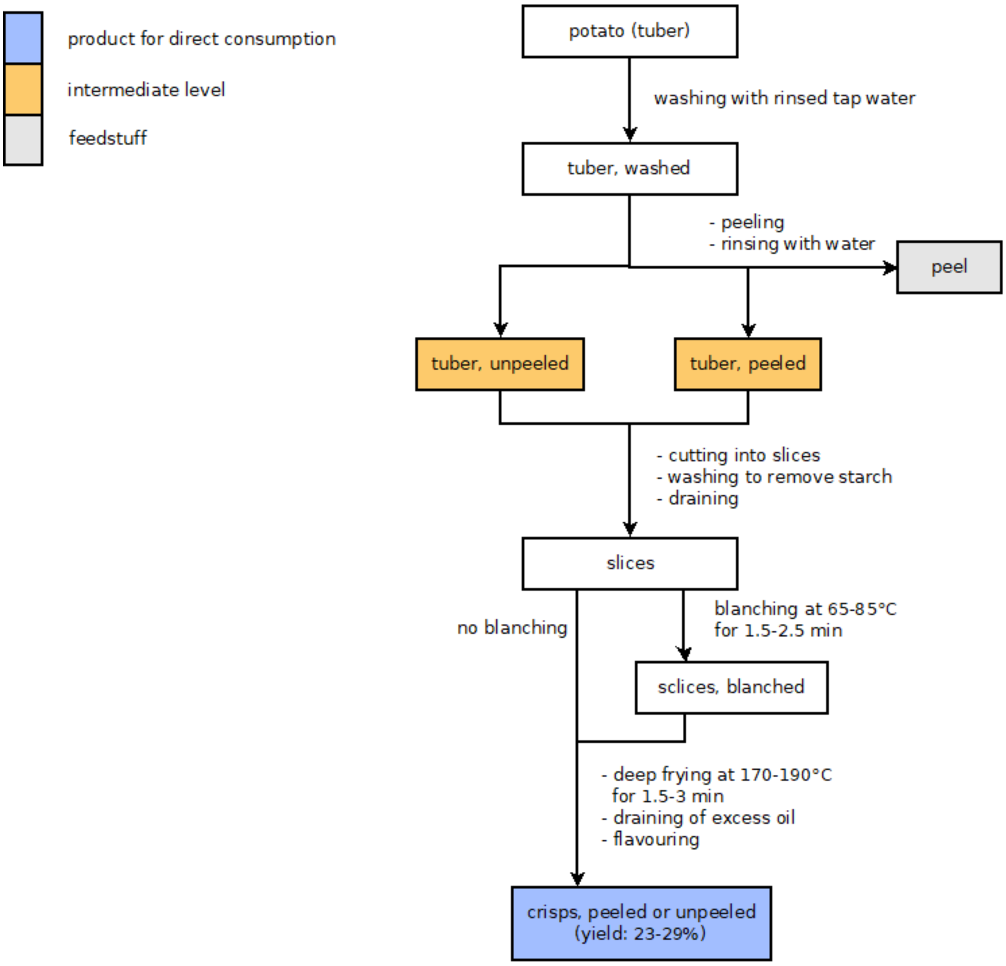
The frying time is influenced by the oil temperature, the dry matter content, the size of the potato strips and the desired product (pre-fried or finished French fries) (Brennan, 2006).

Production of French fries from unpeeled potatoes

Rarely, French fries are made from unpeeled potatoes. Except for the peeling process, production techniques are comparable. However, higher residue levels are to be expected since residues are often predominantly located in the potato peel.

3.5.2. Processing of potato crisps

Potato crisps can be produced from peeled and unpeeled tubers. Peeling is mostly done by abrasion and brushing, sometimes steam peeling is conducted. Unpeeled tubers are only brushed. Prepared tubers are cut automatically into slices, up to 0.2 cm in plain or curvy style (BDSI, 2018). Further rinsing with ambient temperature water removes starch residues from the surface. Potato slices can be dried on a wire conveyor. Potato slices are blanched at 65-85°C for 1.5-2.5 min (BDSI, 2018). This step depends on the product characteristics and is required to lower the level of reducing sugars. Afterwards, sliced potatoes are fried at 170-190°C for 1.5-3 min until a moisture level of about 1-2% is reached (BDSI, 2018; Brennan, 2006; Fellows, 2016). Frying times and temperatures may differ depending on the product and sugar content. The potato crisps are finally drained, flavoured and packed.



A yield factor for the product for direct consumption is referenced by BDSI (2018).

Figure 14: Processing of potatoes to potato crisps (IX-002)

3.5.3. By-products of frying and deep-frying

By-products from potato processing operations, e.g. wet and dry peel can be used as feedstuff (OECD, 2013). Intermediate products such as peeled potatoes can be subjected to other processing operations such as cooking or canning. Remaining starch from the washing step can be recovered as a further by-product.

3.5.4. Scientific studies reflecting typical processing operations

Two studies were selected. One study describes the production of French fries from peeled and unpeeled potatoes as well as the production of potato crisps. Another study covers a typical household preparation of deep-fried potatoes. It should be noted that on industrial scale the potato is first cut into strips followed by blanching (see 3.5.1).

The report of Rice (2009) describes the processing of potatoes to French fries from both peeled and unpeeled potatoes. The study is acceptable according to the quality criteria. It is referenced by EFSA (2012d) in a Reasoned Opinion according to Article 10. Unpeeled potatoes were washed, peeled by steaming and scrubbing, and pre-cooked at 54°C for 40 min. The pre-cooked potatoes were cut into strips, blanched, and dried to a moisture content of 15%. Furthermore, the dried strips were fried at 190°C for 45-50 s. The study reports on subsequent freezing to obtain French fries for trading.

Unpeeled potatoes were also washed, cut into strips and fried for 2.5 to 3 min at 177 to 191°C.

Furthermore, the processing of crisps is reported. Peeled potatoes were sliced, and fried at temperatures around 163 - 191°C for 90 s.

The study of Hoven and Nixon (2012) reports on household processing of potatoes to French fries. Peeled raw potatoes were cut into 1 cm strips using a French fry cutter and were slightly tapped dry with paper towels. The potato strips were placed into a fryer containing maize oil and were fried at 190°C for 15 min. Fried potatoes were removed and placed on paper towels to drain and cool for 5 min.

The study is acceptable according to the quality criteria. It is referenced by EFSA (2015d) in a Reasoned Opinion according to Article 10.

3.5.5. Extrapolation to other commodities

The temperature which is the main parameter influencing the nature of pesticide residues is similar for different frying methods. In addition peeling before frying may remove a significant amount of residues and this should be taken into account when extrapolating to other commodities. Depending on the volume of the hot fat or oil, residues may migrate from the food into the hot oil or fat, especially for fat soluble residues, thereby reducing the residue concentration in the deep-fried food.

No differences to other frying and deep-frying methods are expected.

Processing studies have been submitted exclusively for deep-frying of potatoes. An extrapolation to further deep-fried commodities of the root and tuber vegetable group like carrots, beetroots or sweet potatoes is recommended as long as the peeling conditions are the same.

3.5.6. Comparison to industrial and/or household processing techniques

It is common to produce French fries directly in households. Washed and peeled or unpeeled potatoes are cut into strips of 0.5 to 1 cm width and lightly tapped with paper towels. The potato strips are placed into a fryer containing frying oil and are fried at 150-175°C for 6-8 min. The French fries are then removed from the fryer and placed on paper towels to drain and cool for approximately 5 min. They can be salted and seasoned.

Furthermore the processing of potato crisps is a common industrial process. If crisps are produced at home the processes are comparable.

The processing techniques in industry and household are well reflected by representative processing studies.

3.6. Baking and Roasting

Baking and roasting are both thermal processes which use heated air to modify the properties of food. The term baking is used for dough products (e.g. bread) or baked vegetables while the term roasting is used for products like coffee beans, peanuts and cocoa beans. Roasting of cocoa beans is part of cocoa powder production and is described in chapter 12.

Vegetables can either be baked (e.g. baked potato) or roasted (e.g. roasted potato). The main difference is the temperature, which is lower when baking. Also, roasting of vegetables usually involves the addition of a small amount of oil to prevent burning.

The pesticide residue may be influenced by the thermal process and for some products it may get diluted through addition of other ingredients (e.g. bread baking).

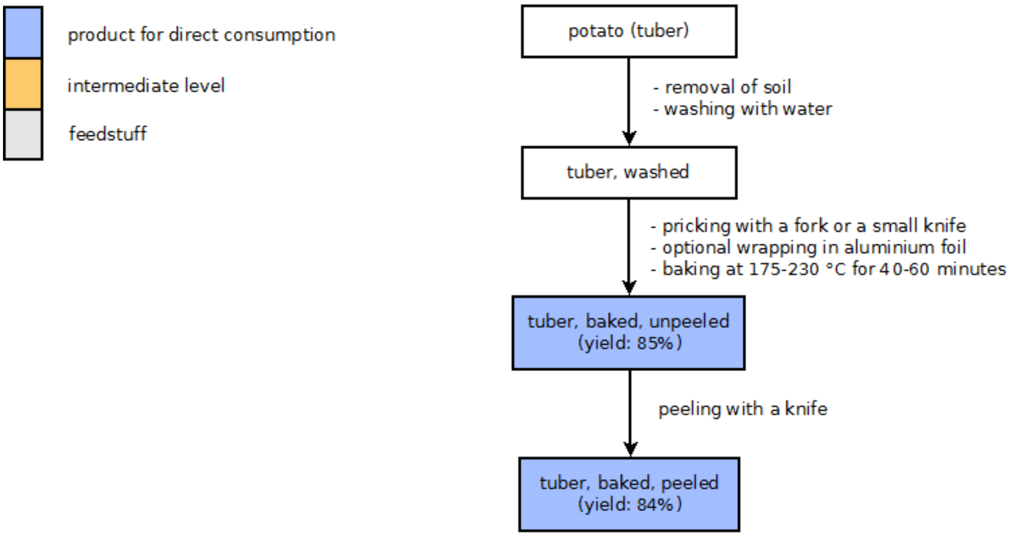
3.6.1. Baking of potatoes

Baked potatoes can be prepared in a conventional oven, a convection oven, or a microwave oven (see chapter 3.7). Some restaurants use ovens designed specifically to handle large numbers of potatoes and keep them warm and ready for service (Wilson et al., 2002). Usually only domestic production or production of smaller quantities is relevant.

3.6.1.1. Processing details

The described procedure refers to a typical household process and is shown in the following Figure 15.

Commonly, potatoes are baked with peel. Damaged potatoes are removed. Adhering soil is rubbed off and the tubers are washed with water. Subsequently, the potatoes are pricked with a fork or a small knife, optionally wrapped with aluminum foil to prevent too much water loss, and baked in a conventional oven for 40 to 60 min at 175 to 230°C. The heating time can vary and depends on the size of the potatoes. Finally, the baked potatoes are peeled thinly with a kitchen knife (Wilson et al., 2002).



The yield factor is composed of a loss of water during heating in the oven (Wilson et al., 2002) and peeling (in the case of peeled baked potatoes) (BLS, 2009).

Figure 15: Processing of potatoes to baked potatoes (IX-004)

3.6.1.2. Scientific studies reflecting typical processing operations

Processing studies for baked vegetables are only available for the commodity potato. EFSA references three studies, one of which is selected as representative.

The study of Melrose and Eberhardt (2006) reports on processing of potato to several products. Baked potatoes are produced by washing and removing of soil, wrapping in aluminium foil and baking for 40-60 min at 230°C. Finally, the baked potato is peeled with a kitchen knife.

The study is cited by EFSA (2005) and acceptable according to the quality criteria.

3.6.1.3. Extrapolation to other commodities

Processing studies have been submitted exclusively for baking of potatoes. An extrapolation to further commodities of the root and tuber vegetable group like carrots, beetroots or sweet potatoes is proposed.

3.6.1.4. Comparison to industrial and/or household processing techniques

Baking of potatoes in an oven is a typical domestic preparation. Processing studies represent this procedure sufficiently.

3.6.2. Coffee roasting

Coffee plants are primarily cultivated in the tropical-equatorial regions. When ripe, the fruits of the coffee plants are picked and processed. Processing includes the removal of peel and flesh and the drying of the beans to a water content below 12% (Schwan and Graham, 2015). The resulting product called green coffee bean is the raw agricultural commodity according to Regulation No 2018/62.

Roasting the green coffee beans produces the characteristic aroma and flavour of coffee.

3.6.2.1. Processing details

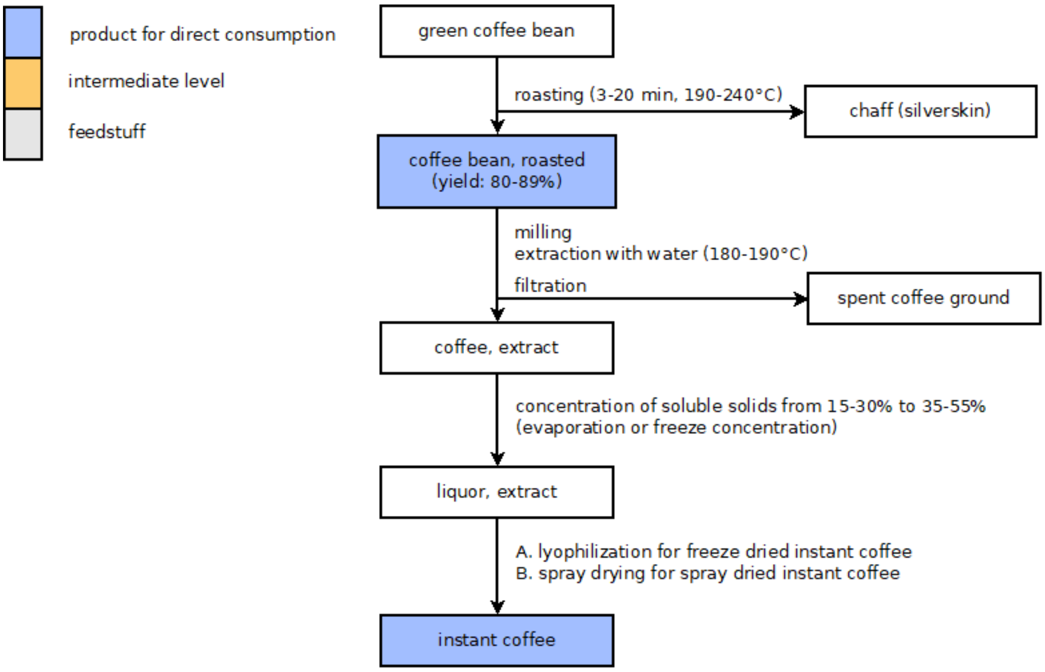
An overview of the relevant steps in the process of preparing roasted coffee and instant coffee is provided in Figure 16. The steps are further described in the text below.

Roasting

Dried green coffee beans (RAC) are roasted at temperatures between 190 and 240°C in a drum coffee roaster (Heiss, 2004). During roasting, the size of the beans doubles due to inner pressure caused by water vaporisation and release of volatile compounds. The outer skin of the coffee beans, chaff or silverskin, falls off. The loss of water and volatile compounds leads to a weight loss of between 11 and 28% (Heiss, 2004). The roasting process is stopped by rapid cooling. This is achieved either by providing cold air or by spraying water on the hot beans.

Roasting time, temperature and the specific roasting profile influence the taste and the colour of the coffee beans. With longer roasting times and higher temperatures darker coffee beans are produced. Roasted coffee can be roughly divided into light, medium and dark roasted varieties. Roasted coffee beans can be traded as whole beans or in grinded form.

Heat-labile pesticides are expected to degrade during the roasting process.



The yield factor for roasted coffee is referenced in Heiss (2004). No yield factor for instant coffee could be retrieved.

Figure 16: Processing of green coffee beans into roasted coffee and instant coffee (XIII-001)

Further processing: Instant coffee powder and coffee beverage

The roasted coffee beans are grounded in a mill to a particle size of 1000-2000 µm. The coffee solubles are then extracted with water at high temperatures between 180 and 190°C (Heiss, 2004). The resulting extract is concentrated and subsequently dried, either by spray drying or by freeze drying.

For consumption, the roasted and grinded coffee beans are extracted with hot water (90-94°C) by various types of coffee making to produce coffee (beverage) of various strengths, while the instant coffee powder only needs to be mixed with hot water (90-94°C). This step is not covered by the processing factor (which is for coffee bean roasting).

Food consumption values may be expressed as the amount of roasted coffee beans or instant coffee powder used to produce the coffee beverage or they may be expressed as the amount of coffee beverage consumed. For coffee beverages a coffee to water ratio of 8.25 g (whole bean) coffee (± 0.25 g) and 150 ml water is proposed (SCA, online). The ratio can be different depending on the intended strength of the coffee beverage. For instant coffee, 1 - 2 g instant coffee powder per cup (200 mL) is generally used to produce the ready-to-drink beverage.

Neither coffee beans nor instant coffee are consumed as such, but as coffee beverage. Due to the addition of hot/boiling water, coffee is considered a composite food. No processing study was available on the processing of (grounded) coffee beans to coffee beverages.

3.6.2.2. By-products of coffee roasting

Coffee chaff is the main by-product of coffee roasting. It can be pressed to pellets and used as fertiliser or fuel pellets.

3.6.2.3. Scientific studies reflecting typical processing operations

Only a few studies cover coffee roasting and the production of instant coffee. For the latter process always the freeze drying process was used. The following study was selected as representative. The study is not cited by EFSA but is acceptable according to the quality criteria.

The study of Jordan and Gooding (2007) reports roasting of green coffee beans and further processing of roasted coffee into instant coffee (with the freeze drying method). The green coffee beans were cleaned and subsequently roasted at temperatures of 200 - 215°C for 10 to 30 min. The roasted coffee beans were then grounded with a coffee grinder. The ground material was sifted with an 18 and 36 mesh sieve. Material below the 18 mesh sieve and on top of the 36 mesh sieve was then extracted with hot water (130-160°C) under pressure above atmospheric conditions. The coffee extract was cooled down (12-24°C), filtered and concentrated in a vacuum evaporator (solids content between 15 and 30%). The resulting liquor extract was then filtered, frozen and subsequently freeze dried. After freeze drying, the product was reduced to granules.

3.6.2.4. Extrapolation to other commodities

Decaffeination is performed on green coffee beans prior to the roasting process. The caffeine is extracted from the beans either with organic solvents or more commonly with water or supercritical carbon dioxide. It is expected that this additional extraction step tends to decrease the pesticide concentration in the coffee bean. Therefore, coffee reflects the worst case when compared to decaffeinated coffee.

3.6.2.5. Comparison to industrial and/or household processing techniques

The representative study on coffee roasting reflects the industrial process. Further processing of roasted coffee into instant coffee is possible with two different methods, spray drying and freeze drying method. No studies are available covering spray drying. The described procedures are not of relevance on domestic level.

3.6.3. Peanut roasting

Peanuts belong to the “oilseeds” group and are considered as kernels without shell (RAC according to Regulation No 2018/62). These groundnuts are usually not cultivated in Europe and therefore imported. Several products can be produced of peanuts such as peanut butter, roasted peanuts or peanut oil.

Peanut butter is made from roasted and blanched peanuts, which are then grinded. Salt and peanut oil can be added. This process is not further described because peanut butter is of minor relevance for European consumer groups.

3.6.3.1. Processing details

Peanut roasting influences the taste, texture and flavour of the peanuts and reduces their moisture content. Peanut roasting consists of the processing steps blanching, drying and roasting. According to Regulation (EC) No 446/2009[3] blanching of peanuts is to be regarded as heat treatment designed mainly to remove the skin from the kernel.

There are two methods for roasting peanuts: dry roasting and oil roasting. Both processes are shown in the following flowchart (Figure 17) and are described below.

Dry-roasting

Dry-roasting consists of the processing steps roasting, cooling and blanching. Shelled peanuts are roasted for 40-60 min. The temperature of the peanuts is raised to about 160°C. Depending on the

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[3] Regulation (EC) No 446/2009 of 14 May 2009 concerning the classification of certain goods in the Combined Nomenclature. OJ L 132, 29.05.2009, p. 1-2.

peanut batch and desired characteristics the roasting time and temperature differs. The peanuts are then cooled and blanched. Blanching removes the peanut skin and foreign material. (Nadathur et al., 2016; Woodroof, 1983)

Wet-roasting

Prior to oil roasting, peanuts are blanched. Vegetable oil is heated to temperatures between 138 and 143°C and peanuts are deep fried for about 3 to 10 min.

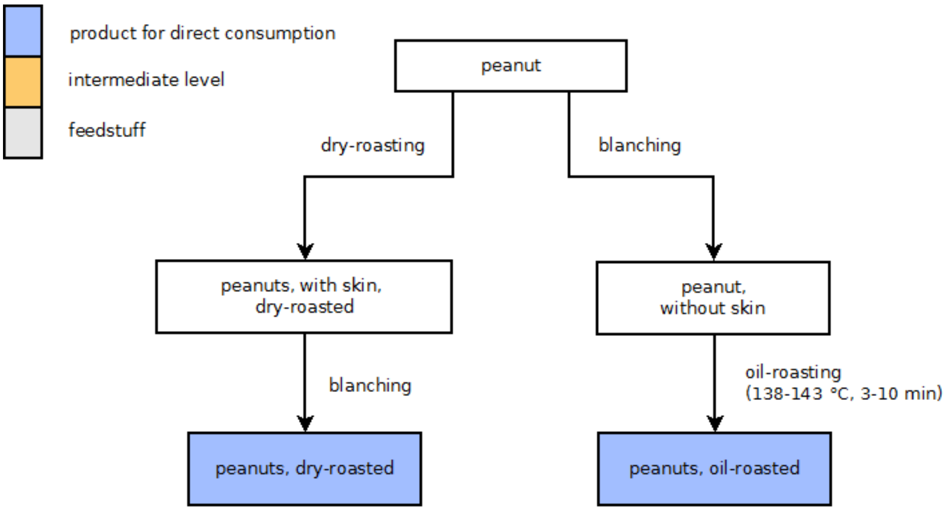


Figure 17: Processing of peanuts into roasted peanuts (IX-005)

3.6.3.2. Scientific studies reflecting typical processing operations

Several studies describe the production of roasted peanuts. However, roasted peanuts are an intermediate product in the studies and are further processed to peanut butter. Only the dry roasting process is described, while no studies for the oil-roasting process were available.

The study of Ellis (2012a) was chosen as representative. The study is acceptable according to the quality criteria and is referenced in a Conclusion (EFSA, 2015b).

Peanuts were shelled manually. The RAC starts with the shelled peanuts. The skins were removed with a rubber roller peeler. Blanching and the subsequent drying step were disregarded in the study to depict the worst case scenario. The peanuts were dry-roasted in an oven at temperatures between 165 and 180°C for 32-41 min.

3.6.3.3. Extrapolation to other commodities

Extrapolation to other oilseeds is not recommended. A recommendation for the extrapolation to roasted tree nuts is not possible due to no available EFSA cited studies.

3.6.3.4. Comparison to industrial and/or household processing techniques

Roasting of peanuts is not a typical household process.

3.7. Microwaving

Microwaving is considered a special form of cooking where heating is induced by electromagnetic radiation with water molecules acting as dielectric. Microwave energy is transmitted as electromagnetic waves and depth to which these penetrate foods is determined by both their frequency and the characteristics of the food. Microwave frequencies range from 300 MHz to 300 GHz (Fellows, 2016). Possible applications of a microwave oven are cooking, thawing, melting, finish-drying, freeze drying, tempering, pasteurisation, sterilisation, frying and blanching. The advantages of microwave heating compared to conventional heating can be summarised as:

- Rapid heating throughout the food without localised overheating or hot surfaces
- Minimum heat damage and no surface browning
- No limitation of heat transfer by boundary films
- High energy conversion efficiencies
- No contamination of foods by products of combustion

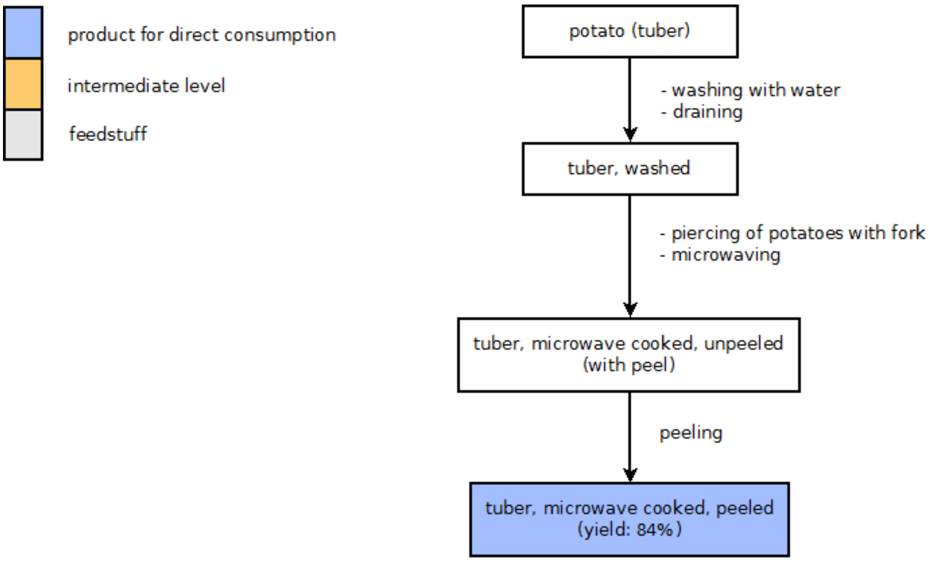
The microwaves transfer their energy and the molecular movement creates frictional heat that increases the temperature of water molecules. They in turn heat the surrounding components of the food by conduction and/ or convection. The amount of heat absorbed by a food, the rate of heating and the location of ‘cold spots’ depend on the food composition, its shape and size as well as the microwave frequency and the applicator design. The composition of food has a greater influence on microwave processing than on conventional heat processing due to its influence on the dielectric properties of the food. The moisture content and the presence of electrolytes, such as sodium chloride, acids or some thickeners, increase the efficiency of microwave absorption and decrease the depth of penetration (Fellows, 2016).

Processing studies that describe microwave cooking are exclusively related to the preparation of microwave cooked potatoes. Unlike for cooking in water, no migration of pesticide residues from the RAC into a surrounding fluid occurs in microwave cooking. No relevant change of residue levels or nature of residues is expected during microwave treatment (except for the degradation of heat-labile substances).

3.7.1. Processing details

The preparation of foods for microwave cooking follows the general preparation steps including washing and sorting. Microwave cooking of potatoes is carried out with unpeeled potatoes. Figure 18 illustrates this procedure. Microwave cooking is a common household procedure and is not relevant on industrial scale.

The potatoes are pricked several times with a fork or a small knife. The potatoes are cooked in a microwave oven for standard time and power. These depend on the size and quantity. Microwaves for large-scale uses (for example in catering), have significantly higher performances. Household microwaves often have a maximum output of 800 W. According to typical recipes, for a normal portion of potatoes of 150 to 200 g, 10-12 min of preparation time at maximum power is recommended.



A yield factor for the product for direct consumption is referenced in BLS (2009).

Figure 18: Processing of potatoes by microwave cooking (XVIII-001)

3.7.2. Scientific studies reflecting typical processing operations

EFSA cited only three studies on the microwave cooking of potatoes. The processing details are often not adequately described. One study reports on industrial production using a microwave oven with very high performance (Patel, 1994) which is not be considered representative for household processes.

The individual batches were washed in water for 2 min and then drained for 5 min. The potatoes were pricked four times with a fork. Batches of 3 kg were prepared. The potatoes were baked in a catering microwave for 15 min at 1800 W.

The study is cited by EFSA (2011) and the quality criteria are acceptable.

3.7.3. Extrapolation to other commodities

Processing studies have been submitted exclusively for microwave cooking of potatoes. An extrapolation to further commodities of the root and tuber vegetable group like carrots or sweet potatoes is recommended.

3.7.4. Comparison to industrial and/or household processing techniques

The most important industrial applications are dehydration, baking, tempering and thawing. Likewise, microwave devices can be used commercially for pasteurisation or sterilisation of ready meals. The main difference between industrial and domestic level preparations is the different output of the machinery. Available processing studies for microwave cooking lack the description of sufficient detail and do not cover the full scope of microwave applications.

4. Juice production

Major parts of a number of fruits and some vegetables are not consumed as such (raw) but after conversion into juice. Consumption of juice makes up an important share of dietary intake of many EU consumer groups, hence pesticides residues contained in juice is a major source of overall dietary exposure.

The terms "fruit juice" and "vegetable juice" represent a legally clearly defined and regulated product group (Directive 2001/112/EU[4]).

Table 9 gives an overview of juices covered by the EU database of processing factors. This is considered a representative overview of important fruit and vegetable commodities used for juicing.

Table 9: Overview on commodities from which juice is made (EC, 2020) and for which processing studies are available (*italised*).

Main crop group	Sub crop group	Commodity
fruits	citrus fruits	*grapefruits*
		lemons
		limes
		mandarins
		oranges
	pome fruits	*apples*
		pears
	stone fruits	*apricots*
		cherries (sweet)
		peaches
		plums
	berries and small fruits	*currants (black, red and white)*
		table grapes (red and white variety)
		strawberries
	miscellaneous fruits with inedible peel	bananas
		kiwifruits
		pineapples
vegetables	fruiting vegetables	*tomatoes*
		melons
		watermelons
	root and tuber vegetables	*carrots*
	brassica vegetables	*head cabbages*

Two main categories of juices are distinguished:

- Cloudy or pulpy juices single strength or concentrate (contain insoluble solid particles): For cloudy juices it is essential that the original content of pectins is retained throughout the production. For that purpose fruit enzymes must be inactivated as soon as possible by a heating step.
- Clear juice single strength or concentrate (without the insoluble particles): For clear juices a breakdown of pectins is needed to enable a good yield and high degree of juice concentration. This is done by dosing with specific pectolytic enzymes. In addition, further steps such as clarification by sedimentation with fining agents and (ultra)filtration steps are required.

Juices put on the market can either be single strength or concentrates which are later on reconstituted with water. Concentrated produce is made for practical reasons such as lowering transportation costs.

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[4] Council Directive 2001/112/EC of the European Parliament and of the Council of 12 January 2002 relating to fruit juices and certain similar products intended for human consumption. OJ L 10/58, 12.1.2002, p 1-9.

However an increased import into Europe has been observed in the last five years for "not-from-concentrate" (NFC) orange juice, followed by tomato juice, single citrus juice and pineapple juice (CBI, online). Concentration and reconstitution are not supposed to change the overall residue pattern.

The term 'fruit juice' is reserved for 100% fruit juices, which also include juices that are reconstituted with water to 100% from fruit juice concentrates. If sugar, sweeteners or acid are added to the fruit juice, which is diluted with water, the product must be called nectar or fruit drink. The composition of these products is defined in Directive 2012/12/EU[5].

Apart from some minor differences, juicing of fruits and vegetables includes the same major processing steps preparation, extraction, pressing, clarification, filtration and preservation (heating or freezing). Special kinds of preparation may be needed for the different fruits or vegetables. In order to maximise juice yield and colour and flavour extraction, a hot break process or enzyme treatment is often used. Vegetables can be cooked or fermented with lactic acid before pressing or straining.

One of the major differences is whether inedible parts (peels or stones) are present and have to be removed after washing and prior to squeezing or not. This is of particular importance where pesticide residues are accumulated in/on the outer layer of the fruits or where the stone makes up a major part of the raw agricultural commodity (to which MRLs refer).

Processing aids are commonly used in food industry. However, adding of bentonite, amylase, pectolytic enzymes, gelatine, calcium carbonate, ascorbic/ citric or other acids, sodium chloride, sugar, vinegar or spices occurs at various steps and is normally not simulated in processing studies, as such additions are not considered to significantly affect their outcome. Sugar may be added to achieve a desired Brix degree. Unlike for manufacturing of jam, ketchup, and others, sugar is also not considered to significantly impact the processing factors for juice. This is different for fruit nectars, since the addition of water and sugar is so considerable that the residue is diluted. Therefore it is recommended to recalculate processing factors obtained for nectar to factors for pure fruit juice.

Consumption of freshly produced juice without any further conservation makes up only a small part of all juice consumed. This is due to the fact that it is more time effective to purchase conserved juice but also to enjoy fruit of any kind around the year. As a consequence, household juicing is deemed to make up only a small part of all juice consumed. However, a distinction should be made between different regions in Europe. In northern Europe, much less freshly squeezed juice is consumed than in southern Europe, where this is common practice for citrus fruit.

4.1. Citrus juice

4.1.1. Processing details

The flowchart below (Figure 19) shows the representative process of citrus juice production. The significant processing steps are explained.

Washing and sorting

Fruit washing and sorting is a common initial step in citrus juice production. The washing systems consist of brush washers and/ or spray washers. Additives such as detergents and foam inhibitors are often added to assist removal of soil residues and microbial impurities.

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[5] Council Directive 2012//12/EU of the European Parliament and of the Council of 19 April 2012 amending Council Directive 2001/112/EC relating to fruit juices and certain similar products intended for human consumption. OJ L 115, 27.04.2012, p 1-11.

Juice Extraction

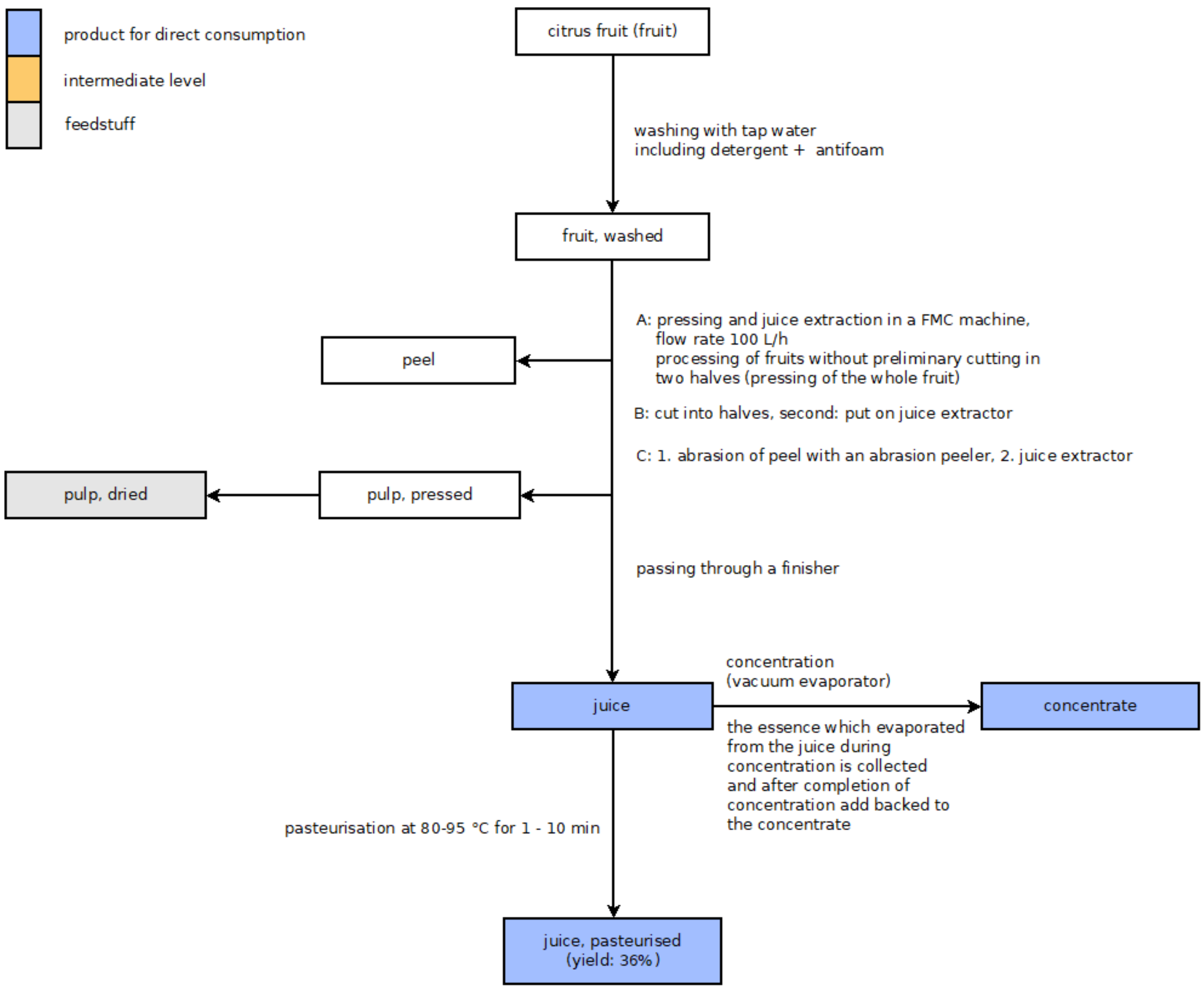
Most citrus fruits have rather thick peels consisting of flavedo (outer coloured cuticula layer of the peel) and albedo (white spongy layer). They contain bitter resins that must be carefully separated in the juice manufacturing process to avoid tainting the sweeter juice. There are three automated extraction methods commonly used in industry, which combine juice and essential oil extraction in one processing equipment.

- *In-Line extractors*: The fruit is placed between two metal cups with sharpened metal tubes at their base. The upper cup descends and the fingers on each cup mesh to express the juice as the tubes cut holes in the top and bottom of the fruit. The fruit solids are compressed into the bottom tube between the two plugs of peel while the juice is forced out through perforations in the tube wall. At the same time, a water spray washes away the oil from the peel which is retained for later use (Heiss, 2004).
- *Tagliabirillatrice – Sfumatrice system:* The second type of extraction has the oranges cut in halves before the juice is removed. The fruits are sliced as they pass by a stationary knife and the halves are then picked up by rubber suction cups and moved against reaming augers which express the juice from the carpels with juicy vesicles of the orange halves. Peels after juicing go to the oil extraction unit for production of essential oils (Citrech Snc, online).
- *Brown extractors:* The third possibility is the preliminary removal of the peel by an abrasion peeler just long enough to abrade the surface of the peel, breaking the oil sacs. The abraded citrus fruits are collected and transferred to the actual juice extraction step by bisection of peeled fruits (Citrech Snc, online).

Plant protection products are often applied to citrus fruits late in the season. Expected residues in citrus juices are lower if the contact between the juice and the peel is reduced as far as possible. All three methods of juice extraction with the simultaneous removal of the citrus peel prevent direct contact of the citrus peel with the pulp, which is pressed. It can be concluded that the way of juice extraction does not have a significant effect on the residue level in citrus juice. This is confirmed by comparison of processing factors from the chosen scientific studies reflecting typical processing operations. There is no study comparing the different types of extraction. Overall, the factors for the processing of citrus fruits to juice are rather small (PF < 0.3) for all reported active substances. About 50% of extractors installed in the United States are In-Line extractors, whilst in Brazil, Argentina and Israel this is the only system used. In-Line extractors are popular also in Italy and Spain, but mainly the Tagliabirillatrice – Sfumatrice system is used.

After extraction, a juice of 11-12 °Brix with a high pulp content of 20-25% is obtained. The mechanically extracted juice containing vesicular membranes, seeds, segments, and peel pieces is transferred to a finisher equipped with a screen to remove the particles (Heiss, 2004).

While the pectin content of citrus fruits is very high, this does not play any role for the citrus juice extraction, since the majority of pectin is situated in the peel.



A yield factor for juice is referenced in BLS (2009).

Figure 19: Representative processing of citrus fruits to citrus juice (II-001)

Pasteurisation

In the production of orange and grapefruit juices, the main problems are heat sensitivity and oxidation sensitivity of ingredients, cloud stability and bitterness of the juices and/or concentrates. In order to achieve the necessary cloud stability of citrus juices, the enzyme pectin esterase must be rapidly inactivated by heat. A short heat treatment also helps preventing microbial spoilage without destroying heat sensitive ingredients. Consequently the finished juice is submitted to pasteurisation (80-95°C for about 1 to 10 min). The pasteurised juice can be bottled aseptically as a direct juice (Heiss, 2004).

For further explanation of pasteurisation see introduction of chapter 3.

Concentration

The extract may also be concentrated (for later reconstitution into juice or nectar). After the juice is removed from the fruit and has gone through the finisher it contains 10 to 12% solids and is sent to an evaporator to remove the water. The concentrated juice has about 65% solids (Matthews, 1994). This concentrate can be mixed with a small amount of citrus oil (maximum 0.005%) and stored in bulk storage tanks. In order not to lose readily volatile flavours during concentration they are evaporated off and can be condensed using refrigerated condensers on the evaporator. These essences contain the characteristic flowery or fruity aromas of the orange and are used to provide flavour to the juice and are re-added later on in the filling plant (or used to produce specialty products called essence) (Heiss, 2004).

4.1.2. By-products of citrus juice production

By-products from citrus juice production come from the peel and the pulp. Products made with these materials include dried pomace (dehydrated feed for livestock), pectin for use in making jellies, essential oils, and citrus molasses.

The de-oiled fresh citrus peels are mostly used directly as cattle feed or dried as a raw material for pectin recovery. A valuable by-product of citrus juice production is the citrus oil recovered from the peel. The essential oils are valuable substances in food industry (Heiss, 2004). For detailed information on citrus oil production please refer to chapter 7.4.2.

Citrus molasses is also a by-product of citrus juice extraction. The fresh pulp obtained after pressing is mixed with lime (calcium hydroxide) and pressed again to remove moisture. From the resulting liquid (pressed juice) the larger particles are removed and then it is sterilised by heating and concentrated. The resulting product contains 71-72% dry matter and 60-65% sugars (Crawshaw, 2004). Citrus molasses is a viscous liquid, dark brown to almost black, with a very bitter taste (Göhl, 1978). It is often sold to distilleries or reincorporated into the dried citrus pulp, but can also be fed directly to animals, or added to grass silage (Grant, 2007; Hendrickson and Kesterson, 1965).

Today, citric acid is no longer produced industrially from citrus juice, but made biotechnologically by fermentation of sugary raw materials such as molasses and maize (Verhoff, 2005).

4.1.3. Scientific studies reflecting typical processing operations

It is noted that the major part of orange juice consumed in the EU is imported from outside the EU with the majority of the trade flows of fruit juices to Europe comprising bulk concentrates that need to be further processed into consumer end-products. Studies describing juicing of oranges were therefore selected both from Europe and the U.S. Three studies were chosen as representative. They differ primarily in the type of juice extraction.

The study of Maloney (1994) includes washing with tap water (including detergent), pressing and juice extraction in an in-line extractor without preliminary cutting of fruits into halves and passing through a finisher. The final product is fresh juice without any pasteurisation. A side process consisted of homogenisation of the peel frits and a part of the wet pomace to wet pulp, followed by pressing and drying to obtain dried pulp and evaporation of the pressed out liquor to molasses. The oil/water emulsion resulting from the extraction process is collected and water is removed by decanting and finally freezing-out.

The study is acceptable according to the quality criteria. It is referenced in a Conclusion (EFSA, 2008).

The study of Brereton et al. (2000) reports an alternative extraction procedure of juice after cutting of fruits into halves and subsequent pressing. The remaining wet pomace (peel and pulp) was grinded and dried in an oven for 4 days. The fresh juice was pasteurised at 85°C for 60 s. Furthermore, a sterilisation step is reported.

The study of Brereton et al. (2000) is acceptable according to the quality criteria. It is referenced by EFSA (2014e) in a Reasoned Opinion according to Article 12.

The study of Krolski (2000) was conducted in the United States and reports on a third method of extraction: Removal of the peel and subsequent cutting of the abraded citrus fruits into halves, followed by juice extraction. The extracted juice was processed through a finisher. Pasteurisation took place at 90°C for 14 min. Furthermore, a concentration step is reported: Orange juice was concentrated using a vacuum evaporator. During concentration, the juice was recirculated through the evaporator until it was condensed to concentrate. The essence, which evaporated from the citrus juice during concentration, was collected in an essence recovery unit that was attached to the vacuum evaporator. When concentration was complete, the essence was added back to the orange juice (ca. 4%). A side process consisted of peel processing for oil production and pulp drying. It is assumed that a concentration of juice and subsequent dilution to the final juice does not have a significant effect on the pesticide residue level.

The study of Krolski (2000) is acceptable according to the quality criteria. The pasteurisation process lasted 14 min. In comparison to common industry procedures this is unusually long. However, the main reason for selecting this representative study was that it adequately reflected the third extraction method. The study has not been cited in any EFSA Conclusion or Reasoned Opinion, but was available from an authorisation procedure.

4.1.4. Extrapolation to other commodities

There is a great variety of citrus species: Tangerines, grapefruit, lemons, limes, mandarins and other citrus fruits. Most of the processing operations described above for orange juice apply to the other species as well. Extrapolation is therefore possible within the whole citrus group.

In general, it can be expected that pasteurisation has no significant impact on the level of pesticide residues, which is confirmed by a comparison of processing factors for pasteurised and non-pasteurised juices (Scholz R et al., 2018a). However, in the case of thermally instable active substances, differences can occur, as pasteurisation may alter the residue. Pasteurisation is not relevant on household scale where fresh citrus juices are consumed directly.

4.1.5. Comparison to industrial and/or household processing techniques

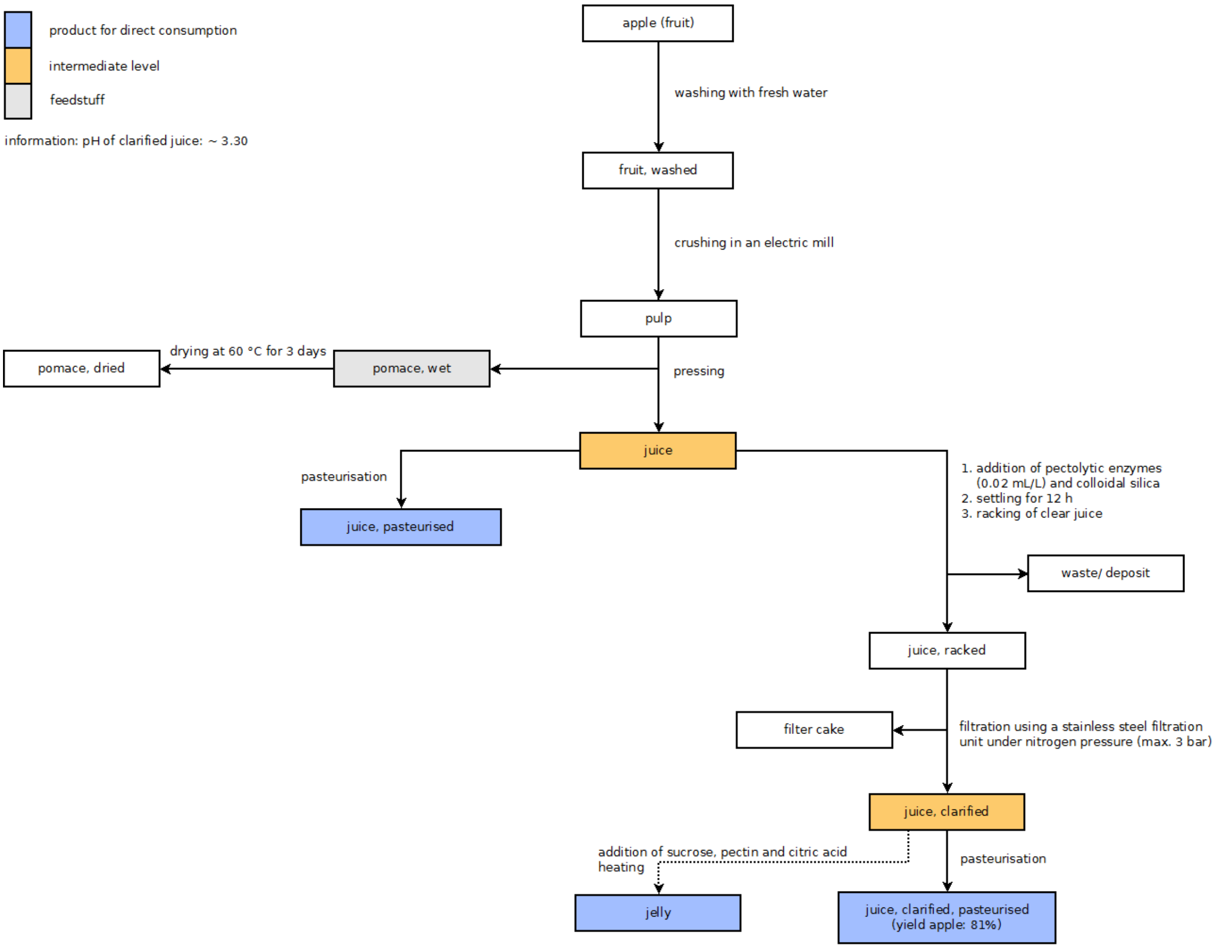
The representative processing studies selected for citrus juice production represent up-to-date technology. It should be noted that manufacturing processes in industry are rarely straightforward as reported in processing studies, but are adjusted according to individual technological solutions and other external conditions (VdF, 2018).

The domestic processing of citrus fruits into juice usually excludes the peeling step. Citrus fruits are cut into halves and then juice is extracted by (hand-)pressing. There is no significant difference between home-made citrus juices and industrially produced citrus juices apart from the pasteurisation step which is relevant on industrial scale only and the higher likelihood of cross-contamination through peel/juice contact during hand pressing. Citrus fruits intended for industrial juice production are usually not treated with pesticides post-harvest. However, surface-treated fruits might be used for domestic production of fresh juice.

4.2. Pome fruit juice

4.2.1. Processing details

The following flowchart (Figure 20) shows the representative process of apple juice production. Typical processing steps are shortly explained below.



A yield factor for juice is referenced in BLS (2009).

Figure 20: Representative processing of apples to apple juice (II-002)

Washing and sorting

Washing and sorting of the raw fruit is a common initial step for all juicing operations. Washing and sorting ensure effective removal of debris, rots, damaged fruits and adhering dirt. Processing studies conducted at laboratory scale reported on washing procedure by hand in a timeframe of 1 to 5 min. Processors sometimes add chlorine dioxide, hypochlorite or other chlorine compounds to control microbial build-up in re-circulated water. Washing may include physical scrubbers, which can actually reduce washing time. In addition, on industrial scale, water is commonly used as a flotation medium to the masher.

Peeling

Unlike for other fruits (e.g. citrus fruits) peeling is not a common process in apple juice manufacturing processes.

Juice Extraction

After washing, the apples are chopped by a grinder, apple mill or a hammer mill and turned into crushed apple pulp. The resulting pulp is sent to hydraulic presses that extract the juice from the mash. Wet pomace is obtained together with unclarified apple juice. The naturally cloudy juice can be preserved directly by pasteurisation.

In order to gain clear apple juice, cloudy raw juice may be further treated with pectolytic enzymes and undergo clarification to remove the starch and pectins holding fine particulates in suspension.

Higher pesticide residues can be expected in cloudy juices than in clear juices, since higher fractions of pulp are contained in cloudy juices and pesticides are often bound to pulp particles.

Pasteurisation

Airborne yeasts present on apple skins or juice making machinery would start fermentation in the finished juice. Therefore virtually all commercially produced pome fruit juice is treated to minimise bacterial contamination in order to extend its shelf life. The most present-day method is pasteurisation at 85°C for 60 s. Both cloudy and clear apple juice is pasteurised (Heiss, 2004).

For further explanation of pasteurisation see introduction of chapter 3.

4.2.2. By-products of apple juice production

By-products include wet pomace (feed for livestock (EFSA, 2016e) and pectin (for use in jelly and jam production).

Dry pomace is obtained by further processing of wet pomace, a by-product from the juice extraction process. The drying temperature is at about 60°C and the process continues for several days. The remaining water content is at about 10%.

4.2.3. Scientific studies reflecting typical processing operations

Processing studies available to EFSA have been submitted exclusively for the commodity apple. Two studies were chosen as representative, and both studies were conducted in the EU.

The study of Eversfield (2012) is acceptable according to the quality criteria. It is referenced by EFSA (2015b). The study includes washing with water, crushing in an electric mill and pressing into wet pomace and unclarified raw juice. Pectolytic enzymes were added to the raw juice for depectination. After 12 h of settling, the clear juice was racked (decanted after settling of solid components) and filtered using a stainless steel filtration unit under nitrogen pressure (maximum 3 bar). Finally, the juice was pasteurised by heating to approximately 85°C for at least 1 min.

The study of Schulz (2002) reports the production of clarified as well as cloudy apple juice. The production of wet pomace and unclarified raw juice is analogous in both cases. For the production of cloudy apple juice the raw juice is merely pasteurised at 90°C for 30 min. The duration of pasteurisation is longer in comparison to common industrial processes in which pasteurisation durations of less than 1 minute are applied. For clarification, pectinase was added to the filtered raw juice, in order to release the lees. The pectinase reaction took 20 to 60 min. To the whole amount of juice, first gelatine and 10 min later colloidal silica was added and the solution was filtered. The clear juice was pasteurised analogous to the unclarified apple juice. The study is acceptable according to the quality criteria. It is referenced by EFSA (2014d) in a Reasoned Opinion according to article 12.

4.2.4. Extrapolation to other commodities

Mainly studies on processing of apples to apple juice were available.

An important part of the process is the use of pectolytic enzymes to achieve a clarification of the juice and to increase the juice yield by enzymatic treatment of the mash. Fruit and vegetable commodities contain different amounts of pectin. Thus, different processing procedures from fruits to (clarified) juice must be considered. Due to comparable pectin content and comparable juice processing techniques extrapolation from apples to other pome fruit like quinces and pears is recommended.

Due to the significant difference in solid fruit content no extrapolation is proposed between clear and cloudy apple juices, though first comparisons have not revealed large differences for clarified and unclarified apple juices (Scholz R et al., 2018a). The data is not yet sufficient to draw a general conclusion.

In general, it can be expected that pasteurisation has no significant impact on the level of pesticide residues, which is confirmed by a comparison of processing factors for pasteurised and non-pasteurised juices (Scholz R et al., 2018a). However, in the case of thermally instable active substances, differences can occur, as pasteurisation may alter the residue.

4.2.5. Comparison to industrial and/or household processing techniques

The industrial apple juice production is sufficiently covered by available processing studies (VdF, 2018). Clear apple juices are generally obtained from clear juice concentrate. However, it is assumed that a concentration of juices with subsequent dilution to the final juice does not have a significant effect on the residue level of active substances. The conventional fining takes place by adding gelatine, colloidal silica and bentonite and by subsequent filtration. Alternatively, the clarification can also be conducted by combining ultrafiltration and adsorption. The pasteurisation is carried out for clear and turbid apple juice (Heiss, 2004).

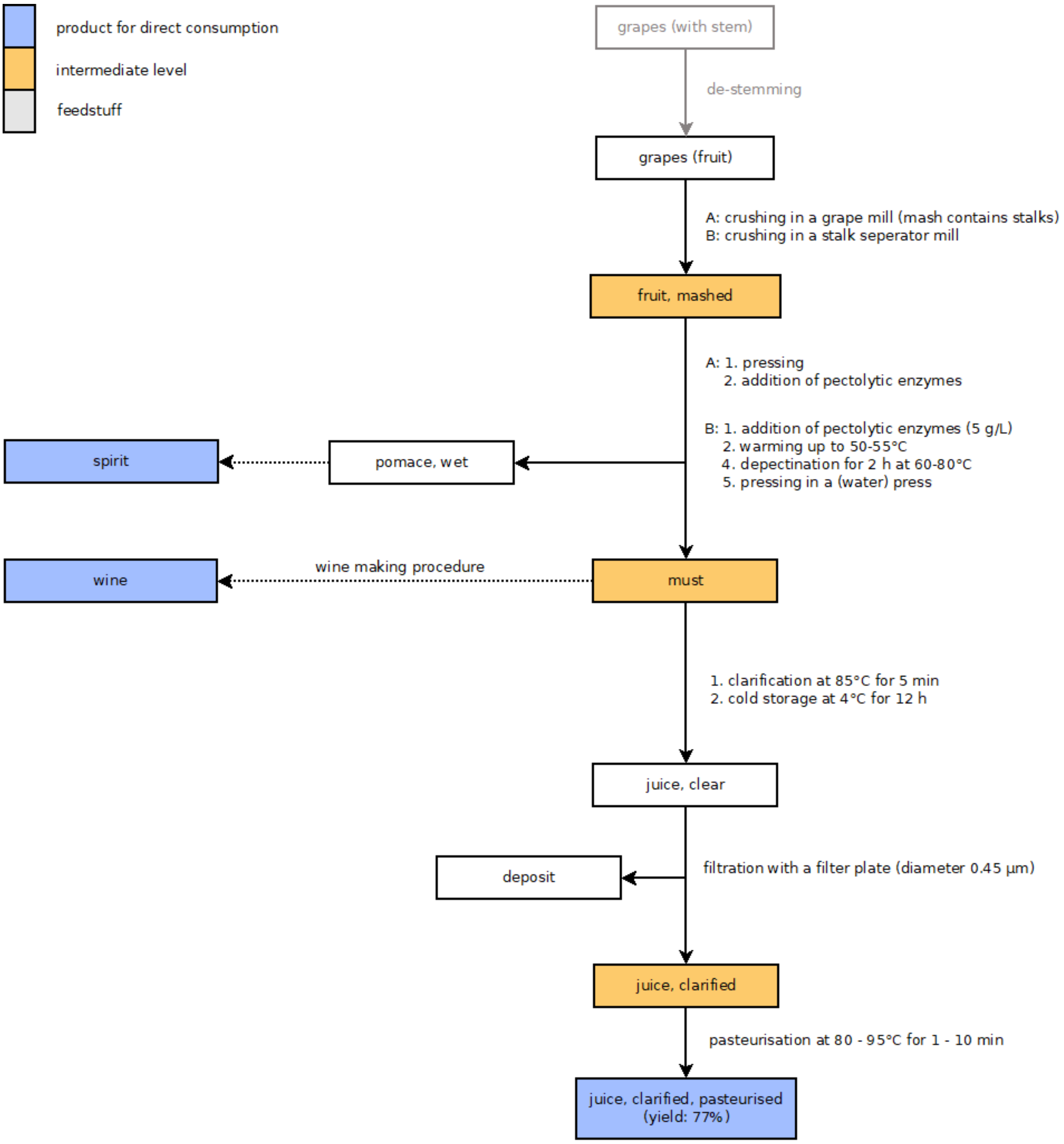
There are two possibilities for household juice production. On the one hand, apple juice can be prepared in the household with a juice centrifugal extractor. Only small amounts of pulp remain in the apple juice. Usually, freshly pressed apple juice is consumed directly, but pasteurisation is also possible. On the other hand, cold press juicers are used in household apple juice production. These juicers extract juice by first crushing and then pressing fruit for a higher juice yield. The pulp content in the final juice is much higher. If a clear apple juice is preferred, the pressed juice must be filtered (Huffpost, online). Thus, the process is more comparable to the industrial techniques. Additional processing steps, such as the addition of depectinases, usually do not take place in household preparation.

4.3. Grape juice

Generally, grape varieties, which produce a high juice yield, are used for the production of grape juice, but also for vinification (see chapter 5). These varieties can often be assigned to the wine grapes. However, EFSA has information that mainly table grapes are used for juice production.

4.3.1. Processing details

The following flowchart (Figure 21) shows a representative process of grape juice production. The grape juice production differs for red and white grape varieties. Typical processing steps are shortly explained below.



Processing steps differ for red and white varieties (A: white varieties; B: red varieties). A yield factor for juice is referenced in BLS (2009).

Figure 21: Processing of grapes into juice (II-003)

Destemming and crushing

Prior to crushing the grape bunches are de-stemmed by normally using a mechanical de-stemmer. Modern machines already combine de-stemming and crushing. In some cases, there is no stalk separation step prior to crushing.

Pressing

The crushed berries of white grapes should be pressed as quickly as possible to prevent any reduction of quality due to oxidation processes and the development of harmful microorganisms (e.g. vinegar bacteria). If the mash cannot be processed immediately, it is recommended to use a mash sulphurisation (with of 30-50 mg/L sulphur dioxide).

Two different types of pressing are used: The so-called hot-pressing and the cold-pressing technique. Hot pressing is commonly applied for deeply pigmented grapes where maximum colour extraction is desired, whereas the immediate or cold press procedure is necessary to maintain the initial colour of light coloured grapes. In most commercial operations, the continuous pressing method is used. Hot-pressing methods yield more juice which contains higher total solids, more non-sugar solids, tannins, pigments and other substances than a cold-press juice operation. Furthermore, pectolytic enzymes are used to increase the juice yield and accelerate or intensify the release of colouring and flavouring substances (Heiss, 2004).

- *Hot-pressing procedure*

  The crushed berries are pumped into a steam jacketed holding tank where pectolytic enzymes are added along with mechanic processing aids to breakdown naturally occurring pectins to facilitate subsequent extraction of juice and to extract colour from the skins into the juice. This is done at 50 to 55°C assisted by mixing with a slow-moving agitator. In addition, inactivation of polyphenol-oxidase by heating prior to depectination prevents loss of anthocyanins during extraction and subsequent storage. Extraction temperatures normally do not exceed 65°C to maintain juice quality (Bates et al., 2001).

  Grapes are unique in that after juice extraction, tartrates must be precipitated which otherwise will crystallize upon cooling. In order to accomplish detartration, the filtered juice is flash-heated at 80 to 85°C for a maximum of 5 min, rapidly cooled in another heat exchanger and placed in tanks for rapid settling of argols. The juice is then passed through a heat exchanger into an automatic filler and then into preheated bottles. The bottles are capped and pasteurised. Alternatively, hot fill into plastic or aseptic packing is also widespread (Bates et al., 2001).

- *Cold-pressing procedure*

  Without heating and addition of pectolytic enzymes the dark colour from the dark-skinned grapes is less exhaustively extracted and the juice is of a lighter colour.

  White grape cultivars lacking skin pigment and yielding a light green to yellow juice cannot be hot pressed. Enzymes may be added to the cold-pressed juice to facilitate the clarification and filtration process following cold stabilisation. However, extended contact time or enhanced temperatures are to be avoided to minimise enzymatic browning and undesirable colour extraction (Jackson, 2014).

Comparing both types of juice extraction, no statement can be made about the process by which a higher residue can be expected. In general, it can be assumed that hot pressing causes higher residues in the raw juice. However, the comparison of studies that carry out both procedures for one active substance shows that red grape juices may have higher, lower or comparable processing factors than/as white grape juices after cold pressing. Since juice yields are comparable and only a few active ingredients are decomposed below 80°C, no worst case can be predicted for the various types of juice extraction, comparable to the red and white wines (chapter 5).

Clarification

The clarification of cloudy juices or raw juices like grape must consists of a clarification step, a centrifugation step, and a filtration step. Fining is the adsorptive separation of fine turbid matter by employing fining agents such as bentonite or gelatine with subsequent fine cleaning. Alternatively, a brief heating step is applied for clarification. Depending on the type of fruit, the juice yield is usually 70-80%. The juice yield can be increased by enzymatic treatment of the mash or cell disruption, e.g. by ultrasound or high-pressure homogenization (Jackson, 2014).

When unclarified grape juice is reported in a processing study, it is assigned to the processed matrix “must” in the EU database of processing factors, because no clarification treatment was applied.

Pasteurisation

All commercially produced grape juices are treated for bacterial contamination in order to extend their shelf lives. The most present-day method is pasteurisation at 85°C for 60 s. White and red grape juice is pasteurised (Heiss, 2004).

For further explanation of pasteurisation see introduction of chapter 3.

Concentration

Juice may be concentrated by evaporation or freeze concentration in order to minimise transportation and storage costs. The application of vacuum decreases the applied temperature leading to a reduction of heat damage. Low temperature evaporators use a maximum of 50°C under reduced pressure for concentration of fruit juices (Bates et al., 2001). This is a commonly practiced operation in juice processing industry. Concentration and re-constitution of juices by adding of water are not anticipated to impact the overall residue in grape juice.

4.3.2. By-products of grape juice production

By-products include dried pomace (dehydrated feed for livestock, but according to OECD (2013) not relevant in the EU). In Europe the main use of grape pomace is for distillation. Liquor distilled from grape pomace is called pomace brandy (spirit, e.g. grappa, Marc de Champagne). Grape pomace is furthermore used as soil fertiliser and fermentation substrate for biomass production. Separating the grape seeds from the pomace to produce grape seed oil is possible as well (Galanakis, 2017). Oil production is generally described in chapter 7. Most of the raw juice is not used as such but is further processed to wine. Please refer to chapter 5.

4.3.3. Scientific studies reflecting typical processing operations

Almost all processing studies conducted on grapes are focusing on the preparation of wine. However, apart from pasteurisation prior to or at bottling of grape juice, the process is comparable to that of must production during winemaking. Nevertheless in order to reflect authentic conditions of grape juice manufacturing the selected processing studies involve explicitly pasteurised juice as an end product. Two studies have been chosen.

The study of Braun et al. (2008) compares hot pressing for red grape varieties and cold pressing for rosé grape varieties. To reduce oxidation processes, potassium meta-bisulphite was added. The raw juice was clarified and finally pasteurised at 83-87°C for 2 minutes. The study is cited by EFSA (2009b) in a Reasoned Opinion and is acceptable according to the quality criteria.

The study of Schäufele (2012) presents a hot pressing procedure. Enzymes are added to achieve depectination and a higher juice yield. Furthermore, the study describes the process of precipitation for removing tartrates by first heating to 85°C for 5 min and subsequent crystallization under cooling conditions at 4°C. Finally, filtration and pasteurisation at 85°C for 5 minutes is reported. The study is cited in a Conclusion (EFSA, 2015a). It is acceptable according to the quality criteria.

4.3.4. Extrapolation to other commodities

Extrapolation to other commodities due to comparable pectin content and also to comparable juice processing techniques is recommended for the following commodities: Currants, blackberries and other small berries. The peculiarity of grape juice production is the removal of tartaric acid by both strong heating to about 85°C and subsequent cooling to 4°C. The heating step is in the same temperature range in which pasteurisation usually takes place. Accordingly, no significantly different influence on residue levels is expected compared to other fruit juices.

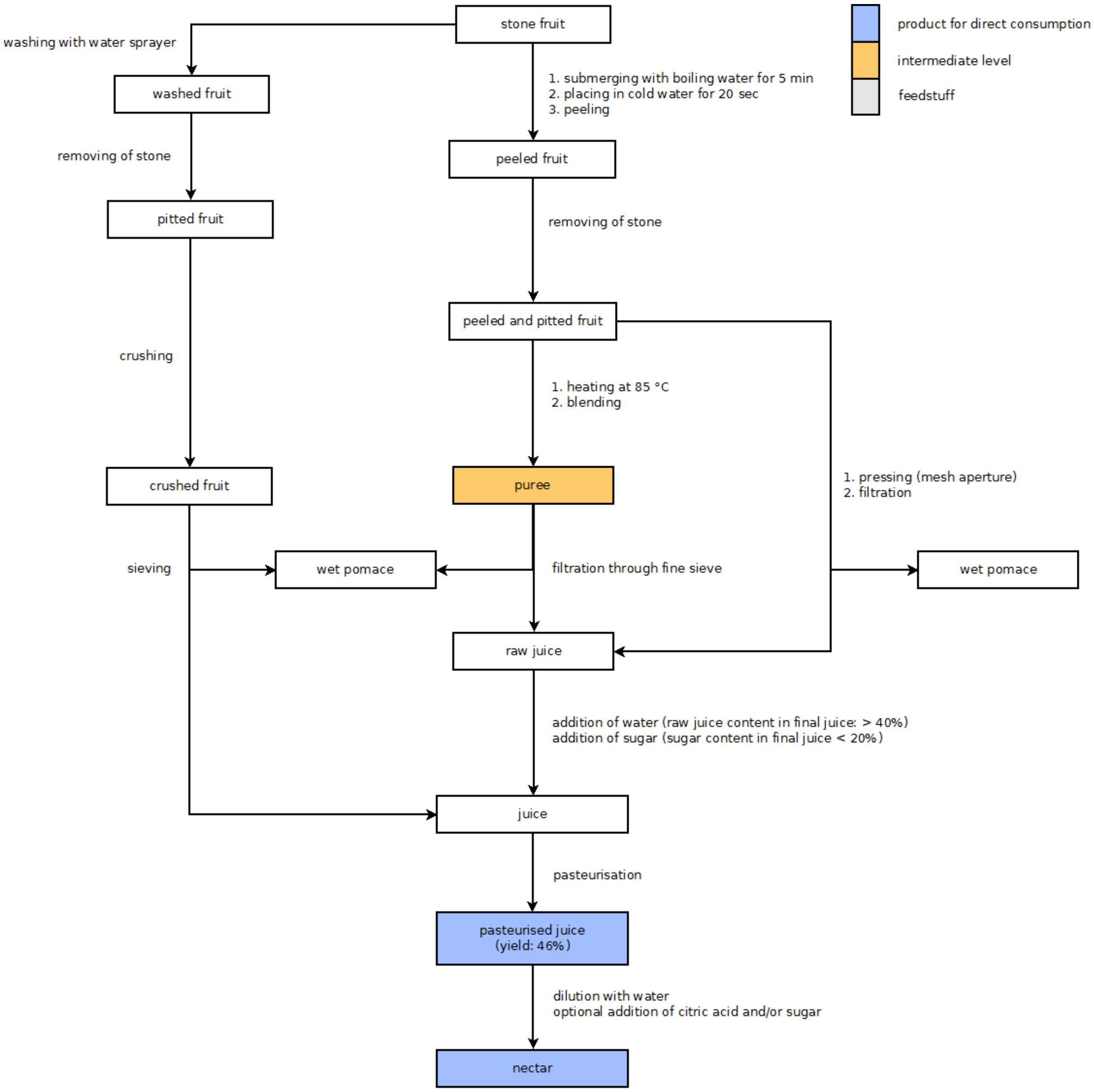
4.3.5. Comparison to industrial and/or household processing techniques

The industrial grape juice production is sufficiently reflected in the processing studies (VdF, 2018). Household procedures are unlikely to employ pectolytic enzymes and remove tartaric acid. Nevertheless, raw juices can be domestically produced by either steam juicing or by crushing and sieving of washed grape berries. Processing studies also report on the production of raw juice. Thus, domestic production of grape juice is representatively covered in the processing studies.

4.4. Stone fruit juice

4.4.1. Processing details

The following flowchart (Figure 22) shows a representative process of peach and apricot juice exemplarily for stone fruit juice production. Typical processing steps are shortly explained below.



A yield factor for juice is referenced in BLS (2009).

Figure 22: Processing of stone fruit to juice (II-004)

Washing and sorting

As other fruit varieties, peaches are sorted to remove damaged ones. A washing step is performed only if the peel is not removed by short blanching or steam peeling. Processing studies conducted at laboratory scale reported on washing by hand or by using a water sprayer.

Peeling and pitting

Most stone fruits can be used for juice extraction without peeling. Peaches can be processed two different ways: Either they are pressed directly after removing of the relatively large stone. A preliminary peeling is not necessary since solid press residues (including peel) are removed by filtration and remain as wet pomace. The second possibility is to produce the juice from peach purée, which is obtained from a previously peeled and pitted fruit.

Peaches may be peeled by steam peeling or by lye peeling. In the lye peeling procedure, whole peaches are ether immersed in or sprayed with lye solution at a temperature of at least 99°C for 15 to 20 s. They are held for another 60 s and spray washed with water (Bates et al., 2001). Steam- and lye peeling is not described in detail in processing studies, but a comparable technique to steam peeling is used by placing peaches first into boiled water for approximately 5 min, and then immediately into cold water for 20 s to crack the peel. Processing studies conducted at laboratory scale reported also on peeling by hand. Both peeled and unpeeled peaches are pitted by using a fruit pitting machine. In household processing of stone fruits, stones are removed with a knife by hand.

Juice Extraction

Peaches may be pressed directly after pitting. They are cut into halves and crushed. Separation of juice and pomace is performed by sieving. The direct pulping of the whole fruit with peel yields around 15% more pulp in comparison to a preliminary peeling step (Bates et al., 2001).

Peeled and pitted fruit are cut into halves. If peaches are heated before pulping, the process is easier, oxidation reduced and cloudiness stabilised (Bates et al., 2001). Heating takes place at 85°C and a purée is obtained, which can be further processed into juice or baby food, for instance. For juice production, the purée is filtered through a fine sieve to retain solid fractions. After filtration, the juice is often diluted. Fruit nectars have a fruit content of more than 40%.

In general, higher residues are expected in peach juices, which are produced by cold pressing. On the one hand, the peel is in contact with the juice during pressing and, on the other hand, no heating takes place, which could degrade heat-sensitive pesticides.

Cherries may be pressed without removing the stone. The removal of the stone is then carried out during filtration together with other solid fruit constituents. Heating the whole fruit to about 60°C and adding macerating enzymes greatly facilitates juice and colour extraction. A cold pressing procedure produces a more fresh flavoured juice.

Pasteurisation

Comparative to the fruit juices described so far, pasteurisation takes place at about 85°C for 1 min (Heiss, 2004). For further explanation of pasteurisation see introduction of chapter 3.

4.4.2. By-products of juice production of stone fruits

During the heating of peeled and pitted pieces, purée is obtained, which can be further processed to baby food. Further information on purée can be found in chapter 3.3.4.

4.4.3. Scientific studies reflecting typical processing operations

There are various studies available describing peaches or apricots juice production out of which the following are deemed most appropriate to cover typical processes.

The study of Ryan (2004) reflects the direct pressing of washed and pitted peaches. The pulped, crushed fruits were sieved to obtain juice, which is finally pasteurised at common conditions. The study is acceptable according to the quality criteria. It is referenced in an EFSA Reasoned Opinion (EFSA, 2014e).

A different process is described by Simek (2007) involving peeling of fruits and a heating step during pulping. Peeled and pitted fruits were heated at 95°C and then crushed to obtain fruit purée. The purée was filtered through a fine sieve and raw juice was collected. Nectar was made by dilution with syrup (with 20% sugar content). The nectar was pasteurised for 5 min at 93°C. The study is acceptable according to the quality criteria and is referenced in a Reasoned Opinion according to article 10 (EFSA, 2013d).

4.4.4. Extrapolation to other commodities

Extrapolation is suggested from peach juice to juices made from other stone fruits like apricots and plums. There is no difference in processing of sweet or sour cherry varieties, but sugar is added in case of juice or nectar production from sour cherries. Nectars are prepared by dilution of pure pasteurised juices or pasteurised purées with water. As this can also dilute pesticide residues, it is recommended to recalculate processing factors obtained for nectar to factors for pure fruit juice or purées.

The "hot break" process for juice extraction is conducted at 85°C. The heating step is in the same temperature range in which pasteurisation usually takes place. Accordingly, no significantly different influence on residue levels is expected compared to unpasteurised juices. However, pasteurisation of juices resulting from the "cold break" process can result in different pesticide residue level in the case of thermally instable active substances.

In general, it can be expected that pasteurisation has no significant impact on the level of pesticide residues, which is confirmed by a comparison of processing factors for pasteurised and non-pasteurised juices (Scholz R et al., 2018b). However, in the case of thermally instable active substances, differences can occur, as pasteurisation may alter the residue.

4.4.5. Comparison to industrial and/or household processing techniques

The representative studies on peach juice production reflect sufficiently the industrial processes. In industry, peaches may be peeled by steam peeling or by lye peeling. *Steam peeling* takes place in special vessels, where the fruits are heated with water steam for about 1 min. By sudden ease of pressure, the peels are removed or loosened. During *lye peeling* the peaches are washed in a lye bath containing 0.5-20% sodium hydroxide for a few minutes at increasing temperatures. Subsequently, neutralisation is achieved with citric acid (VdF, 2018).

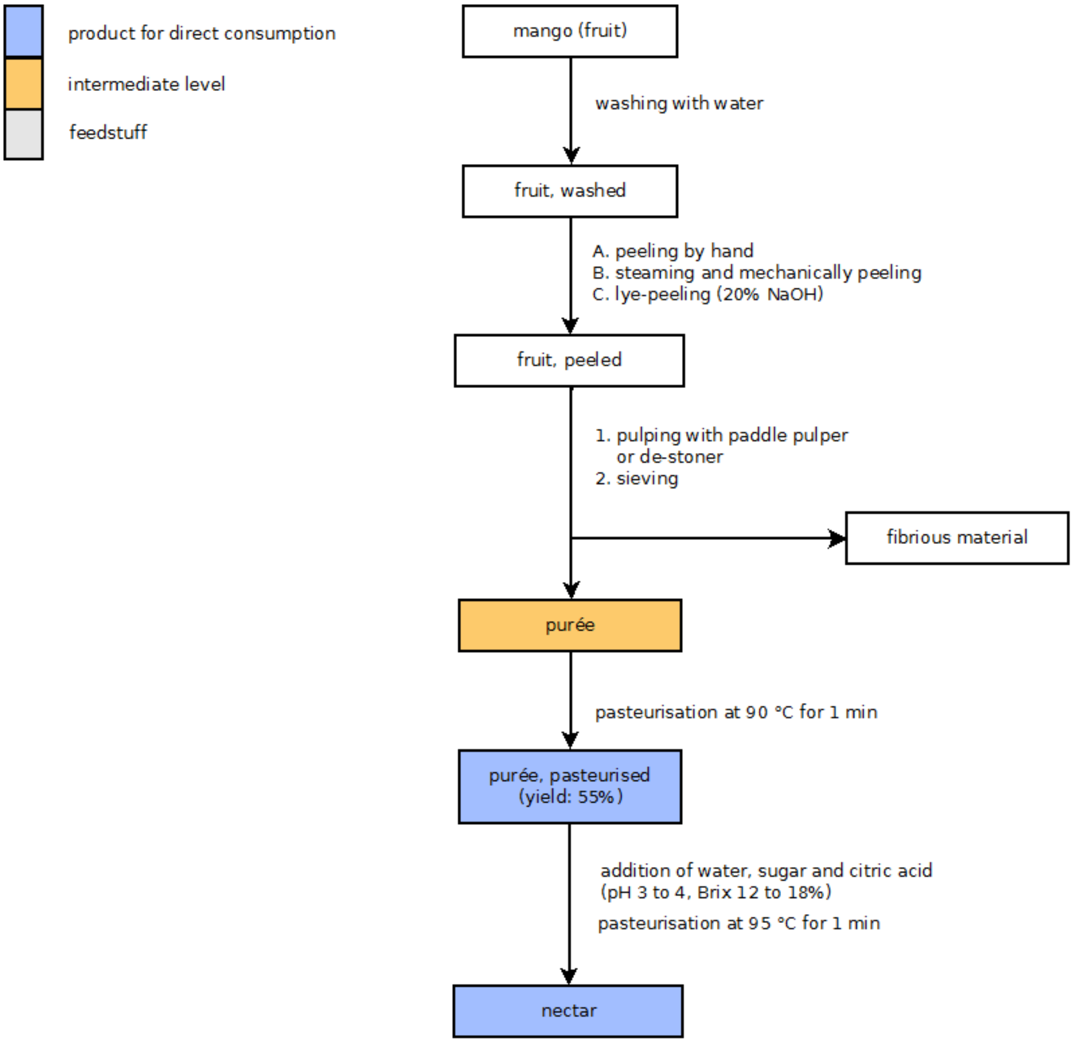
The household processing of stone fruits to juices is carried out in the same way as the household production of apple juice with either steam juice extractors or cold pressing. The only difference is the removal of the stone before juice extraction takes place. Comparable residues of active substances are to be expected in industrial and domestic processing.

4.5. Tropical fruit juices and/or nectars

Commercially significant tropical juices are made from pineapple, banana, mango and papaya, as well as increasingly guava and passion fruit (FAO, 1995). There is only one EFSA cited processing study describing the production of tropical fruit juice. Nevertheless, the processing of tropical fruits into juice is discussed in more detail below. Bananas and mangoes account for the largest proportion of tropical fruit production. Both commodities are processed into fruit purées first due to their lower water content and soft ripe flesh. Purées are finished to nectar by dilution with water, sugar and other additives.

4.5.1. Processing details

The following flowchart (Figure 23) shows a representative process of mango nectar production. Typical processing steps are shortly explained below.



A yield factor for mango purée is referenced in (Gosh and Gangopadhyay, 2002). The minimum content of fruit juice or fruit pulp in nectar is 25% (BMJV, 2004).

Figure 23: Processing of mango into juice (II-005)

Washing, sorting and peeling

Mangoes are sorted, brush-washed and rinsed with water. Mango varieties characterised by a thin peel and little bitters in the peel can be processed without peeling. Varieties with a thicker, leathery peel with a higher polyphenol content causing bitterness must be peeled. There are three common peeling methods: peeling of raw fruits by hand, heat treatment by scalding for 2-3 minutes, cooling down in water followed by mechanical peeling, and lye peeling, which is used especially for thin-skinned varieties. In the process, fruits are scored with brushes and immersed in hot sodium hydroxide solution (around 20%) with a surfactant. Finally, the peel is removed by water washing and abrasion (Bates et al., 2001; Reyes-De-Corcuera et al., 2014).

Pulping

The removal of the stone takes place simultaneously with the pulp extraction. Either paddle pulper or de-stoners are used. Paddle pulper removes very effectively the pulp from the intact stone. Fibrous material is removed as well as peel residues. To ensure microbial stability, the pH of the purée has to be lowered to a value of around 3 to 4. Additionally, mango purée is often de-aerated prior to pasteurisation to minimise browning effects (Bates et al., 2001; Reyes-De-Corcuera et al., 2014).

Pasteurisation and sterilisation

The mango purée is pasteurised to prevent microbial decomposition at common conditions: 90°C for 1 minute (Reyes-De-Corcuera et al., 2014).

Nectar preparation

Nectars from mango fruits are prepared by mixing the purée with water, sugar and citric acid to a Brix between 12 and 18%. The nectar is again pasteurised at 95°C for 1 minute (Reyes-De-Corcuera et al., 2014).

4.5.2. Extrapolation to other commodities

Extrapolation is suggested from mango juice and/or nectar to juices and/or nectars made from other exotic fruits with inedible peel like banana. The preparation is comparable for fruits having a soft pulp. Differences result from the removal of the stone in mango, which leads to a different yield factor for purée or juice.

4.5.3. Comparison to industrial and/or household processing techniques

The processing of tropical fruit juices is generally in accordance with general practice (VdF, 2018).

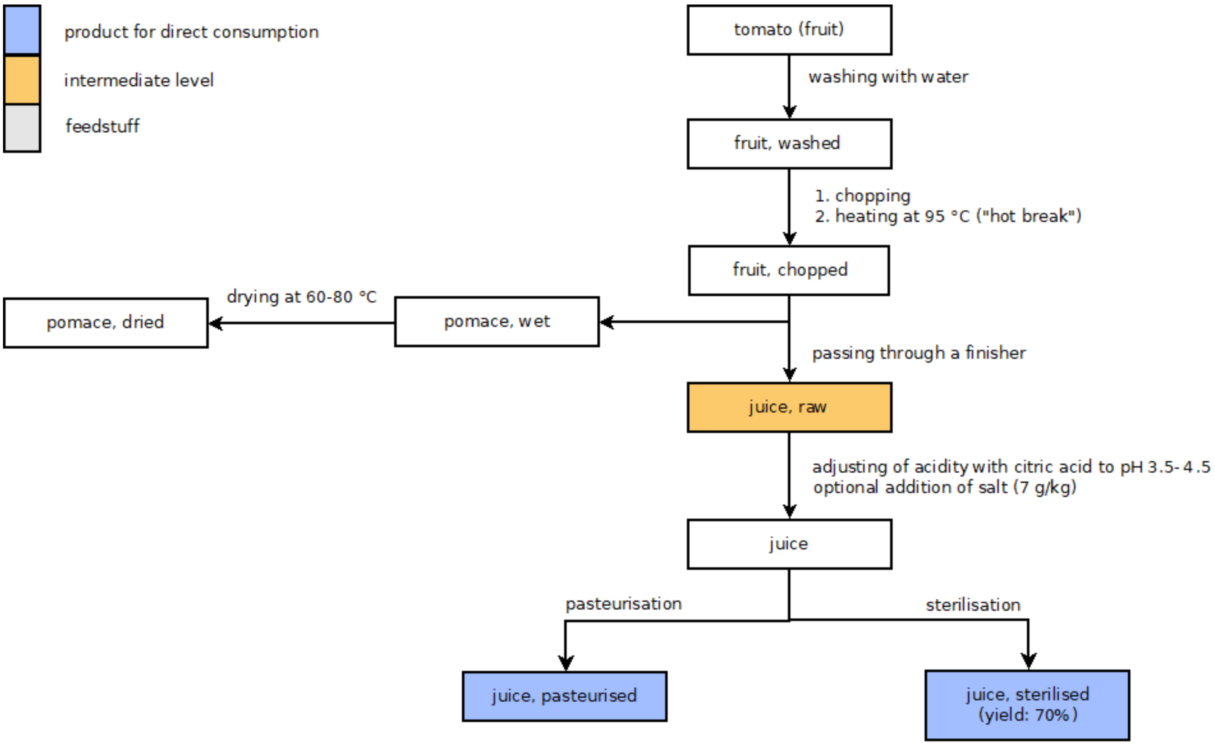
The industrial production of mango pulp is not fundamentally different from home-made processing. Peeling of mangoes is done by hand with a knife. Puréeing is usually done in a blender. Like for other fruit purées or juices, no sterilisation or pasteurisation step is involved in domestic production and the products are normally consumed directly.

4.6. Vegetable juices

The European market for vegetable juices makes up only 0.5-3% of the total European juice market, with about 90% of the vegetable juices being produced from tomatoes. The remaining 10% of the vegetable juices are produced mainly from spinach, carrots, beetroot, celery or sauerkraut (Hamilton and Crossley, 2004).

4.6.1. Tomato juice

Among the juices derived from fruiting vegetables, tomato juice is by far the most commonly consumed one. The flowchart below (Figure 24) shows a representative process of tomato juice production. Typical processing steps are shortly explained.



A yield factor for juice is referenced in BLS (2009).

Figure 24: Processing of tomatoes to juice (VII-002)

Washing and sorting

As for other crops, tomatoes are sorted to remove damaged ones. A washing step is performed with tap water. Some studies reported on washing with warm water or, in case of processing studies conducted in the United States, with chlorinated water.

Peeling

Peeling is not a common processing step in the production of tomato juice.

Juice Extraction

After washing, tomato fruits are chopped by a grinder or in an automated pulper/finisher combination. In the so-called "hot break" chopped fruits are heated to 90-95°C to inactivate enzymes. The resulting pulp is sieved through a finisher to obtain raw juice and wet pomace that is further processed by drying to receive dried pomace. Seeds and peel components are always completely retained. The pH value of the juice is set to 3-4, and sodium chloride (7 g/kg) can be added for seasoning.

Pasteurisation and sterilisation

In order to prevent microbial decomposition, the tomato juice is pasteurised at 85-90°C for approximately 3 min, comparable to the pasteurisation of fruit juices. Furthermore, sterilisation of the filled cans or bottles takes place at 120°C for 40-45 s. For further explanation of sterilisation and pasteurisation see introduction of chapter 3.

4.6.2. By-products of tomato juice production

By-products include dried pomace (dehydrated feed for livestock, but according to OECD (2013) not relevant in the EU) and intermediate products which are further processed to other tomato products, such as purée, tomato paste or canned tomatoes.

Dried pomace is obtained by drying wet pomace, a by-product from the juice extraction process. The drying temperature is about 60 to 80°C and the process continues for several days. The remaining water content is 10%. Raw tomato juice is further processed to purée, paste and canned tomatoes, which includes heating procedures. Detailed information is given in chapter 3.3.

4.6.3. Scientific studies reflecting typical processing operations

Only one study was selected, as other recent studies cited by EFSA describe a comparable process.

The study of Mäyer (2012e) includes washing with warm water, crushing by a chopper and heat breaking to inactivate enzymes. Following hot break procedure, the crushed fruits were sieved by a finisher and separated into wet pomace and raw juice. Citric acid and sodium chloride were added to the raw juice. Finally, the juice was pasteurised by heating to approximately 85°C for at least 3 min and sterilised at 120°C for 45 s. The study is acceptable according to the quality criteria. It is referenced by EFSA (2015b) in a Conclusion.

4.6.4. Extrapolation to other commodities

Extrapolation of tomato juice to other vegetable juices, as proposed by OECD (2008a), cannot be recommended after comparison of processing techniques and fruit structures.

4.6.5. Comparison to industrial and/or household processing techniques

The industrial processing of tomatoes to juice is sufficiently covered by the representative study of Mäyer (VdF, 2018). Addition of pectolytic enzymes as a production aid is normally not simulated in processing studies. Besides mechanical comminution, extraction of juice is generally promoted by a heating step. In the cold-break process, the homogenised tomatoes are heated only to ca. 60 to 75°C giving a greater retention of colour and flavour components and reducing formation of undesirable compounds. The lower temperature also does not entirely inactivate the enzymes thus allowing these enzymes to break down some of the pectins and thereby reducing the viscosity of the juice. Alternatively, pectin enzyme systems are applied to break down the pectin upon juicing, thus reducing juice viscosity.

The domestic production of tomato juice is rather rare. The tomatoes are frequently peeled, then boiled and puréed. If appropriate, a dilution with water takes place in order to achieve the desired consistency.

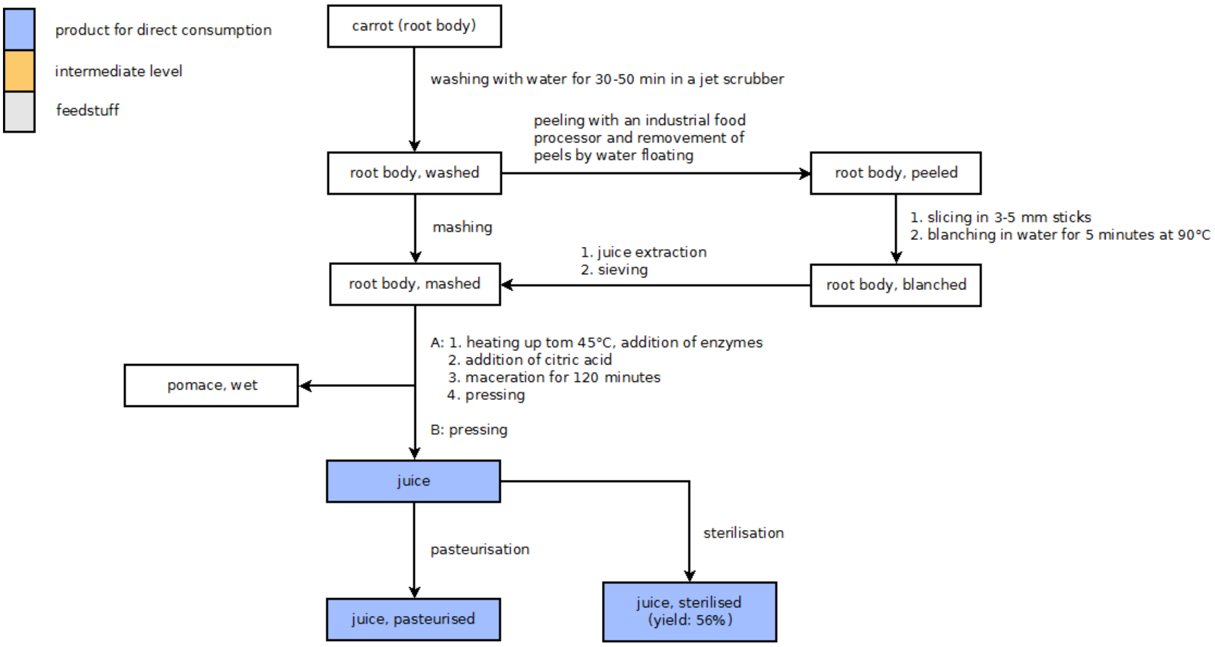
4.6.6. Carrot juice

Carrots are the vegetable crop of second largest importance in juice production. The flowchart below (Figure 25) displays the two possible procedures of carrot juice preparation.

4.6.7. Processing details

Fresh carrots are difficult to squeeze and fresh juice coagulates upon heating. Thus, at industrial scale carrots are blanched at about 80 to 90°C for several minutes to soften the roots and facilitate juicing by extraction and pressing. Homogenisation is achieved by addition of enzymes and adjusting of the pH to 5 with lactic or citric acid. The obtained juice is further preserved by pasteurisation and/ or sterilisation.

In the household, carrot juice is normally obtained by cold pressing. A pasteurisation takes place rarely, since fresh juice is often consumed directly.



A yield factor for juice is referenced in BLS (2009).

Figure 25: Two ways of processing carrots to carrot juice (VII-003)

4.6.8. By-products of carrot juice production

No relevant amounts of by-products are obtained. Intermediate products may however be used also for different processing operations. Blanching also takes place as a preparatory step for the production of canned carrots. Blanched carrots can be consumed directly or be processed to purée. Both processing steps are described in detail in chapter 3.

4.6.9. Scientific studies reflecting typical processing operations

Two studies were chosen as representative. The study of Scharm (2001b) represents a common industrial juice extraction by preliminary blanching and homogenisation by addition of enzymes. The second study of (Plier, 2012) reflects a typical household procedure applying cold pressing.

The study of Scharm (2001b) includes washing with water in a jet scrubber, peeling with an industrial food processor and removing of peels by floating with water. The peeled carrots were sliced in small pieces and blanched for 5 min in water at 90°C. Mash obtained from juice extraction and sieving was further treated with enzymes and citric acid. After maceration for 2 h, raw juice was preserved by sterilisation at 120°C for 5 min. The study is acceptable according to the quality criteria. It is referenced in a Reasoned Opinion by EFSA (2014d).

The study of Plier (2012) reflects a typical household procedure. The carrots were washed with water, mashed and pressed to obtain raw juice, which was pasteurised at 80 to 92°C for 1 to 2 min. Carrots for juicing were not peeled. The study is acceptable according to the quality criteria. It is referenced in an EFSA Reasoned Opinion (EFSA, 2016a).

4.6.10. Extrapolation to other commodities

Extrapolation is recommended from carrot juice to other root and tuber vegetable juices like beetroot juice.

4.6.11. Comparison to industrial and/or household processing techniques

The industrial processing of carrots to juice is sufficiently covered by the representative studies (VdF, 2018).

In the household, carrot juice is normally obtained by cold pressing. A pasteurisation takes place rarely, since fresh juice is often consumed directly.

In general, it can be expected that pasteurisation and/or sterilisation has no significant impact on the level of pesticide residues. However, in the case of thermally instable active substances, differences can occur, as pasteurisation may alter the residue.

4.6.12. Further vegetable juices

Processing code VII-004 is assigned to the preparation of further vegetable juices.

While tomato and carrot are the major starting products for vegetable juices, a number of other vegetables can also be used, e.g. head cabbage, celery, beetroot, and spinach. The juice processing is, although similar in principle, vegetable specific. If heating causes coagulation, preheating prior to juicing or subsequent homogenisation can provide a stable purée-like product. Reduction in pH can be achieved by adding suitable fruit juices or fermented vegetable juices. Sauerkraut juice is the extraction juice produced in the manufacturing of sauerkraut. Its pH is at about 3.3 and it contains appreciable amounts of ascorbic acid (Bates et al., 2001). Further details on the production of sauerkraut juice are described in chapter 6.1.

5. Wine manufacturing

Wine manufacturing from wine grapes may principally be subdivided into white wine and red wine production. Red wine is produced by the alcoholic fermentation of the mash of red grape varieties. White wines are made by alcoholic fermentation of the must after solid particles of wine grapes have been removed (filtered off), irrespective of the variety.

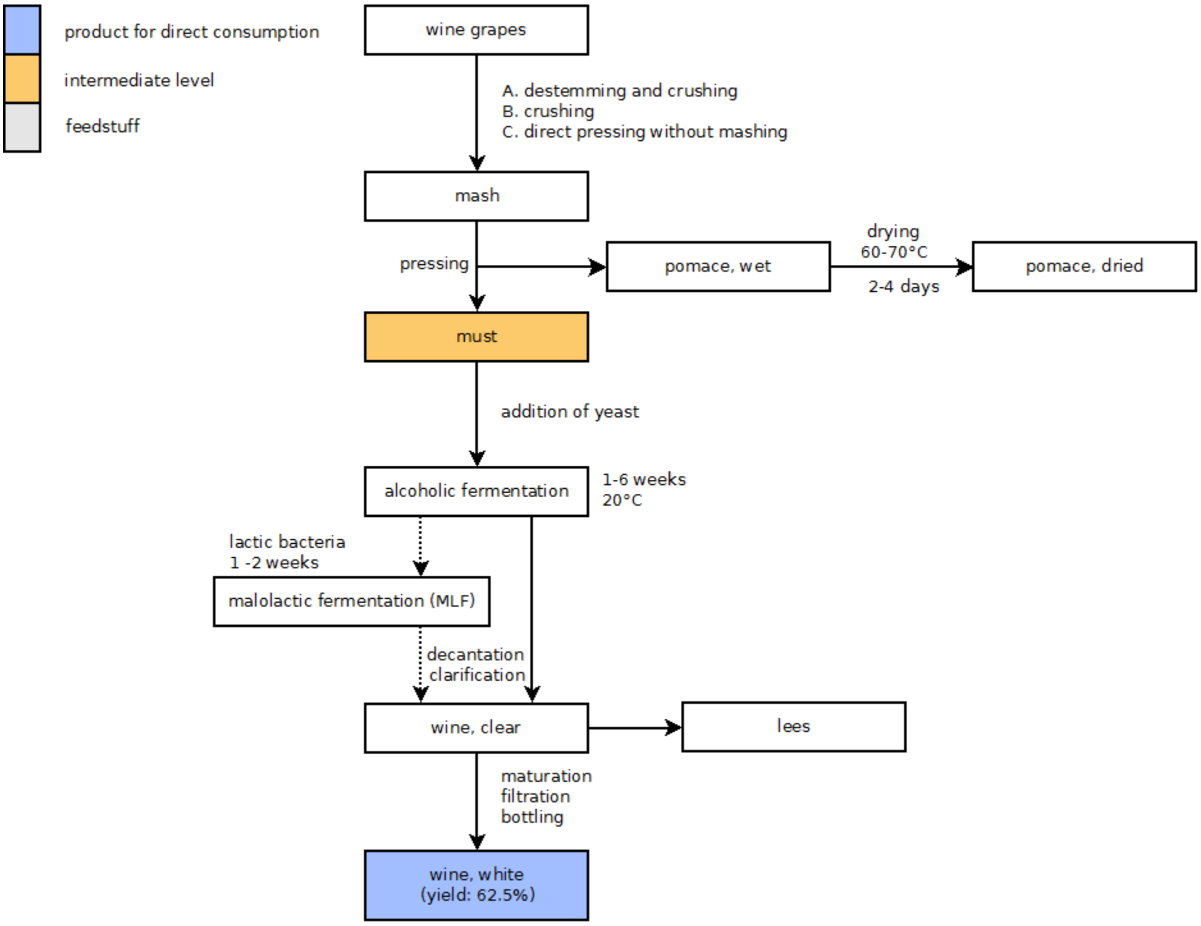
Vinification begins when the wine grapes reach the winery. Washing of the raw agricultural commodity is normally not practiced for reasons of not removing the naturally occurring yeast on the surface, and the lacking integrity of the surface of some of the grapes which may already have been broken during harvest and transport.

The basic steps in vinification are briefly outlined below, along with representative studies each on white wine and red wine.

5.1. White wine

5.1.1. Processing details

Figure 26 shows a representative process of white wine production. The significant processing steps are explained below.



Yield factors for bottled wine are referenced in Robinson (2006).

Figure 26: Processing of wine grapes into white wine (V-001)

Crushing and Pressing

After destemming, the berries are mashed to break up the structures and release the juice. For white wines the mashing phase is kept short (3-24 h) and the must is quickly pressed in order to separate the juice from the grape skins and seeds. Alternatively, grapes may be immediately pressed without a preceding mashing phase. About 60-80 L of must are obtained from 100 kg of wine grapes. After crushing and/or pressing, antioxidants like sulphurous acid, sulphur dioxide or potassium metabisulfite are immediately added (Jackson, 2014). The initial steps of the wine production are similar to the grape juice production. Additional information for juicing is given in chapter 4.3.

The concentration of non-systemic pesticides is normally higher on the grape skin than the interior of the berries. Therefore, extended mashing is expected to lead to higher pesticide concentrations in the must in comparison to direct pressing.

Alcoholic fermentation

After pressing, the must is usually pre-clarified by sedimentation or fining to remove part of the clouds prior to fermentation into wine. The temperature controlled fermentation is started by either spontaneous fermentation or by adding specific yeast strains. Yeasts transform sugars present in the juice into ethanol and carbon dioxide. White wine is fermented at temperatures around 20°C.

Malolactic fermentation

Occasionally a further biologic reduction of acids is achieved by lactobacteria converting malic acid into lactic acid. This process is more common for red wines but is also performed for around 20% of white wines (Jacobsen, 2006).

Clarification

Once fermentation is completed, the clarification process begins. Following natural sedimentation of the lees the young wine is decanted (“racking”). Cold storage at temperatures between -5°C and 10°C is a common technique for precipitating tartrates. After a further maturation the remaining clouding material is removed through fining (with fining agents like gelatine or bentonite) and/or filtration.

5.2. Red wine

5.2.1. Processing details

Figure 27 shows a representative process of red wine production. The significant processing steps are explained below.

Crushing and Pressing

After destemming, the berries are mashed to break up the structures and release the juice. Mash fermentation is the most widely used technique for red wine meaning that the juice is not separated from the pomace in order to effectively extract the desired colourants and tannins which are located in the skins of the berries. Extraction efficiency can be enhanced by addition of pectolytic enzymes or by heating the mash to temperatures between 60°C and 80°C for about 30 minutes (thermovinification). Like for white wine manufacturing sulphurous compounds are added to prevent oxidation of valuable ingredients and damage from microbial contaminants. The initial steps of the wine production are similar to the grape juice production. Additional information on juicing is given in chapter 4.3.

During mashing, pesticides residing on the grape surface (mainly non-systemic pesticides) come into contact with the grape juice. As described in chapter 4.3, this can lead to increased residue levels in the mash. Therefore, it can be expected that red wine reflects the worst case for wine production because of the longer mashing phase. In contrast to this, thermovinification could have a reducing effect on pesticides sensitive to heat.

Alcoholic fermentation

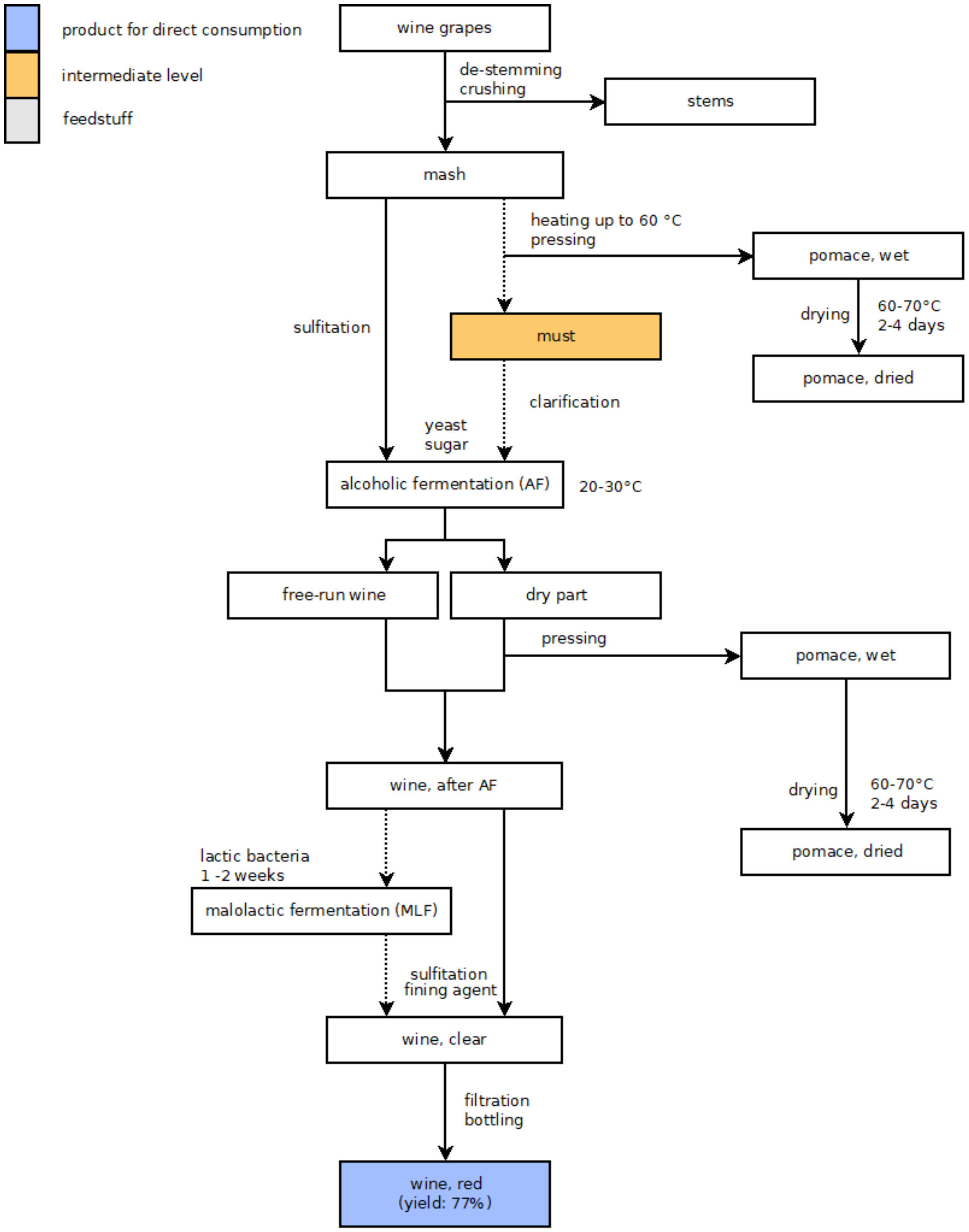
Whilst the fermentation starts on the must for white wine after removal of pomace it is done on the mash in the case of red wine (mash fermentation). The generated alcohol enhances the extraction of the colourants and tannins. Depending on the desired product and temperature of the mash (normally around 30°C) the fermentation period lasts roughly for 1 to 3 weeks. After fermentation, wine is received either free-run or by mechanical pressing, forcing more tannin out of the pomace.

Malolactic fermentation

After the fermentation the malolactic fermentation is often performed as a secondary fermentation. Specific lactic acid bacteria (usually *Oenococcus oeni*) are added to the young wine to convert malic acid into lactic acid.

Clarification

Identical to white wine there are various techniques for clarification and stabilisation of red wine like decantation, fining and filtration.



Yield factors for bottled wine are referenced in Robinson (2006).

Figure 27: Processing of wine grapes into red wine (V-002)

5.3. Rosé Wine

Processing code V-003 is assigned to the processing of rosé wine.

Rosé wines are very light-coloured wines. They contain some of the colour of red grape skins but not as much as red wines. There are several ways to produce rosé wine:

- The most common technique is the maceration method (skin contact method). For this method, red wine grapes are processed analogous to the red wine process, but with a very short skin-contact period (maceration).

- Another method is to process red wine grapes according to white winemaking practises, therefore without any maceration time. The obtained wine is lighter than rosé wine from the maceration method and is called vin gris.
- The Saignée method (bleeding) produces red wine and rosé. During the fermentation of red wine, a part of the juice is drained off. The remaining juice is left with a higher ratio of skin contact and is therefore concentrated. The drained juice is fermented without further skin contact to rosé.

5.4. "Stored wine"

In some studies processing factors are reported for "young" wine along with factors for "stored" or "mature" wine. However, these terms are not defined. In the studies, samples of "young" wine are sometimes taken directly after fermentation and sometimes after bottling. "Stored" or "mature" wine has been stored after bottling for three to six months. There is basically a trend to lower concentrations in "stored" wine, indicating that this is not the worst case commodity in comparison to "young" wine. If a study reported "young" and "stored" wine, the worst case was selected for the database, i.e. the processed commodity with the higher processing factor was chosen. For future studies, storage of the wine is not deemed necessary.

5.5. By-products of wine production

By-products of winemaking are vine shoots, stalks, grape pomace and lees. Grape pomace is the main fraction of the waste and consists of grape skins, pulp and seeds. In the case of red wine it is fermented pomace with a low sugar and phenolic compound content. White wine pomace is not fermented and is therefore potentially richer in sugars and phenolic compounds.

In Europe the main use of grape pomace is for distillation. Spirit distilled from grape pomace is called pomace brandy (e.g. grappa, Marc de Champagne). Grape pomace is furthermore used as soil fertiliser and fermentation substrate for biomass production. Separating the grape seeds from the pomace to produce grape seed oil is possible as well (Galanakis, 2017). Oil production is generally described in chapter 7.

5.6. Scientific studies reflecting typical processing operations

All basic steps in preparation of red and white wine are adequately reflected in various processing studies. Rosé wine in only produced in few studies and always with the vin gris method. Two representative studies for the production of red and white wine and one study for the production of rosé wine have been selected. In the corresponding study reports the standard operating procedures are comprehensively described.

The study of Blaschke (2006) reports the production of wine from red and white grape varieties. For white wine, the wine grapes were crushed and pressed. The must was sulphurised and clarified (by decantation). Yeast and nutrient salt was added to the clarified juice and fermentation was done at temperatures between 15 and 20°C. After fermentation the young wine was stored for clarification at approximately 15°C and potassium metabisulfite was added. The wine was racked and bentonite was added for further clarification. After a second racking the wine was filtered and bottled for maturation. The bottled wine was stored cold for 6 months. For red wine, red wine grapes were destemmed and crushed. Sulphur was added and the mash was heated up to 60°C in 40 min (thermovinification). After heating, the mash was cooled down and subsequently pressed to extract the must. All further processing steps were carried out like for the white wine production. The study is acceptable according to the quality criteria. It is referenced by EFSA (2009a) in a Reasoned Opinion according to article 10.

The study of Grolleau (2000) reports the processing of wine grapes into red and white wine. For white wine, white grapes were pressed with a water press. The recovered must was decanted for 12 h with the addition of pectolytic enzymes and potassium metabisulfite. After decantation, yeast was added to the must to start the fermentation process. During the fermentation, crystallized sugar was added to obtain the desired alcohol content. After the alcoholic fermentation the young wine was racked and gelatine and potassium metabisulfite were added. The wine was then stored cold (temperatures between 5 and 10°C) for 15 days. Filtration was carried out over cellulose filter plates (2.5 and 1.5 µm) and the filtered wine was bottled. For red wine, malolactic fermentation was additionally executed after the alcoholic fermentation. Lactic bacteria *Leuconostoc oeni* were added to the young wine to convert L-malic acid to L+lactic acid. The study of Grolleau is acceptable according to the quality criteria. It is referenced by EFSA (2012b) in a Reasoned Opinion according to article 12.

The study of Braun et al. (2008) reports the processing of red grapes into rosé wine with the vin gris method. Grapes were crushed in a grape crusher and subsequently pressed. Potassium metabisulfite was added and the must was clarified. Yeast and nutrient salt was added to start the fermentation. After the alcoholic fermentation the young wine was racked and bentonite was added. Upon completion of the clarification, the wine was racked a second time and potassium metabisulfite was added. The wine was filtered through filter pads, bottled and stored at approximately 12°C. The study is acceptable according to the quality criteria. It is referenced by EFSA (2009b) in a Reasoned Opinion according to article 12.

5.7. Extrapolation to other commodities

Extrapolation from red or white wine is possible to other types of wine like rosé wine or sparkling wine. Depending on the manufacturing process, rosé wine production follows the white or red wine production route.

Sparkling wine is wine with higher levels of carbon dioxide. It is produced similarly to wine but undergoes a second fermentation. Sugar and yeast is added to the wine and carbon dioxide is produced. Processing code V-004 is assigned to the production of sparkling wine.

Fruit wine is produced from the must of other fruits, usually enhanced by the addition of sugar. The process is comparable to wine production from grapes. Extrapolation from wine grapes to other fruits is therefore possible.

5.8. Comparison to industrial and/or household processing techniques

The representative processing studies reflect common industrial or artisanal methods. Winemaking is not a typical household process.

6. Fermentation and pickling

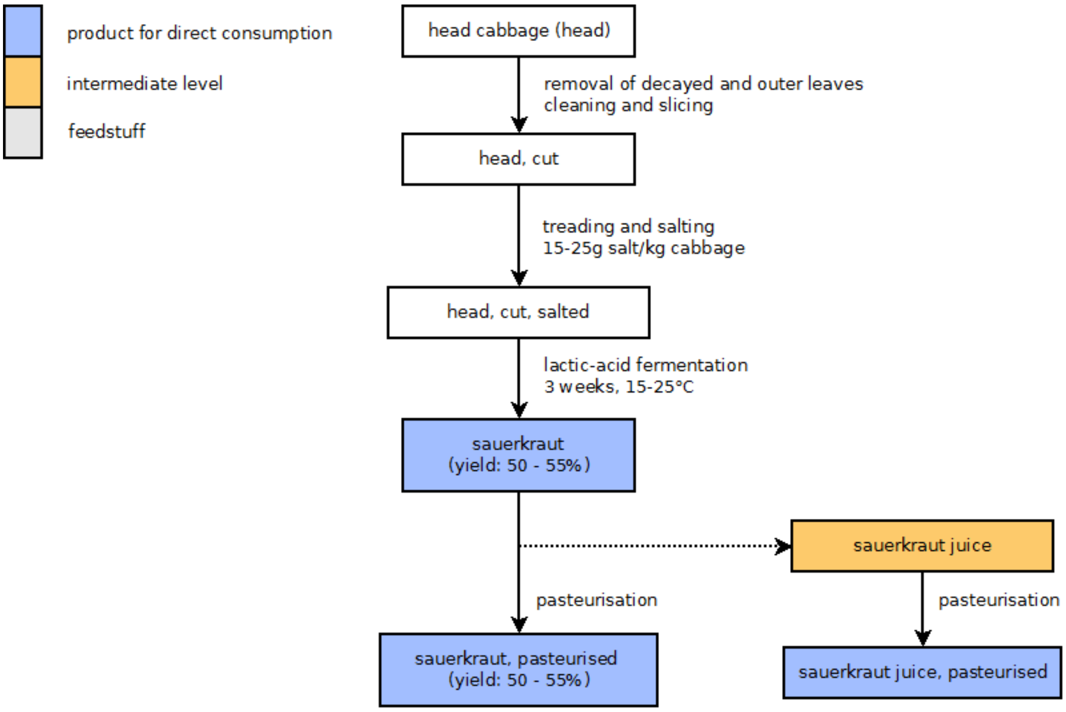
Pickling is a preservation method in which the pH value of the food is lowered in order to enhance the storage stability. Pickled food is either fermented in brine (solution of salt in water) or immersed in an acid solution, usually vinegar.

Fermentation is the enzymatic conversion of organic substances into alcohol, gases and organic acids. Alcoholic fermentation takes place during the production of beer (chapter 9) and wine (chapter 5). Organic acids are formed, for example, in the production of vinegar (acetic acid fermentation), preserved table olives, sauerkraut (lactic acid fermentation) and soya sauce.

6.1. Sauerkraut production

6.1.1. Processing details

Sauerkraut is sliced, salted and lactic acid fermented head cabbage (generally white head cabbage). A flowchart of the sauerkraut production process is provided in Figure 28. The significant processing steps are explained below.



Yield factors for products for direct consumption are referenced in Heiss (2004).

Figure 28: Processing of cabbage into sauerkraut (XVII-001)

Cleaning and Slicing

The outer leaves and the core of the cabbage heads are removed. The cleaned cabbage heads are then shredded or chopped into 0.7 to 2 mm wide strips (Farnworth, 2008).

It is expected that the cleaning process, especially the removal of the outer layers, has a significant effect on the residue concentration of non-systemic pesticides, which are normally more concentrated on the outer layers of the cabbage than on the inner parts.

Treading and Salting

Sodium chloride is added in proportion to cabbage weight (1.5-2.5% salinity). The cabbage strips are packed into suitable containers. The air between the strips is removed as far as possible and the container is sealed airtight. The sodium chloride and the pressure lead to an osmotic extraction of water and nutrients from the tissue cells. The released juice is an excellent nutritional medium for bacteria involved in the fermentation (Ternes, 2008).

Lactic-Acid Fermentation

Raw cabbage contains sufficient numbers of lactic acid bacteria for spontaneous fermentation. The majority of the sauerkraut produced in Europe and North America is produced this way. However, addition of starter cultures or back-slopping is possible as well. Back-slopping is the inoculation of the raw material with small quantities of already successfully fermented brine.

The fermentation is considered complete when the titratable acidity, expressed as lactic acid, is 1.5%.

Pasteurisation

Sauerkraut can be stored cold and sold fresh. More commonly (80%) it is pasteurised to extend the shelf life (Hammes, 1990). The pasteurisation is done to the packed sauerkraut at temperatures around 90°C for a few minutes. Pasteurisation can have a great impact on the processing factor, depending on the heat stability of the contained pesticides. For further explanation of pasteurisation see introduction of chapter 3.

Sauerkraut juice

For sauerkraut juice, a part of the fermented juice is separated from the sauerkraut. Subsequently, the juice is pasteurised.

6.1.2. Scientific studies reflecting typical processing operations

The study of Schulz and Scharm (2001) reports the processing of white cabbage heads to sauerkraut and sauerkraut juice.

For sauerkraut production, cabbage heads were cleaned manually (removing outer layers and stalks) and sliced with an electrical universal cutting machine into long strips. The strips were transported to a fermenting tub and were subsequently stamped. Salting was carried out by adding salt brine (15% sodium chloride concentration). Starter cultures and additional water were added. Fermentation at room temperatures lasted 20 to 22 days. After the fermentation, the sauerkraut juice was separated by run off. Sauerkraut (550 to 600 g) and sauerkraut juice (50 g) were filled in jars and pasteurised at 95°C for 30 min.

The study is acceptable according to the quality criteria. It is referenced in a Reasoned Opinion by EFSA (2014d).

6.1.3. Extrapolation to other commodities

Extrapolation to other fermented head and leafy brassicas is possible. For example, napa cabbage and Korean radish are salted and fermented similarly to sauerkraut when the dish Kimchi is prepared.

6.1.4. Comparison to industrial and/or household processing techniques

Household processing techniques to produce sauerkraut correspond to the common industrial methods. However, pasteurisation is usually not done in the household, which may affect the processing factor of heat-labile pesticides.

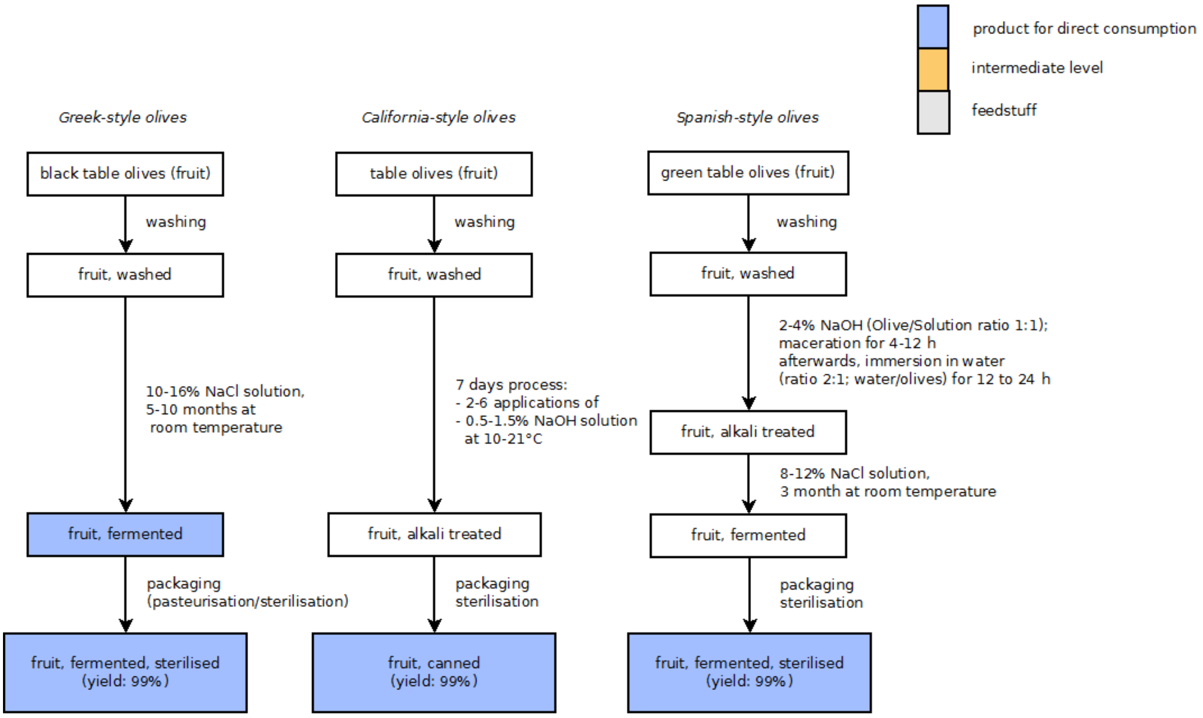
6.2. Preserved table olives

6.2.1. Processing details

Raw olive fruits are very bitter due to the high concentration of phenolic compounds (especially oleuropin) and need to be processed before consumption. There are several methods used for the production of table olives with a huge variety of local and regional styles. Among the most popular are the Greek, Spanish and Californian style preservation methods. Greek style preserved olives are naturally fermented black olives. Spanish style preserved olives are made from green olives where the fruits are treated with a lye-solution to remove bitter flavours. Subsequently the olives are fermented in brine.

Californian style preserved black olives are normally not fermented, but treated with lye to remove bitterness and exposed to air for darkening (Holzapfel, 2007).

A flowchart of all three production processes is provided in Figure 29. The significant processing steps are explained below.



Yield factors are referenced in BLS (2009).

Figure 29: Pickling of olives (XVII-002)

Sorting and washing

The olives are sorted to separate damaged fruits and are washed with water to remove adherent dirt.

Leaching

Leaching is done for Spanish-style olives. The lye eliminates a part of the oleuropin and therefore bitterness. The olives are placed into a lye solution (1.5-4% sodium hydroxide) and macerated for 4 to 12 h. Subsequently, the olives are washed with water to eliminate the remaining sodium hydroxide from the fruits.

Brine treatment and fermentation

The washed, respectively lye-treated olives are placed in brine (8-12% sodium chloride concentration) and undergo spontaneous fermentation. Alternatively, inoculation of starter cultures is possible. The olives are stored at ambient temperatures and are regularly stirred.

Packaging and sterilisation

The olives and a part of the brine are packed. Sodium chloride content of the brine is adjusted by addition of sodium chloride or new brine is used. Addition of vinegar is possible as well. Sterilisation is unnecessary for olives when fermented in brine as long as the salt concentration and pH are favourable for preservation.

6.2.2. Scientific studies reflecting typical processing operations

Two processing studies for fermented table olives are available.

The study of Simek (2013) describes the processing of raw olives into Spanish style preserved olives. Raw olives were washed and placed into a 2-4% sodium hydroxide solution for 5 to 8 h. Afterwards the olives were immersed in water for 12 to 20 h. The washed olives were placed in brine (10-11% sodium chloride concentration) and kept at room temperature for 3 months. The sodium chloride concentration was monitored and, when required, readjusted to keep the concentration above 8.5%. After fermentation the processed olives in brine were sterilised at 115°C during 20 min. The study is acceptable according to the quality criteria. It is referenced in a Reasoned Opinion by EFSA (2016c).

The study of Haigh and Cairns (2011) describes the processing of raw olives into Greek-style preserved olives. This study was acceptable according to the quality criteria but was not reported by EFSA in any Conclusion or Reasoned Opinion. The olives were washed by immersion, drained and placed in brine (11% sodium chloride concentration). The olives were stored at room temperature for thirty days and regularly stirred. Subsequently, the olives were stored for sixty days in a cold room (5-10°C). After storage, the olives were canned (500 g olives and 250 g brine) and sterilised at 115 to 120°C for 10 min.

Due to the different processing steps of the three preservation methods and the different physicochemical properties of the different pesticides, no worst case could be derived.

6.2.3. Extrapolation to other commodities

No extrapolation to other commodities is recommended.

6.2.4. Comparison to industrial and/or household processing techniques

Household processing techniques to produce preserved olives are comparable to common industrial methods.

6.3. Pickled gherkins

There are two kinds of pickled gherkins: fermented pickles and fresh pack pickles.

6.3.1. Processing details (fresh pack pickled gherkins)

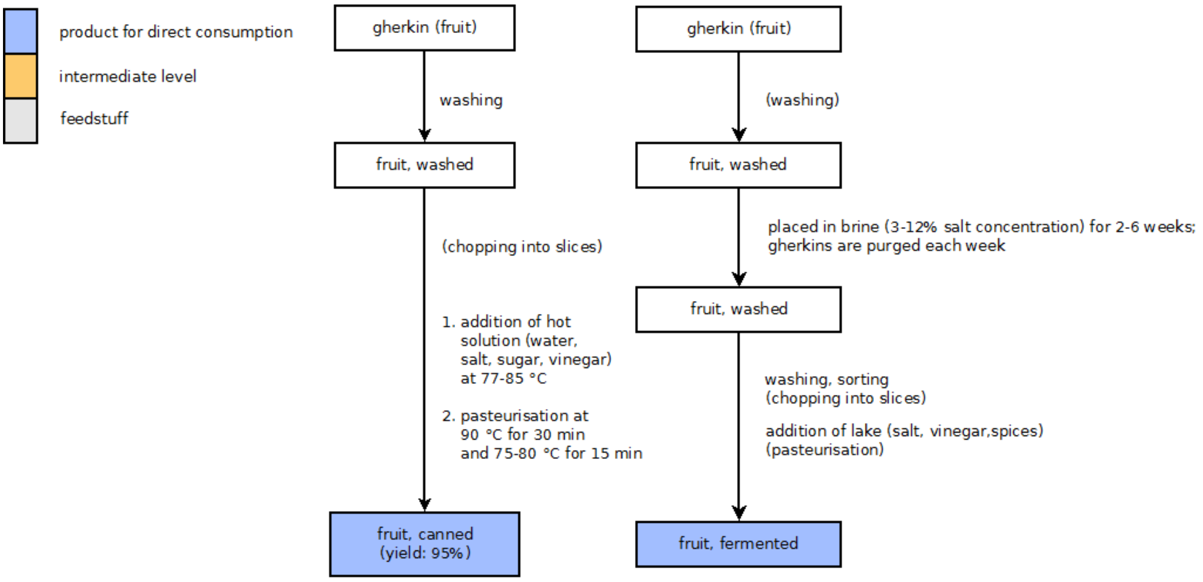
For fresh pack pickles, gherkins are washed and placed in cans or jars. A solution of vinegar, salt, sugar and spices is added. Fresh pack pickles are pasteurised to extend shelf-life. A simplified flowchart of the process is shown in Figure 30.

6.3.2. Processing details (fermented gherkins)

The significant processing steps of fermented gherkins are shown in Figure 30 and are further explained below.

Washing

Stems are removed and the gherkins are soaked in water for 60-90 min to remove dirt and to enlarge the turgor within the cells. The gherkins are then strained and sorted.



The yield factor is referenced in BLS (2009). Although both products for direct consumption are pickled, they are differentiated in "fruit, canned" and "fruit, fermented" because of different processing steps.

Figure 30: Processing of gherkins into pickled gherkins (XIX-001)

Fermentation

The washed gherkins are placed in fermentation vessels and brine is added. There are two brining methods, the low-salt method (with 3-5% sodium chloride) and the high-salt method (with 8-10% sodium chloride). The addition of spices and acetic acid is possible as well. Acetic acid decreases the pH and promotes a better fermentation. Fermentation takes place at 18-20°C and lasts 2 to 6 weeks depending on the temperature, raw material, sodium chloride concentration in brine and initial amount of lactic bacteria. After the fermentation process the gherkins are packaged. Stabilisation by heat treatment is optional.

6.3.3. Scientific studies reflecting typical processing operations

There are only a few studies available which describe the production of pickled gherkins (fermented or fresh pack).

The study of Boissinot (2014) reports the processing of fermented gherkins. For the fermentation process the gherkins were washed and filled into a demijohn. Brine (3% sodium chloride content) was added at the same amount as the gherkins. Spontaneous fermentation lasted 4 weeks. Subsequently, the gherkins were canned (500 g fermented gherkins and 250 g fresh brine per can) and sterilised at 115-125°C for about 10 min. The study is acceptable according to the quality criteria. It is referenced by EFSA (2016c) in a Reasoned Opinion.

The study of Scharm (2001a) reports the processing of canned gherkins (fresh pack) and is cited by EFSA (2014d) in a Reasoned Opinion according to article 12. The study is acceptable according to the quality criteria. Washed gherkins were cut into halves and filled into jars. A hot solution of water, sodium chloride, sugar and vinegar was prepared (77-85°C) and added to the gherkin slices. Pasteurisation took place in an autoclave while heating to 90°C for 20 min, keeping the temperature for 20 min and cooling down to 75-80°C for 15 min.

6.3.4. Extrapolation to other commodities

Extrapolation from pickled gherkins to other pickled vegetables is possible as long as peels do not need to be removed from the commodity in question.

6.3.5. Comparison to industrial and/or household processing techniques

The processing of fermented gherkins reduces the pesticide residue level. Washing removes a part of the non-systemic pesticides from the gherkin surface. The dilution with brine is expected to reduce the amount of hydrophilic pesticides. Stabilisation by heat treatment, pasteurisation or fermentation, contribute to the degradation of heat-labile pesticides.

Household production of fermented gherkins corresponds to the common industrial methods. Heat treatment (pasteurisation or sterilisation), which may affect the processing factor of heat-labile pesticides, is not necessarily done in the household.

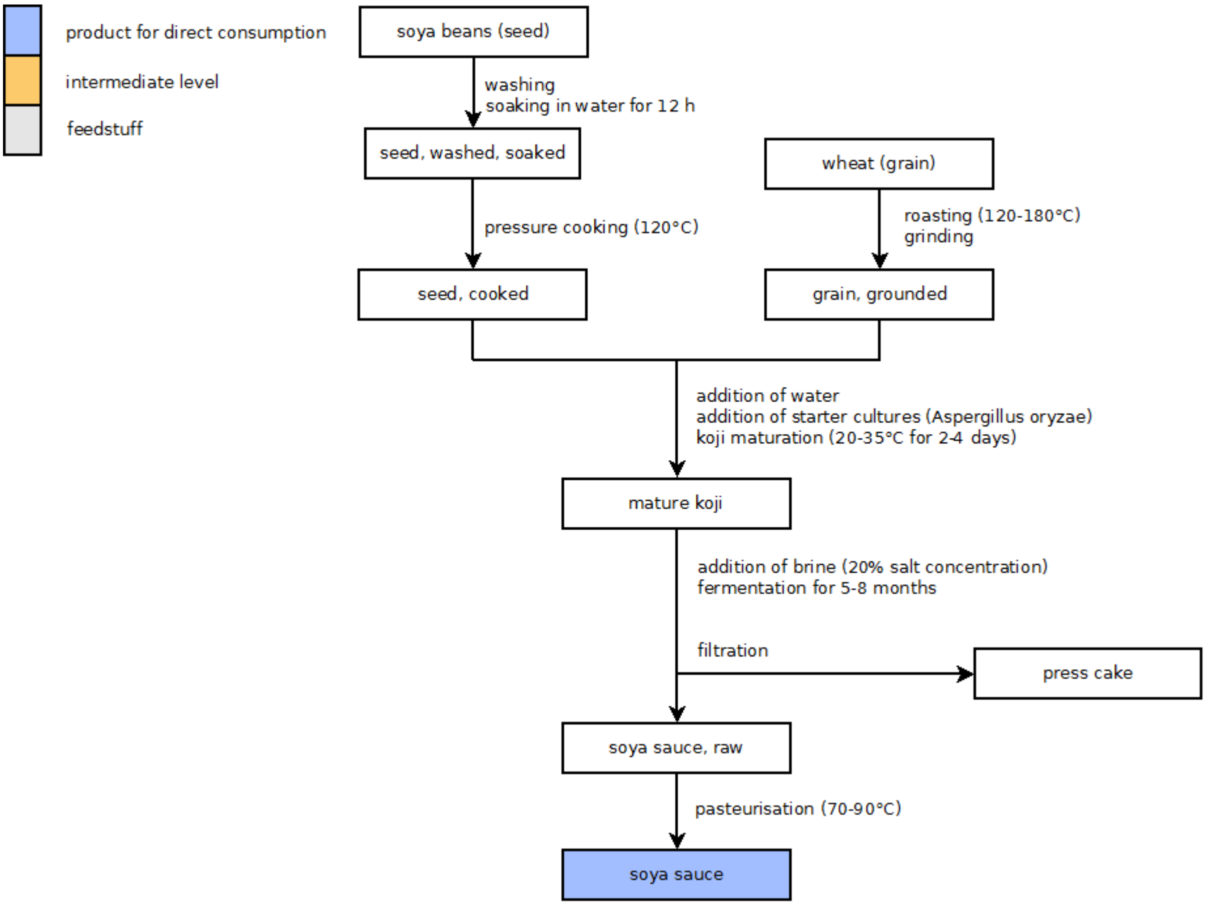
6.4. Soya sauce

Traditionally brewed soya sauce is a condiment which is made from soya beans, roasted wheat grain, water and sodium chloride. This mixture is inoculated with mould cultures (*Aspergillus oryzae* or *Aspergillus sojae*) and subsequently fermented. In addition to the traditional method, production by hydrolysis is made. Soya sauce made from acid-hydrolysed vegetable protein is not fermented.

Soya sauce is an example of a composite food (such as beer). Though processing factors for soya sauce are of only limited use because residues cannot be unambiguously traced back to one of the ingredients, the process is kept in the compendium due to its unique nature.

6.4.1. Processing details

A flowchart of the production of traditionally brewed soya sauce is provided in Figure 31. The significant processing steps are explained below.



In an exemplary recipe 22 g wheat and 22 g soya beans are used for 100 g soya sauce (BLS, 2009).

Figure 31: Processing of soya beans and wheat into soya sauce (XVII-003)

Washing and cooking

Whole soya beans are washed, soaked in fresh water for several hours (10-14 h) and subsequently cooked under pressure.

Roasting and grinding

The wheat grain is roasted at temperatures between 120 and 180°C for a few minutes and is subsequently grounded.

Koji maturation

Soya bean kernels and ground wheat are mixed with water. The ratio of cooked soya beans to wheat is usually 1:1 but may vary, depending on the type of soya sauce to be prepared. Subsequently, starter cultures are added. The mixture (koji) is incubated for 2-4 days at temperatures between 25 and 35°C.

Fermentation

The matured koji is mixed with brine (20% sodium chloride concentration) and fermented for 5-8 months at temperatures between 15 and 30°C. During the fermentation, the koji enzymes hydrolyse proteins in soya beans and wheat to amino acids and low-molecular-weight peptides. Starch is converted to simple sugars, which are fermented primarily to lactic acid, alcohol and carbon dioxide. The pH value drops from near neutral down to 5. After fermentation, the raw soya sauce is separated from the spent koji by pressing (Steinkraus, 2004).

Pasteurisation

After pressing, the raw soya sauce is pasteurised at temperatures between 70 and 90°C for a few minutes to inactivate residual enzymes and undesirable microorganisms. Additional clarification by sedimentation or centrifugation is possible. For further explanation of pasteurisation see introduction to chapter 3.

6.4.2. Scientific studies reflecting typical processing operations

There is only one study available, which describes the processing of soya beans into soya sauce (Mäyer, 2012c).

Whole soya beans were washed with water and then soaked in fresh water for 10-14 h. After draining, the soya bean kernels were pressure cooked at approximately 120-125°C for one hour. Wheat grains were roasted at temperatures between 120 and 135°C for 30 min. Soya bean kernels and ground wheat (in roughly equal proportions) were mixed with water. Subsequently, starter cultures were added. The mixture (koji) was incubated for 24 to 28 h at temperatures between 30 and 35°C and relative humidity of 55-75%. After the first incubation period the koji was incubated another 24-48 h at temperatures around 20 and 25°C. The mature koji was mixed with brine (22-28% sea salt concentration) and fermented for 180 days at temperatures between 15 and 30°C. After fermentation, the raw soya sauce was separated from the spent koji by pressing. The raw soya sauce was pasteurised at temperatures between 70 and 90°C.

The study is acceptable according to the quality criteria. It is referenced by EFSA (EFSA (2015b)) in a Conclusion.

6.4.3. Extrapolation to other commodities

No extrapolation to other commodities is recommended.

6.4.4. Comparison to industrial and/or household processing techniques

Processing of soya beans and wheat into soya sauce is expected to decrease the pesticide concentration. Both main ingredients are treated at high temperatures (pressure cooking and roasting) and are subsequently diluted with brine. However, there is not yet sufficient data to confirm this assumption.

The production of soya sauce is not a common household process in Europe.

6.5. Rice wine

Rice wine is the name for alcoholic beverages produced entirely or predominantly by saccharification and alcoholic fermentation of rice or rice starch. These beverages are particularly popular in the Asian region. The alcohol content is between 5 and 20 %, depending on the variety.

For the production of rice wine, cooked rice is usually mixed with starter cultures. The composition of the starter cultures can vary greatly depending on the type of rice wine. However, they usually contain moulds, yeasts and lactic acid bacteria. The moulds break down the starch into simple sugars. The yeasts ferment the sugars into alcohol. The lactic acid bacteria are involved in the formation of flavour-giving substances.

In Europe, one of the best-known rice wines is Japanese sake.

6.5.1. Processing details

A flowchart of the production of sake is provided in Figure 32. The significant processing steps are explained below.

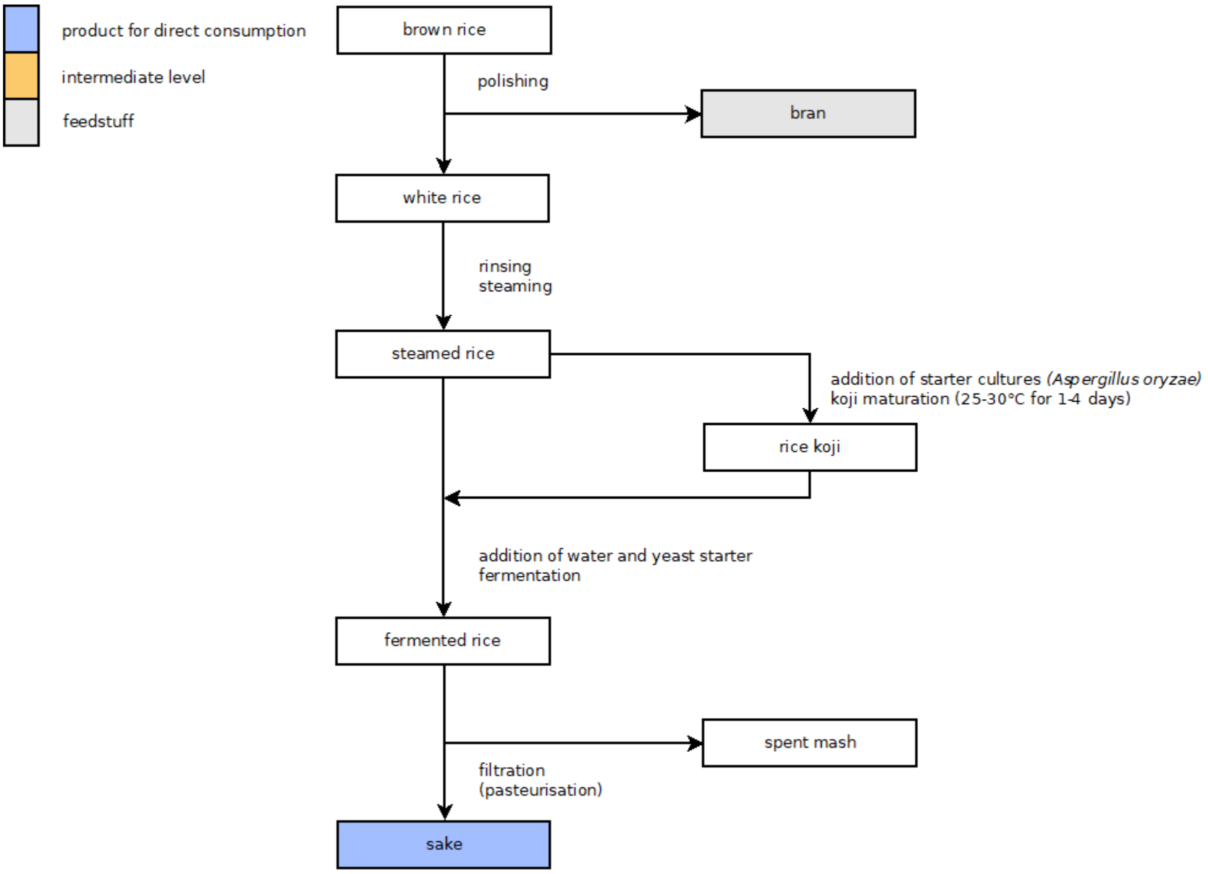


Figure 32: Processing of rice into sake (XVII-004)

Polishing

Brown rice is polished to remove bran. The amount of rice lost during polishing can vary widely. Sometimes up to 40% of the rice grain is removed by polishing for sake production. This increases the amount of starch in the remaining grain (Ashcraft et al., 2020).

Washing and soaking

The polished rice is washed with water to remove powder and dust residues that may adhere to the rice grains after the polishing process. After washing, the rice is soaked in water. The soaking time depends on the size of the rice grains and the degree of polishing.

Steaming and Koji making

After soaking, the rice is drained and then steamed for about one hour. Then the rice is cooled down to 30-35°C. About 20-25% of the rice is used to make koji. The rice is inoculated with *Aspergillus oryzae* and placed in an environment with high humidity (80-90°C) and temperatures around 25-30°C.

Fermentation

The koji rice is mixed with the remaining steamed rice. Water and yeast are added. The conversion of starch to sugar and the fermentation of sugar to alcohol now take place in parallel. The fermentation takes between 18 and 32 hours.

Filtration and pasteurisation

After fermentation, the raw sake is pressed off from the spent mash and is then filtered. The raw sake is often pasteurised to protect it from flavour changes caused by yeast residues and to prevent spoilage.

6.5.2. By-products of rice wine production

Rice bran can be used as animal feed or can be further processed into rice oil. Heat-treated bran may be used for human nutrition (OECD, 2015).

6.5.3. Scientific studies reflecting typical processing operations

There is only one study available, which describes the processing of rice into sake (Woodard, 2015).

Brown rice was milled into white rice and bran by friction. The white rice was then rinsed with water and subsequently soaked in 38°C warm water for 40-50 minutes. The rice was drained and steamed at 88-98°C for 40-50 minutes and then cooled to 38°C. 20% of the rice was inoculated with *Asperigillus oryzae* and placed in an environmental growth chamber for 36-72 hours to produce rice koji.

The remaining rice was mixed with the rice koji, distilled water, citric acid and yeast. The mixture was placed in a container to ferment for 14 days. After the fermentation period, the liquid raw sake was separated from the spent mash. The sake was then filtered and pasteurised (60-66°C, 10-20 min).

The study is acceptable according to the quality criteria. It is referenced by EFSA in a Reasoned Opinion (EFSA, 2018).

6.5.4. Extrapolation to other commodities

No extrapolation to other commodities is recommended.

6.5.5. Comparison to industrial and/or household processing techniques

The production of sake is not a common household process in Europe.

7. Oil production

Edible oils are mostly produced from oilseeds and oil fruits. Furthermore, processing of maize, citrus peel and tree nuts to edible oils is possible. The level of pesticide residues with lipophilic character may be affected by different procedures of oil production. The preparation of vegetable crude oils can be performed by one of the following procedures:

- Direct pressing by an expeller
- Direct solvent extraction
- Pre-press solvent extraction (combined procedure)

The most frequently used extraction technique in industry is the pre-press solvent extraction. Direct solvent extraction is most advantageous for oilseeds, oil fruits or grains with low oil content, because maximum oil yields are expected, while direct pressing results in lower oil yields (Hamilton and Crossley, 2004).

Further treatment is necessary to obtain odourless, heat stable oils with long shelf-life.

The refining process can be divided into chemical and physical refinement and includes the following main steps (depending on the oil type the sequence can be simplified):

- Chemical refining:
    - Degumming/ post-degumming
    - Neutralisation
    - Bleaching
    - Winterisation (for wax containing oils)
    - Deodorisation
- Physical refining:
    - Bleaching
    - Winterisation (for wax containing oils)
    - Deacidification – deodorisation

In most cases, especially for hydrophilic pesticides, a reduction of residues in oils as compared to raw oilseeds can be observed. In contrast, more lipophilic pesticides can concentrate in oil. However, only very poorly water-soluble pesticides were found to significantly concentrate in oil. Regarding the refining processes, deodorising is the most effective step for decreasing pesticide residue levels in oils due to the high temperatures of 190 to 270°C.

Table 10 summarises the commodities from which oil is produced and to which processing studies have been submitted.

Table 10: Overview on major crops from which oil is made. For *italicised* commodities oil processing studies have been reported in various EFSA Reasoned Opinions or EFSA Conclusions.

Main crop group	Sub crop group	Commodity
cereals		*maize*
fruits	citrus fruits	*grapefruits*
		lemons
		limes
		oranges
	tree nuts	coconuts, walnuts
vegetables	leaf and vegetables, herbs and edible flowers	*mint*
oilseeds and oil fruits	oil fruits	*olives, oil palms*
	oilseeds	*cotton seed*
		grape seeds
		linseed
		peanuts
		pumpkin seeds
		rape seed
		soya beans
		sunflower seed

The production of oils and fats is a major branch of the global economy. Of the 90 million tons produced annually, 75 million tons are used for human nutrition. The rest is mainly used for the production of soap and cosmetics as well as for animal feeding or serves as a raw material in the chemical and pharmaceutical industry (Heiss, 2004). Part of the oils also goes to technical markets. The world's most important commodities for production of edible plant oils are soya beans, rape seeds, sunflower seeds and palm kernels (Statista, online). In Europe, oil is mainly produced from soya beans, sunflower seeds, rape seeds, olives and maize (Fediol, online).

In the EU refined tropical oils from palm, palm kernels or coconut are also consumed. They are generally imported as crude oils. However, no processing studies are available for the oil production from tree nuts, like coconuts or walnuts, and oil palm fruits.

7.1. Olive oil

The European Union is leading producer (70%), consumer (56 %) and exporter (66%) of olive oil (EC, online-a). Spain is the main producer. In contrast to other oils the complete fruit is processed.

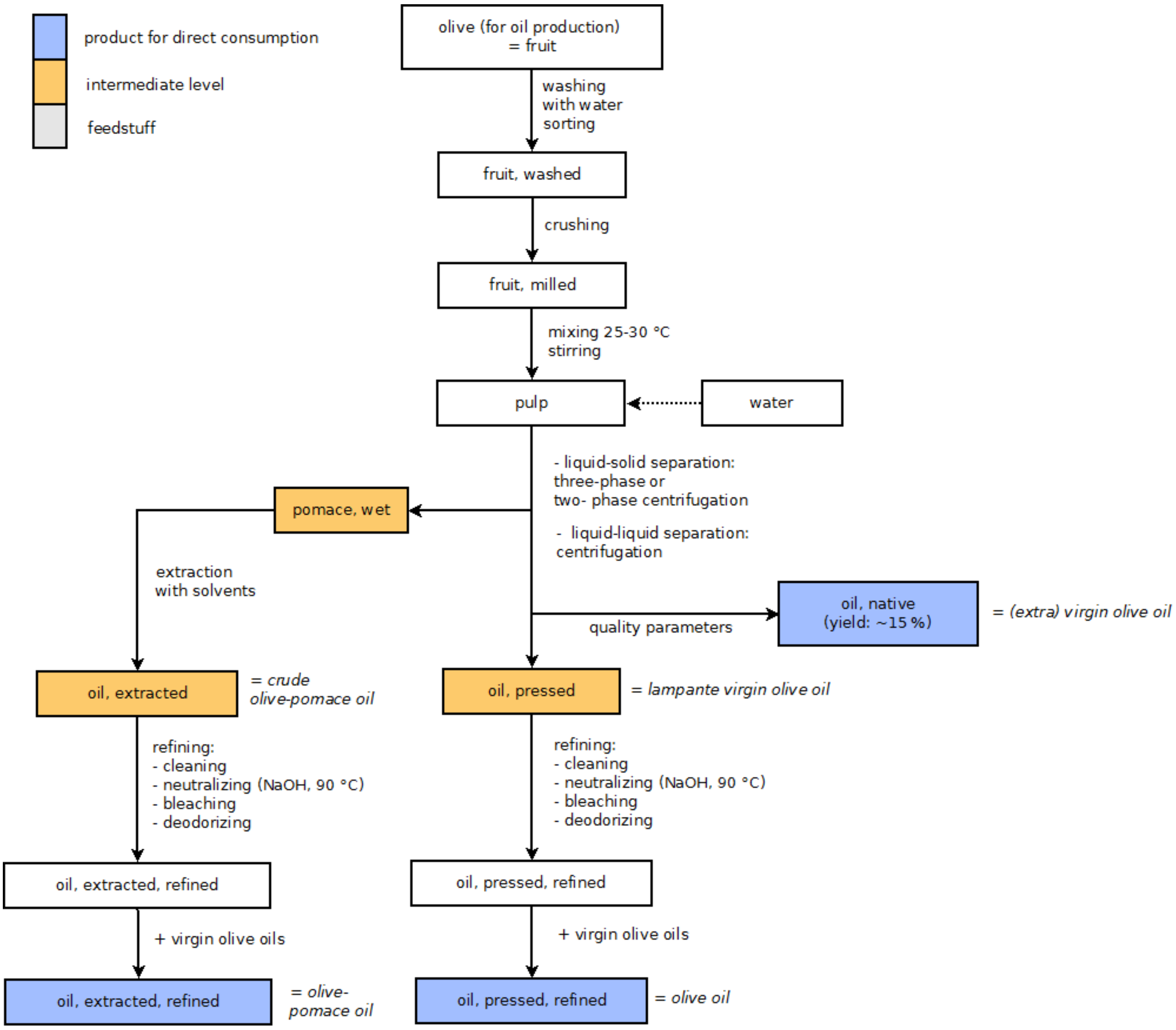
7.1.1. Processing details

For oil production the olives are harvested at an optimum maturity stage, when the fruit contains a maximum of oil and is coloured purple black. Five to ten litres of olive oil can be produced from 50-70 kg olives (Olea, online). The industrial procedure is described as reported in the literature by Hui et al. (2006); Sinha et al. (2011); Thomas et al. (2015) and is shown in Figure 33. Neither literature nor regulatory studies report pH data. The yield factor for olive oil is displayed in the figure.

Production of virgin olive oil proceeds via several steps: washing, crushing, mixing and separation. Especially separation of solid and liquid (water and oil) contents influences the pesticide residue. A reduction of levels of hydrophilic pesticides is possible. In contrast, lipophilic pesticides can accumulate in processed olive oil.

Some olive oils (lampante virgin olive oil or olive pomace-oil) need further refining to remove undesirable flavour and chemical compounds that might be toxic or affect the oil stability. The different oil types and their refining processes are described below.

The residue level of pesticides in refined oil is usually lower than in virgin olive oil.



The yield factor of olive oil depends on the olive variety, water status and ripeness of olives and ranges from 4 to 21%. For example the variety Manzanillo has an oil yield of 15% which is referenced in Vossen (online).

Figure 33: Processing of virgin olive oil and refined oil (X-001)

Leaf removal and washing

Cleaning systems are used to separate leaves and twigs by air. According to Regulation (EC) No 2018/62 the RAC is defined as whole fruit after removal of stems and soil. Other impurities may be removed by water.

Crushing

The olives are crushed (milled) and pressed into the olive pulp (in the literature also named "paste"). This releases oil droplets. Hamer type metallic crushers are mainly used.

Malaxation (thermo-mixing) and liquid-solid separation

The pulp is mixed at 25-30°C to improve the yield. The olive mash is stirred slowly and constantly for about 30 min. This maximises the amount of oil released from the vacuoles. Meanwhile the oil droplets agglomerate.

Prior to separation, water can be added to the paste to ease centrifugation (three-phase decanter). Modern centrifuges do not need additional water. For a high-quality olive oil the industrial production is performed without additional water (two-phase centrifugation). The common method for separating liquid (oil and remaining water from washing) and solid contents (skin, pulp and broken pits) is the two-phase centrifugation with a horizontal decanter. The available processing studies, which represent the common olive oil production, report an addition of water during mixing.

The remaining solid is called olive pomace and still contains a small amount of oil. The pomace can be further processed by extracting and refining into refined olive pomace oil. Finally a blend of this oil and virgin olive oil is made and used for human consumption. (Note: in trade this oil is still called olive pomace oil, not olive oil) (Thomas et al., 2015). The refining process is explained below.

Liquid-liquid separation

The oily liquid contains residual water and solids. The solids are separated with vibratory sieves or filters. The remaining oil-water mixture is separated by centrifugation. The resulting olive oil is produced and classified according to the oil quality into extra virgin olive oil and virgin olive oil. Both can be consolidated to native oil.

Lampante virgin olive oil is a virgin olive oil which is not directly used for human consumption, because of its physicochemical and sensorial properties and is therefore subjected to refining (Thomas et al., 2015).

Refining

To remove undesirable substances such as free fatty acids, phospholipids, coloured compounds and water (Antonopoulos et al., 2006) four refining steps are necessary: cleaning, neutralisation, bleaching and deodorising.

Lampante olive oil and crude olive-pomace oil do not fit for direct human consumption and must be refined to become edible. Undesired substances are removed by chemical or physical refining processes (Peri, 2014).

Cleaning step: First the lampante oil is gravity settled and filtered.

Chemical refining: To eliminate undesired substances sodium (commonly used), potassium or calcium hydroxide is added to the oil at a temperature of 65-90°C (Peri, 2014). The chemical neutralisation forms soaps in water. By centrifugation a soapstock (soap and water soluble substances) is produced.

Olive-pomace oil requires a crystallization step (winterisation) by cooling down the oil to 5-8°C to eliminated compounds such as waxes or saturated triglycerides.

During the next step 0.5-1.5% bleaching earth (activated adsorbent) is added to remove colouring from the oil. For bleaching different temperature ranges are reported: 60-90°C (Bandioli, 2006) and 90-110°C for 20-30 min (Peri, 2014) under vacuum. The decolourised oil is filtered. Last step of refining is the deodorisation of the bleached oil. For this purpose the off-odours are removed by steam treatment under vacuum conditions (220-230°C for 60 min) (Peri, 2014).

Physical refining: The process is similar to chemical refining, but without the chemical neutralisation step. Pre-treatment can be conducted with mineral acids to remove impurities. The bleaching step is equal to chemical refining. The fatty acids and other volatile substances are removed by steam distillation (stripping) at high temperatures (240-250°C) and low pressure (deodorising) (Peri, 2014).

Pesticide levels can be reduced by chemical as well as physical refining (temperatures up to 240°C).

7.1.2. By-products of olive oil production

During extraction olive pomace (press cake) is produced, which still contains oil. Olive pomace can be treated with solvents or be centrifuged a second time to produce crude olive-pomace oil and refined olive-pomace oil. The pomace is not used for animal feeding (OECD, 2013).

7.1.3. Scientific studies reflecting typical processing operations

The study of Anderson (2006) was chosen as representative for the process of virgin olive oil and refined oil production. It is acceptable according to the quality criteria and is referenced by EFSA (2015f) in a Reasoned Opinion.

The processing of virgin olive oil started with washing of whole olives and milling in an Abencor Analyser Mill. The pulp was placed in jars and mixed with Abencor Thermomalaxer for approximately 30 min at 25°C. After 20 min boiling water was added. To separate liquid from solid contents the mixture was centrifuged. Finally the floating oil was filtered to produce virgin olive oil. In the database of processing factors, pressed olive oils of this type are reported as "native oils".

Furthermore the unfiltered oil was refined. For this purpose sodium hydroxide solution was added and heated for 30 min at 60-70°C. The processed soap and oil was separated by decanting and oil was finally filtered. Water was not added before separating the liquid-solid fractions.

In the available processing studies the procedure of refining is explained as follows: The unfiltered raw oil (from virgin oil process) is mixed with sodium hydroxide solution and heated to 60-70°C for 30 min. Soap and oil is separated by decanting and oil is finally filtered. The refining process is more diverse under industrial conditions than under laboratory conditions, where the bleaching and deodorisation steps are not performed.

7.1.4. Extrapolation to other commodities

No extrapolation is proposed. Even an extrapolation to palm oil is not possible due to differences in processing.

7.1.5. Comparison to industrial and/or household processing techniques

The representative processing study selected for olive oil production represents industrial up-to-date technology (see Figure 33) except for not conducting all industrial refining steps.

Traditional (domestic) olive oil production in Southern Europe is in principle comparable to the described industrial process, but is less mechanised. Therefore the yield is higher. The industrial process is considered as the worst case and the most relevant process.

7.2. Maize oil

Maize grain contains about 3 to 5% oil, of which 80% is located in the germ and 20% in the endosperm. The maize germ itself contains 40% oil (Fediol, 2018). The extraction is carried out either by pressing or by chemical extraction with solvents. Extracted or refined oil is colourless, odorless and tasteless. The yellowish colour is achieved by the addition of beta-carotene. In order to be used as edible oil, maize oil must first be dewaxed. Its main use is in cooking, where its high smoke point makes refined corn oil a valuable frying oil. It is also a key ingredient in margarine.

One liter of maize oil is made from 100 kg of maize. The global maize oil production is mainly located in North and South America, while only about 10% is produced in Europe (Thomas et al., 2015).

7.2.1. Processing details

The germs can be separated by dry or wet processing: wet milling and dry milling. Dry milling produces maize flour, grits and oil. Wet milling produces starch, starch hydrolysates and oil. Both methods also provide by-products which are used as animal feed. Wet processing tends to be preferred due to higher oil yields. The cleaned grain is first conditioned by steeping in warm water and is then milled and slurried with water. The germs are collected by flotation, washed, and dried. In dry processing, the grain is separated into germ and endosperm fractions by screening. The oil is isolated from the germs by pre-expelling followed by solvent extraction with hexane. In the following, more detailed information on dry and wet maize processing is given.

7.2.1.1. Dry milling procedure

Figure 34 shows the representative processing of maize grain to oil by a dry milling procedure.

Cleaning

The moisture content of the grain is adjusted to 10-15% by drying in an oven at 55-70°C, if the moisture content of the raw commodity is greater than 15%. Following drying, grains are cleaned by aspiration and screening. Light impurities are separated from the maize grain by using an aspirator. After aspiration, the grain is screened to separate large and small screenings from the maize grain.

Dry milling: Separation of germs

The cleaned grain is moisture conditioned to ~ 20% and tempered for approximately 2 h. After tempering, the grains are milled to crack the kernels. Maize stocks from the mill are dried in an oven for 30 min at 55-70°C, and are further screened to separate germs, bran, and large grits from small and medium grits, meals and flour.

The material mixture of bran, germ and large grits is aspirated to remove bran from the germ, germ with attached hull and endosperm, and large grits. This step is repeated to reduce the amount of endosperm and bran in the germ fraction.

Oil recovery

There are two ways to obtain crude oil: Direct solvent extraction and pre-press-solvent extraction as a combined procedure of screw pressing and solvent extraction (Hamilton and Crossley, 2004).

Direct extraction is followed by flaking. The crushed, conditioned germs are placed on flaking rollers and formed into small platelets. This increases the surface area considerably and the solvent can act better (Heiss, 2004). Germ material is heated to 70-80°C for 10 min and is further flaked. Germ flakes are submerged in warm hexane (50-60°C). After 30 min, the miscella, a mixture of crude oil and hexane, is drained and fresh hexane is added to repeat the cycle two more times. Miscella is passed through a vacuum evaporator to separate the crude oil from the hexane. The crude oil is heated to 90-120°C for hexane removal. It is then filtered and collected for further refining.

The pre-press solvent extraction combines the mechanical pressing and the solvent extraction. First, the germ is conditioned by adjusting the moisture content to 12%. The germ material is heated to 90-100°C for 30 min and passed through an expeller to mechanically remove the crude oil. The resulting fractions are crude oil and pressed cake. The residual oil in the pressed cake is extracted with the solvent hexane at temperatures around 55°C. After 30 min the solvent is drained and fresh hexane is added to repeat the cycle two more times. The miscella is passed through a vacuum evaporator for removal of hexane residues. The expelled and solvent extracted crude oil fractions are combined for further refining.

Refining

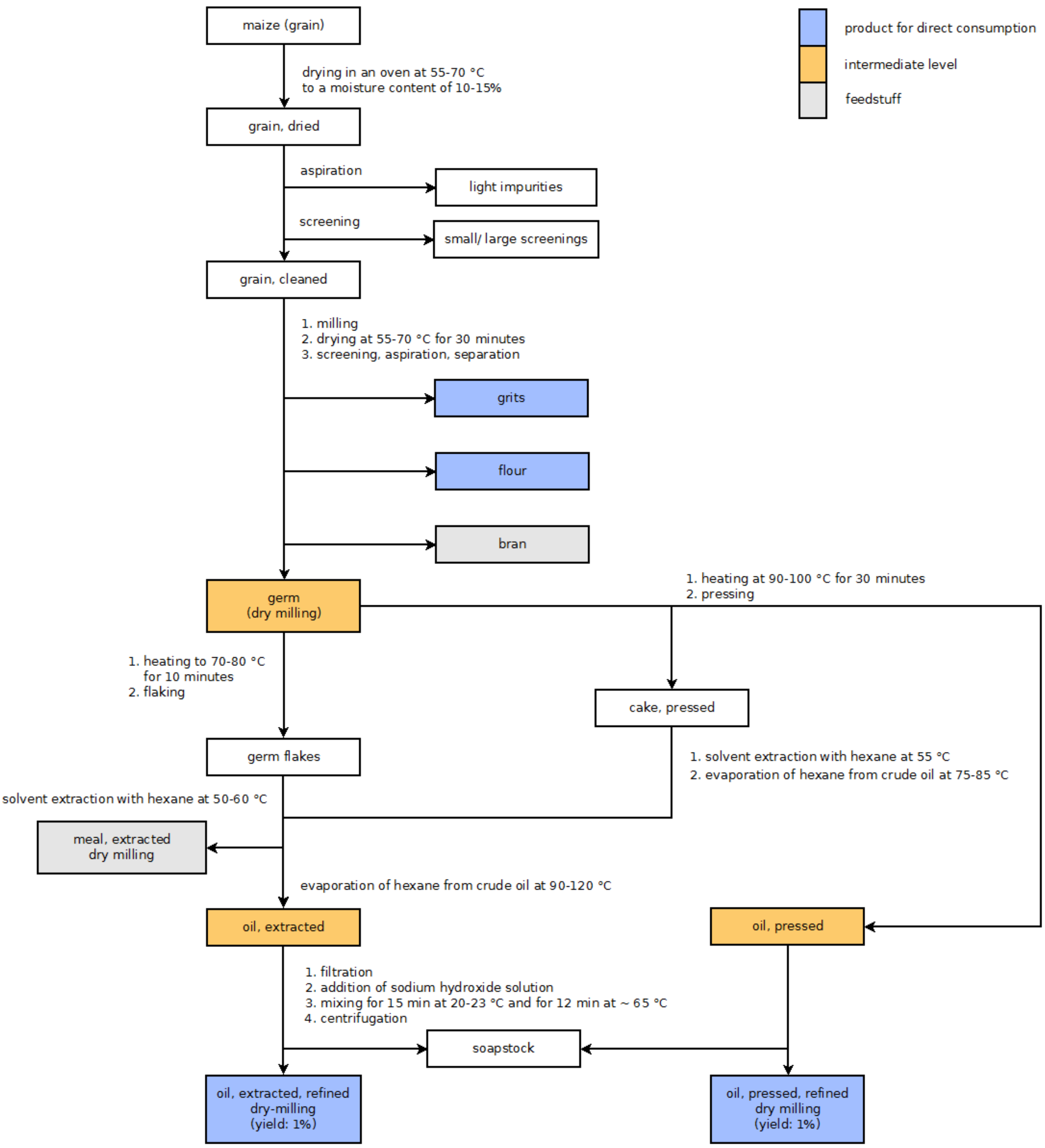
Crude oils contain various natural impurities, which give an unpleasant flavour and colour to the oil. The content of free fatty acids can cause spoilage, which prevents storage or further processing steps. Therefore, the crude oils must be refined prior to consumption. Refining includes the following main steps (Hamilton and Crossley, 2004):

- Neutralisation with sodium hydroxide
- Bleaching with bleaching earth/Fuller’s earth
- Deodorising with water steam at high temperatures

Crude oil and sodium hydroxide solution are mixed for 15 min at room temperature and subsequently for 12 min at ~ 65°C. The neutralised oil can be either refrigerated overnight or centrifuged, and finally decanted and filtrated. Resulting fractions are refined oil and soapstock.

In the United States the term ‘refining’ tends to be used for the removal of free acids (neutralisation), while in Europe it is applied to the whole series of processes including neutralisation, bleaching and deodorising (Gunstone, 2008).

Oil is heated to 40-50°C and activated bleaching earth is added (1.0% by weight of oil), and placed under vacuum. Temperature is increased to 85-100°C for 10 to 15 min. After reducing the temperature, the bleached oil is filtered. To obtain deodorised oil, bleached oil is steam bathed for 30 min under vacuum and temperature is held at 220-230°C. During the cooling period a 0.5‰ citric acid solution is added.

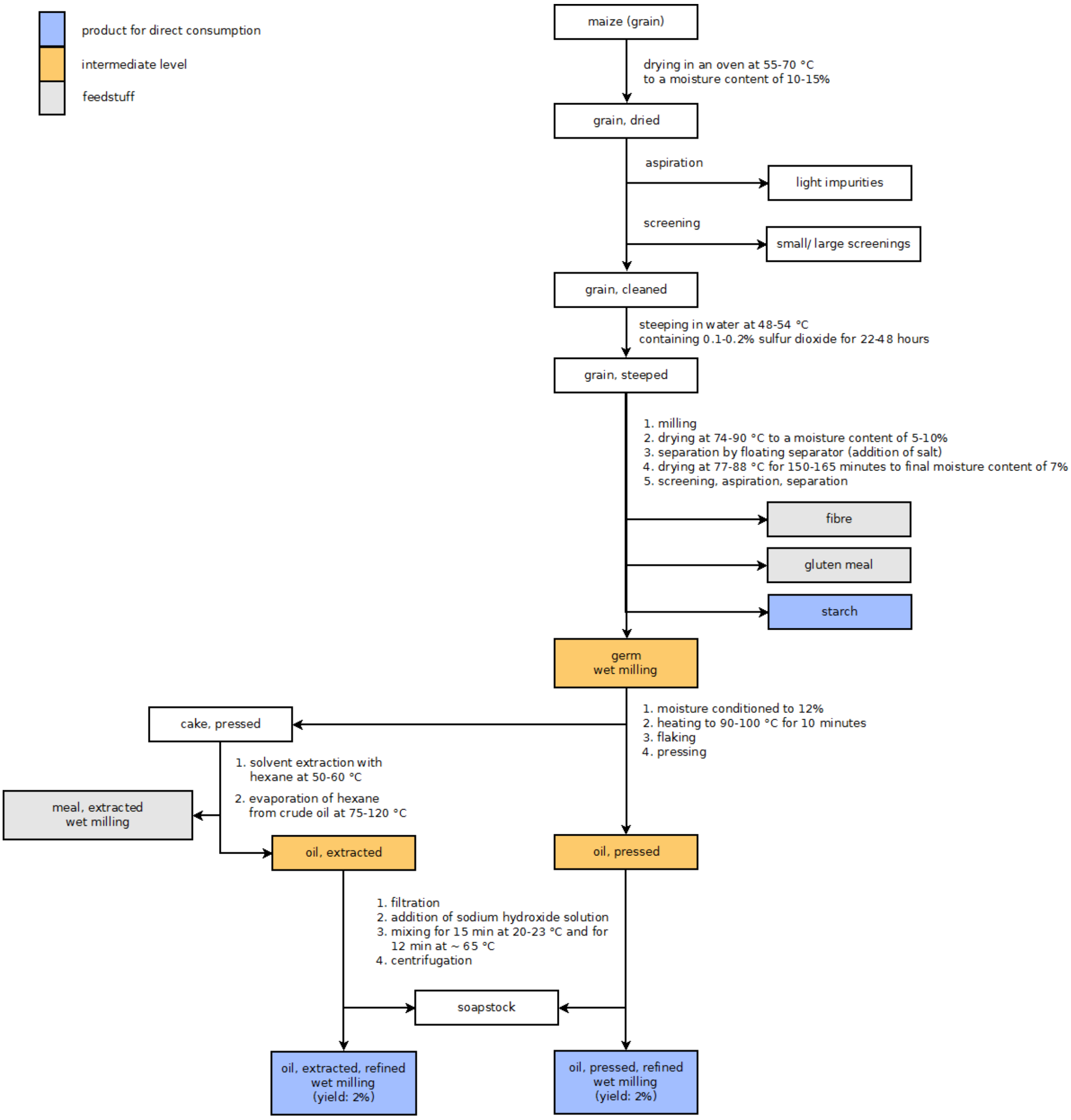


A yield factor for oil is referenced in Inglett (1970).

Figure 34: Processing of maize to oil following the dry milling procedure (X-002)

7.2.1.2. Wet milling procedure

The wet-milling process is graphically represented in the following flowchart (Figure 35). Partially, the processing steps are similar to the dry milling process. This concerns both the cleaning of maize grain and the refining of crude oil. The term 'wet milling' originates from conditioning of the grain by steeping in water prior to crushing and separating of the germ. In particular, the range of by-products differs between the two processes: Gluten and starch are obtained from wet milling processes, while maize flour and grits are obtained from dry milling.



A yield factor for oil is referenced in Singh et al. (2001).

Figure 35: Processing of maize to oil following the wet milling procedure (X-006)

Cleaning

The cleaning of the grain is similar to the process described for dry milling in chapter 7.2.1.1.

Wet milling: Separation of germs

The cleaned grain is steeped in warm water containing 0.1-0.2% sulphur dioxide at around 50°C for 22-48 h. At the end of the steeping period, the whole grain is milled and the majority of the germs and hulls are removed by centrifugation. Germs and hulls are dried at 77-88°C to reduce moisture to a content of 5 to 10%. After drying, germs and hulls are separated using aspiration and screening (Corn Refiners Association, online).

Oil recovery

Germs are moisture conditioned to 12%, heated to 90-100°C, flaked and pressed in an expeller to liberate part of the crude oil. Resulting matrices are expelled crude oil and pressed cake. The residual oil in the pressed cake is extracted with the solvent hexane at temperatures of 50-60°C. After 30 min the solvent is drained and fresh hexane is added to repeat the cycle two more times. The miscella is passed through a vacuum evaporator for removal of hexane residues at 75-120°C. The expelled and solvent extracted crude oil fractions are combined for further refining (Corn Refiners Association, online).

Refining

The refining of the combined crude oil fractions is similar to the process described for dry milling in chapter 7.2.1.1.

7.2.2. By-products of maize oil production

Other products of maize processing, which can be used by consumers, depend on the type of crude oil recovery. In the dry milling process, grits, maize flour and bran are obtained. Detailed processing is described in chapter 10.4. Contrary to the products of dry milling, fibre, gluten and starch are produced during the wet milling process. Wet milling of maize is described in chapter 11.1.

7.2.3. Scientific studies reflecting typical processing operations

Two studies were selected as representative. They have been carried out in the United States, but no differences are expected compared to European oil production. Both studies present the wet milling and the dry milling procedure.

The study of Johnston and Saha (2009) reports the cleaning of maize grains as a preliminary step before dry or wet milling processes are conducted. Procedures are comparable to the representative process displayed in the flowcharts on maize oil production. During the dry milling process, cleaned grains were conditioned to a moisture content of 21% and tempered for 2 h. After tempering, conditioned grains were cracked and dried at 55-70°C for 30 min. Dried maize stock was milled and screened to obtain bran, germs and large grits, as well as small and medium grits, meal and flour. For oil production, germs were heated to 70-80°C for 10 min and flaked in a flaking roll. Flakes were submerged in hexane at 50-60°C. The extraction cycle was repeated twice. The solvent extracted crude oil was further refined by neutralisation with sodium hydroxide, bleaching with bleaching earth and deodorising at high temperatures, comparable to the representative process.

During the wet milling process, dried and cleaned grains were steeped in warm water (50-55°C) containing sulphur dioxide for 22 to 48 h. Subsequently, conditioned grains were milled and separated into germs and hulls, fibre, gluten and starch using a water centrifuge. After conditioning to a moisture content of 12%, germs were heated at 95-105°C, flaked and pressed in an expeller to release crude oil and pressed cake. Pressed cake with residual crude oil was solvent extracted with hexane at 50-60°C. The extraction cycle was repeated twice. Finally, pressed and extracted crude oil fractions were combined and further refined analogous to the dry milling process.

The study of Johnston and Saha (2009) is referenced by EFSA (2016d) in a Reasoned Opinion and is acceptable according to the quality criteria.

The study of Grant and Francis (1991) differs in the description of the dry milling process. Grains were cleaned by aspiration to remove light impurities. Germs were conditioned to a moisture content of 22%. After 2.5 h tempering period, the kernels were cracked. The maize stock was dried at 60-70°C for 30 min and further screened to obtain milled by-products and germs. The germ was moisture conditioned to 12%, heated at 88-99°C for 30 min and pressed to release crude oil and pressed cake with residual crude oil. The pressed cake was further extracted with hexane at 54-56°C to increase the crude oil yield.

The extraction cycle was repeated twice. Both, the expeller crude oil and the solvent extracted crude oil were combined and further refined by neutralisation, bleaching and deodorising. The wet milling procedure was comparable to the study report of (Johnston and Saha, 2009).

The study does not fulfil all quality criteria, namely residue levels were lower than the LOQ and the study was therefore not suitable for deriving processing factors. However, the method of production is sufficiently described so that the study was nevertheless chosen as representative. It is referenced in a Conclusion by EFSA (2014b).

7.2.4. Extrapolation to other commodities

Extrapolation is proposed to other oils derived from cereal germs, such as wheat germ oil.

Maize oil production from conditioned germ is comparable to the production of oil from oilseeds. However, preparation and conditioning are significantly different. In the refining of crude maize oil no degumming step is conducted as for oilseeds. Neutralisation, bleaching and deodorisation steps are comparable to the refining of oilseed crude oils.

7.2.5. Comparison to industrial and/or household processing techniques

The choice of the milling method depends primarily on the type of maize. Typically, softer varieties of maize are wet milled. Varieties with medium or hard endosperm are dry milled. In processing studies, one maize variety is often processed with both milling techniques. The described processing conditions in the studies comply with the typical industrial production of maize oil (Corn Refiners Association, online; Fediol, 2018).

No domestic processing of maize into maize oil is conducted.

7.3. Oil production from oilseeds

Oilseeds represent a large proportion of raw commodities used for edible oil production. In the following chapters, the processing of the most relevant commodities for oilseed oil production is described in detail.

7.3.1. Processing details

The processing of crude oil is comparable within the whole group of oilseeds. The described processing steps normally refer to the whole group and, in some cases deviations are pointed out. The flowchart (Figure 36) shows the processing of different oilseeds to crude oil. Refining of the crude oil is comparable for all oilseeds and is illustrated in Figure 37. Both flowcharts in combination represent the complete oil extraction process. Yields are indicated in the flowchart for refined oil.

Preparation before processing: Cleaning and conditioning

The moisture content for all oilseeds except cotton seed is adjusted to 7 to 12% by oven drying at 55 to 70°C. Following drying, seeds are cleaned by aspiration and screening. Light impurities and screenings are separated from cleaned seeds.

With the exception of rape seed, all cleaned seeds or kernels are surrounded by hulls, which have to be broken mechanically. Dehulling is a principal processing step to increase protein content in the meal after extraction. The hulls are separated from the kernels, which are subjected to further processing either by direct pressing to obtain native oil or by conditioning for an increased oil yield using subsequent hot pressing and/or solvent extraction procedures.

In the flaking step, seeds are flattened by flaking rolls to destroy oil containing cells and to increase the oil yield. This is an especially important step for soya beans and rape seed. Flaking is followed by conditioning by indirect heating at 100°C for 30 min, facilitating the pressing and oil recovery. Cotton seed is not dried, but only delinted.

Cold pressing

Cleaned seeds are pressed directly at room temperature by an expeller. The obtained crude oil is then filtered. Oils being designated as native oils must not be extracted by solvents. Native oils are characterised by a nutty flavour and an intense yellow colour. They are of high quality and can be consumed directly. For cold pressed, native oils, the seed is pre-treated exclusively by mechanical methods. Post-treatment of the oil takes place only by decanting, filtering and/or centrifugation (DLMBK, 2011).

For use in stronger heat treatments such as frying or baking, native oil is not suitable, since free fatty acids can decompose. For such thermal applications, crude oils must be refined.

Press cake is a by-product of crude oil recovery by pressing. In order to increase the crude oil yield, the press cake can be further extracted with solvents, typically hexane. The extraction of the press cake is described in more detail in the following subsection.

Hot pressing

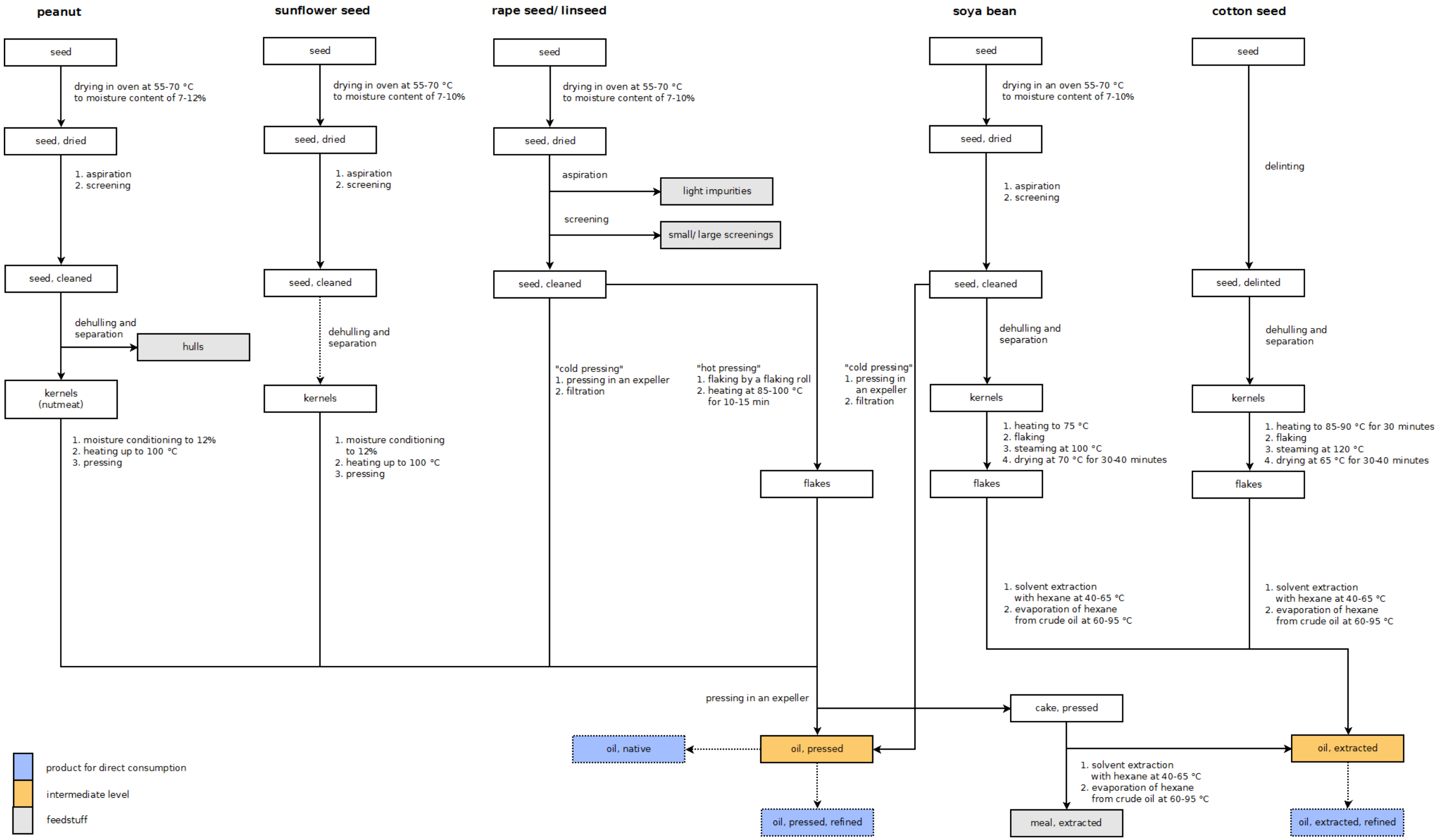
In the hot pressing process, flakes are pressed in a mechanical expeller after conditioning to obtain pressed crude oil. The fine seed particles are removed from crude oil by pre-screening filtration.

The press cake still contains 18-20% oil, which is recovered by solvent extraction. The expeller pressed cake is placed in an extractor and submerged in warm hexane (40 to 65°C) to obtain the residual crude oil from the pressed cake. After 30 min, the miscella (mixture of crude oil and solvent) is drained and fresh hexane is added to repeat the extraction cycle two more times. After the final draining, the extracted pressed cake is desolventised by mixing and heating to temperatures of 60 to 100°C. Expeller and extracted crude oil fractions are combined for further refining.

Solvent extraction

The third way of crude oil recovery is the direct solvent extraction of conditioned flakes. The parameters are comparable to the solvent extraction of pressed cake. This procedure is mainly applied to soya beans and cotton seed.

To maximise the oil yield and process efficiency, the pressed cake or flakes and hexane are contacted in counter current way, spraying the solvent over the solid material. The miscella (mixture of oil and hexane) is desolventised in a multi-stage evaporator/stripper elevating the temperature from 60 to 100°C, obtaining the extracted oil. After final draining the solvent is removed from the deoiled material in separated or integrated desolventising, drying, and cooling systems, yielding the extracted meal. The pressed and extracted oils are blended for further refining or can be processed separately.



The processing sequence differs slightly by crop. The crude oil production can be carried out by means of direct pressing, by solvent extraction or by a combination of pressing and subsequent extraction of the pressed cake. Further processing to native and refined oils is reported in Figure 37.

Figure 36: Oil production for various oilseeds (X-003)

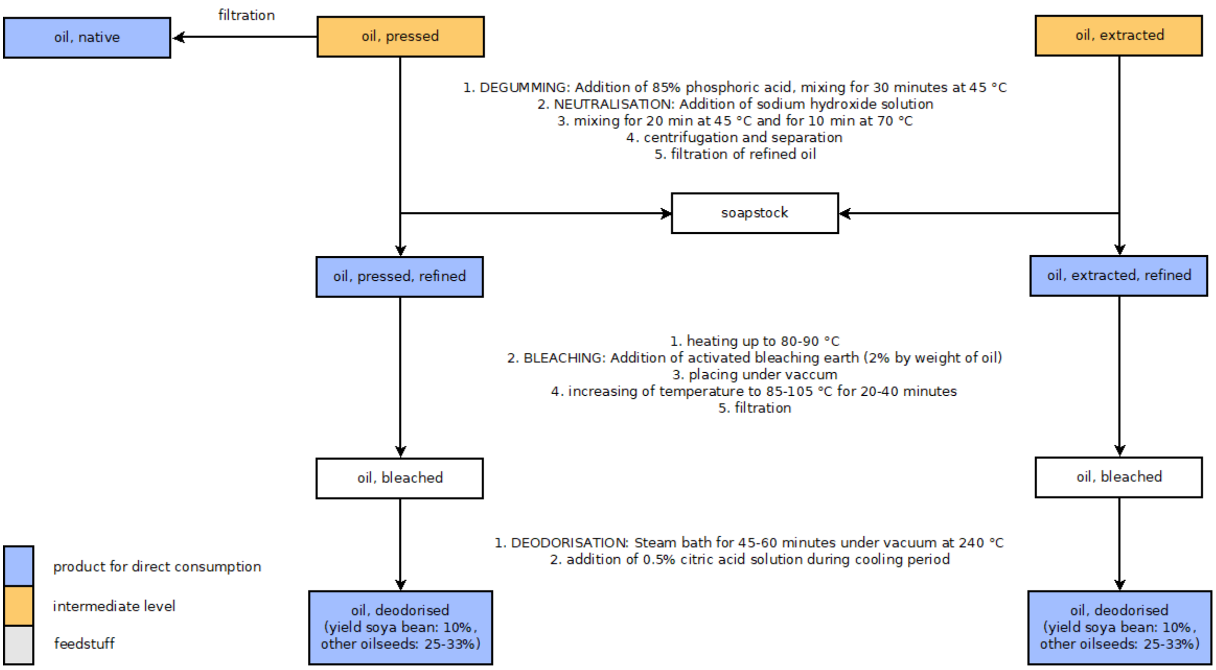
Refining

Crude oil can contain different natural impurities, which can lead to an unpleasant flavour and colour of oil. The content of free fatty acids can cause spoilage and decomposition, which hinders longer storage or the utilisation for heating processes. Therefore, crude oils are typically refined. Only native oils are passed on to consumers for direct consumption as filtered crude oils of highest quality.

The objective of refining processes is to obtain stable, transparent and clear oils with neutral taste and odour. Moreover, crude oils may contain external contaminants which have to be removed. The two principle processes differ in the way of free fatty acid removal. In the chemical refining they are removed by saponification with sodium hydroxide, while in the physical refining process they are evaporated in the deodorisation stage with the other volatile substances. Selection of the process type depends on the kind and quality of the crude oil. Seed oils are traditionally refined chemically. For fruit oils and more and more for seed oils as well the physical refinement is used (Fediol, 2018).

Refining of all kinds of crude oils obtained from different oilseeds includes nearly the same four main steps: Degumming, neutralisation, bleaching and deodorisation. Figure 37 shows the common refining processes for both pressed and extracted crude oils.

As already described in the chapter on maize oil, in the United States the term ‘refining’ tends to be used for the removal of free acids (neutralisation), while in Europe it is applied to the whole series of processes including degumming, neutralisation, bleaching and deodorisation (Gunstone, 2008).



Yield factors are referenced in (BLS, 2009; Thomas et al., 2015).

Figure 37: Refining procedure for crude oils made from various oilseeds (X-003)

Crude oil contains 200 – 800 mg/kg phosphor bound in phosphatides, which are optionally reduced by degumming prior to the other refining steps. Degumming consists of hydrating phosphatides with water at 70 to 90°C and separating so-called gums by centrifugation. Gums consist mainly of phosphatides, but can also contain entrained oil and meal particles. Lecithin for feed and food purposes can be obtained by drying the gums in film evaporators. Furthermore, crude oil is pre-treated with 85% phosphoric acid. After acid addition, oil is stirred for 20 to 40 min at 80 to 90°C. Following this process, sodium hydroxide solution is added, the amount of which is based on the content of free fatty acids in the crude oil. The mixture is blended for 20 min at 40 to 45°C and further for 10 min at 65 to 70°C. Neutralised oil is centrifuged to separate alkali refined oil and soapstock. Refined oil is filtered (Fediol, 2018).

During bleaching, the refined oil is heated to 40 to 50°C. Activated bleaching earth (2.0% per weight of oil) is added to the oil and the solution is placed under vacuum. Temperature is increased to 85-105°C for 20 to 30 min. After cooling, the bleached oil is filtered.

Sunflower oil contains waxes, which are removed in a separate step called winterization in order to improve the visual aspect of refined oil intended for bottling. The classical dry process includes crystallization of waxes when cooling the oil gradually to 6 to 10°C (for 4 to 12 hours) and filtering the formed crystals with the help of filter aid (Fediol, 2018).

Bleached oil is steam-bathed for 45 to 60 min under vacuum and temperature is hold between 220 and 240°C. During the cooling period, a 0.5‰ citric acid solution is added.

Yield factors for native and refined oils were not reported in comparison in scientific literature. Therefore reported factors do not distinguish between refined and native oils. The objective of refining is to remove impurities, like waxes, that should result in only a minor decrease of oil yields (Pal et al., 2015).

7.3.2. By-products of oil production from oilseeds

By-products from the cleaning procedure of soya bean seeds and cotton seeds are light impurities and screenings as well as hulls. These by-products can be used as feedstuffs (OECD, 2013). Furthermore, extracted meal, which is obtained by extraction of pressed cake of all oilseed varieties, is also used as feedstuff.

7.3.3. Scientific studies reflecting typical processing operations

Six studies were selected which are representative for oil production from different oilseeds. Some studies have been carried out in Europe, others in the United States. No differences are expected compared to European oil production.

The study of Thiel (2010) reports on drying rape seed samples at 55-70°C to a moisture content of 7-10%, followed by cleaning and by flaking in a flaking roll. Flakes were heated at 85-100°C for 10-15 min and pressed according to the so called hot pressing procedure. Obtained fractions were (expelled) crude oil and pressed cake, which was further extracted with hexane to increase the crude oil yield. The expelled and extracted crude oil fractions were combined and refined by degumming through addition of phosphoric acid, neutralisation with sodium hydroxide, bleaching, and final deodorisation. The study is referenced by EFSA (2016b) in a Conclusion and is acceptable according to the quality criteria.

The study of Renner (2005) described a different process of crude oil recovery. Cleaned seeds were directly pressed in an expeller according to the cold pressing procedure. The pressed crude oil was filtered. The pressed cake was further extracted with hexane to increase the crude oil recovery. Both, the expeller crude oil and the solvent extracted crude oil were combined and further refined by degumming, neutralisation, bleaching and deodorisation. The refining procedure was comparable to the study of (Thiel, 2010). The study is acceptable according to the quality criteria. It is referenced by EFSA (2015g) in a Reasoned Opinion according to Article 12.

The study of Thiel (2009) reports on the processing of peanuts into refined peanut oil. Peanuts were dried to a moisture content of 7-10% at 55-70°C, cleaned and dehulled, then moisture conditioned to 12%, heated to 85-95°C and pressed. The resulting pressed cake was further solvent extracted with hexane at 60-70°C. The extraction cycle was repeated twice. Crude oil was heated to 90-95°C for hexane removal. Crude oil fractions from pressing by an expeller and solvent extraction were combined, filtered and finally refined by neutralisation. The study is acceptable according to the quality criteria. It is referenced by EFSA (2012d) in a Reasoned Opinion according to Article 10.

Sunflower oil production was reported by Lenz (2008). Seeds were dried to a moisture content of 7-10% at 55-70°C. Cleaned seeds were dehulled and subsequently moisture conditioned to 12%. Further processing was made according to the representative process. The kernels were pressed in an expeller. Obtained fractions were pressed crude oil and pressed cake, which was further extracted with hexane to remove the residual crude oil. Both crude oil fractions were combined and further refined by neutralisation, bleaching and deodorisation. The study is acceptable according to the quality criteria. It was not cited in any EFSA Conclusion or Reasoned Opinion, but was available from an authorisation procedure.

The study of Mäyer (2012c) reports on the processing of soya bean to soya oil. After drying to a moisture content of 13.5% and cleaning of the whole seed, kernels were separated by hulling. Kernel material is heated to 70-80°C and flaked in a flaking roll. Further processing was made according to the representative process: After flaking, crude oil was recovered by solvent extraction. Furthermore, the crude oil was refined by neutralisation, bleaching and finally deodorisation. The study is acceptable according to the quality criteria. It is cited by EFSA (2015b) in a Conclusion.

The study of Mäyer (2012a) reports on the processing of cotton seed to refined oil. Cotton seed was delinted to remove most remaining lints and produce delinted cotton seed with approximately 3% lint remaining on the seed. Delinted seeds were hulled and the obtained kernels conditioned to a moisture content of 12-13.5%, heated at 80-90°C and flaked. Further processing was made according to the representative process: After flaking, solvent extraction was employed to recover the crude oil, which was then refined. The study is acceptable according to the quality criteria. It is cited in a Conclusion by EFSA (2015b).

7.3.4. Extrapolation to other commodities

In general, an extrapolation of results can be recommended within the oilseeds group.

Differences only concern the preparation and conditioning of the seeds, while the oil production by direct pressing, direct extraction with hexane or a combination of both is used for all oilseeds. The refining of crude oils is also following the same process sequence for all oilseeds.

The production of grape seed oil is comparable to the extraction of oil from oilseeds. Grape seed oil can also be obtained by cold or hot pressing. It is available for consumption both as native and refined oil. An extrapolation can therefore be recommended from grape seeds to oilseeds for oil extraction.

7.3.5. Comparison to industrial and/or household processing techniques

Available processing studies adequately reflect the industrial oil production from oilseeds. Drying temperatures and durations sometimes varied. For example, peanuts are normally dried industrially at lower temperatures (approximately 40°C (Hamilton and Crossley, 2004)). Processing studies report on drying temperatures around 70°C.

Processing of oilseeds into oil is not a common domestic process.

7.4. Essential oils

Essential oils occur mainly in plants in oil cells, secretory ducts or cavities, or glandular hairs. Because of their liquid nature at room temperature, essential oils are called oils. However, they should not be mixed up with "fixed oils". Fixed or fatty oils comprise naturally occurring non-volatile lipids and their esters. Essential oils are produced from dried or fresh plant materials by distillation. Citrus oils are the only essential oils obtained by cold pressing.

Three techniques of distillation are used for recovery of essential oils (except citrus oils):

- *Water distillation (hydrodistillation):* This technique involves boiling plant material in water. Volatile essential oils co-evaporating with the water are trapped on the surface of a condenser and are collected as liquids in a collecting vessel. Because of their low water solubility, the essential oil phase can be easily separated from the water phase. Exemplary, rose oil is obtained by water distillation.
- *Steam distillation:* Plant materials are packed in a perforated basket or on a perforated plate within a closed vessel, and steam, which is generated outside, is fed from the bottom into the vessel. Steam carries away the essential oils from the plant material. Condensing water and oil

is trapped and phases easily separate because of different densities. This is the distillation technique most favoured by industry for the production of essential oils.

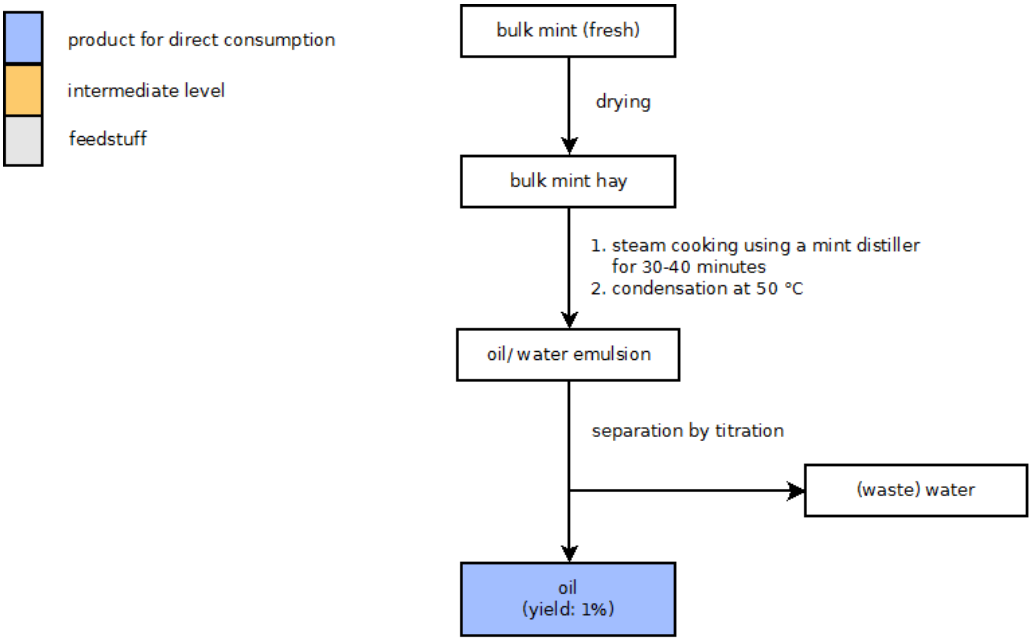
- *Water and steam distillation:* This technique is similar to steam distillation except for the fact that steam is generated at the bottom of the vessel below the perforated plate. This technique is favoured by small scale "cottage" industry.

Essential oils are not consumed directly, but are used as flavour and fragrance ingredients in many foods, cosmetics, perfumery, pharmaceutical, chemical, and toiletry applications. Mint oils are generally used in toothpaste, mouthwash, or lozenges. Convenience foods and frozen foods are flavoured with essential oils or oleoresins. Prepared foods such as baked foods, snack foods, soft drinks, liquors, tobacco, sauces, gravies, soups or salad dressings contain essential oils.

7.4.1. Mint oil

Processing studies for mint oil production were not available to EFSA.

The mint extraction procedure by steam distillation includes steam cooking, condensation of steam and mint oil, and the separation of the mint oil from the condensed material.



The yield factor is referenced in Schmickl and Malle (online).

Figure 38: Processing of mint to mint oil (X-004)

In this separation process, the volatile constituents of the mint plant are propelled by steam. In a closed boiling vessel, the crushed plant material loosely sits on a grate. The water vapor produced by the steam generator passes through the boiling vessel and propels the mint oil from the plant. The oil-water mixture condenses in a cooled tube, and in a collecting container, the *Florentine pot*. The water-insoluble mint oil floats on top of the water phase due to its specific weight, and can be separated by gentle draining after water and oil phases have separated completely (Guenther, 2013; Waschkultur, online).

Water-soluble compounds remain in the aqueous phase, but lipophilic substances are expected to remain in the essential oil phase. However, reported processing factors for mint oil are very low (PF ≤ 0.01, irrespective of the solubility properties. Therefore, the expected residue of pesticides is difficult to estimate, due to the fact that in addition to fat solubility and volatilization properties, other parameters such as Henry's law volatility constant, or technical details, e.g. the amount of steam applied, influence the transfer of pesticides into essential mint oils (DVAI, 2018; VDC, 2018).

7.4.1.1. Scientific studies reflecting typical processing operations

The available study (Versoi and Abdel-Baky, 2001) reports on a processing trial conducted in the U.S. Mint hay was steam cooked in a peppermint still for approximately 30-40 minutes. The mixture of steam and oil was condensed and collected for further separation of mint oil from the aqueous fraction by titration.

The study is acceptable according to the quality criteria. It is not cited in any EFSA Conclusion or Reasoned Opinion, but was available from an authorisation procedure.

7.4.1.2. Extrapolation to other commodities

The production of mint oil corresponds to the general production of essential oils from herbs and flowers. Therefore, an extrapolation of mint oil to other essential oils made from herbs and flowers is appropriate. Extrapolation of mint oil to essential citrus oil is not recommended, because citrus oils are obtained by pressing of citrus peel and subsequent solvent extraction.

7.4.2. Citrus oil

The production of citrus oils differs fundamentally from the production of classical oilseed and oil fruit oils, but also from the production of other essential oils. The outer rind of the citrus peel called flavedo contains a large number of small oil sacs or vesicles. Peel oil is a valuable product that is further refined into many different chemical compounds like the terpene D-limonene. Uses range from flavouring foods and beverages to improving the effectiveness of biodegradable cleaning solutions (Kanegsberg and Kanegsberg, 2011).

The five main types of citrus from which peel oils are recovered are orange, grapefruit, tangerine/mandarin, lemon and lime.

7.4.2.1. Processing details

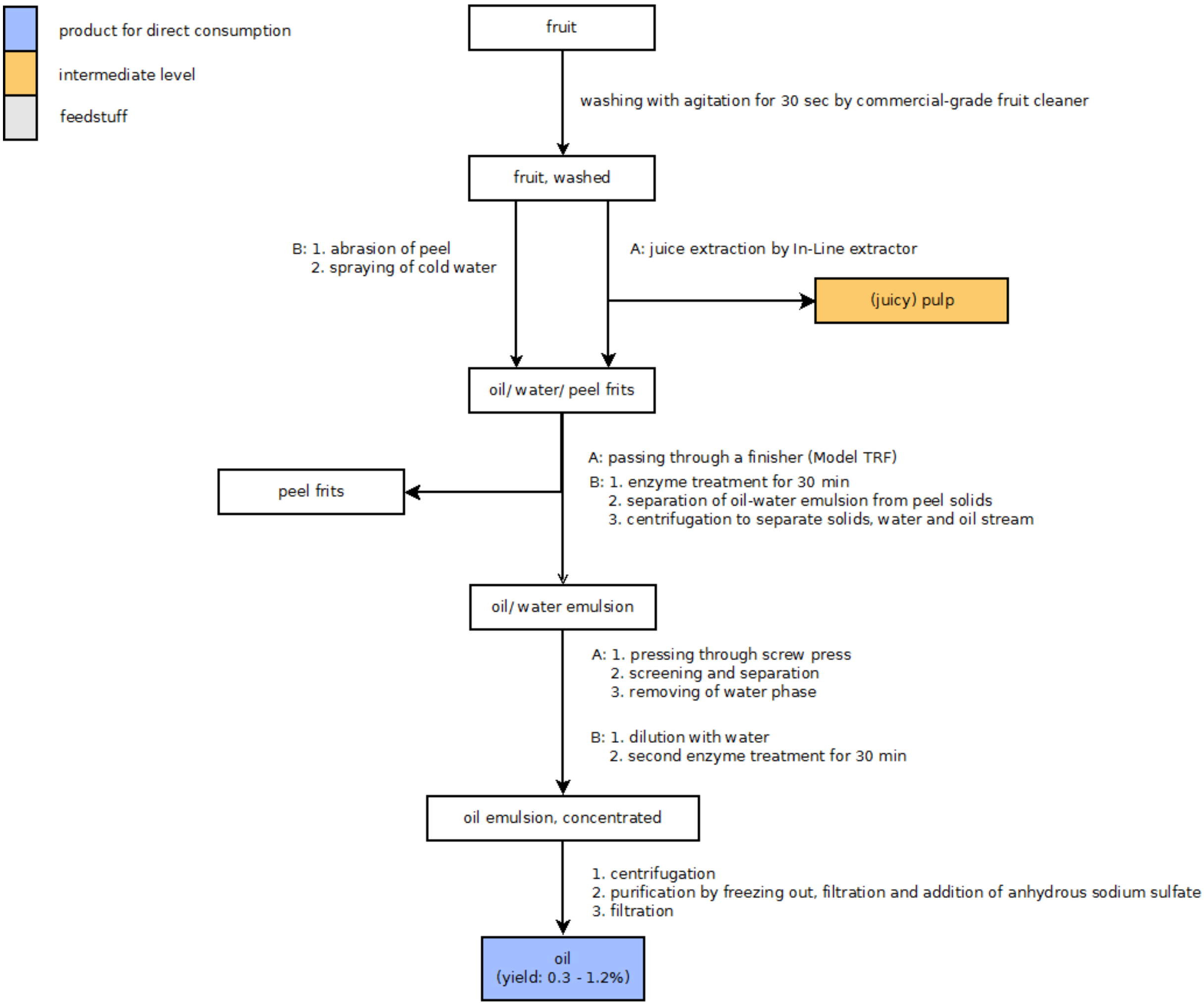
Peel oils are mechanically separated (cold-pressed) in order to retain volatile components. Three general commercial methods are described in literature, which are widely used in industry for extraction of crude oils from peel. These methods correspond to the extraction methods for the production of citrus juices as already described in chapter 4:

- Oil recovery from peel after juice extraction,
- Simultaneous extraction of a juice and oil emulsion from whole fruits,
- Recovery of oil from the peel flavedo after its removal from the whole fruit by abrasion or shaving (Shahidi and Zhong, 2012).

All processing studies on citrus oil production available to EFSA describe the combined extraction of a juice and oil emulsion by In-Line extractors. Another study is available from an authorisation procedure. It reports on the abrasion of the outer peel and subsequent oil extraction by enzymatic treatment.

Furthermore, small-scale production may be performed by hand-pressing. However, this does not represent a large-scale industrial process, so reference is made only to the two other methods. The following flowchart shows the representative process of citrus oil production.

Processing factors for citrus oils are often significantly > 1 indicating an enrichment of pesticides. This can be attributed to the higher residues often found in peel as compared to the fruit pulp of citrus fruits. Residues of fat-soluble pesticides are enriched in the oil vesicles.



A yield factor is referenced in JBT FoodTech (online). Lower yields are obtained by cold pressing while higher yields are obtained by enzymatic treatment.

Figure 39: Processing of citrus fruits to citrus oil (X-005)

Washing

The washing step is carried out in the same way as described in chapter 4.1 on juice production.

Recovery of oil-water emulsion

Two automated methods are commonly used in industry, which combine essential oil and juice extraction. In-Line extractors are described in all reports on citrus oil production available to EFSA. The recovery of the oil-water emulsion by Brown extractors is another method reported in further processing studies, which are available from authorisation procedures.

- *In-Line extractor:* The fruit is placed between two metal cups with sharpened metal tubes at their base. The upper cup descends and the fingers on each cup mesh to express the juice as the tubes cut holes in the top and bottom of the fruit. The fruit solids are compressed into the bottom tube between the two plugs of peel while the juice is forced out through perforations in the tube wall. At the same time, a water spray washes away the oil from the peel which is retained for later use (Heiss, 2004).
- *Brown extractor:* The peel is removed by an abrasion peeler just long enough to abrade the surface of the peel and to break the oil sacs. The abraded citrus fruits are collected and transferred to the actual juice extraction step by bisection of peeled fruits (Citrech Snc, online).

Peel frits and other solid ingredients which are still present in the oil-water emulsion after pressing the citrus peel are either directly filtered off or an enzymatic treatment of the emulsion induces a separation of the phases (oil, water and solids). The complex enzyme preparation contains mainly pectinases, arabinases, hemicellulases, and cellulases which increase the oil yield by separating the oil emulsion (Coll et al., 1996).

Oil extraction

The citrus oil is obtained after a further phase separation and subsequent freezing out of water residues. Anhydrous sodium sulfate (0.5%, w/w) is added to the oil to remove any traces of water left in the oil. After mixing several minutes, the oil is filtered again.

If essential citrus oils are obtained during juice production, distillative methods can be used. Lime oils are also partially recovered by steam distillation (DVAI, 2018; VDC, 2018).

7.4.2.2. By-products of citrus oil production

By-products from citrus oil production come from the peel and the pulp obtained from the combined oil and juice extraction systems. Products made with these materials include pectin for use in jellies, juices, marmalades, and candied peel.

The de-oiled fresh citrus peels are mostly used directly as cattle feed or are dried as a raw material for pectin recovery. Together with citrus oil normally citrus juice is produced. For detailed information on citrus juice production please refer to chapter 4.1.

7.4.2.3. Scientific studies reflecting typical processing operations

It is noted that the major part of citrus products consumed in the EU is imported from outside the EU. Studies describing oil recovery were therefore selected both from Europe and the U.S. Two studies were chosen as representative. They differ primarily in the type of oil-water emulsion recovery and oil extraction.

The study of Maloney (1994) includes washing with tap water (including detergent), pressing and extraction of the water-oil emulsion in a FMC machine without preliminary cutting of fruits into halves. The oil/water emulsion resulting from the extraction process was collected and water removed by decanting and finally freezing-out. After removing of water residues by addition of anhydrous sodium sulfate, the pure citrus oil was obtained. The study is acceptable according to the quality criteria. It is referenced by EFSA (2008) in a Conclusion.

This study of Krolski (2000) reports on a second method of peeling: removal of the peel by abrasion and pressing of the obtained peel frits to release a water-oil emulsion. After separation from solids an enzyme complex was added for an improved oil refinement. Subsequent centrifugation led to separation of oil, water and solids fractions. After freezing out and drying by addition of anhydrous sodium sulfate, the pure citrus oil was obtained.

The study is acceptable according to the quality criteria. It is not cited in any EFSA Conclusion or Reasoned Opinion, but was available from an authorisation procedure.

7.4.2.4. Extrapolation to other commodities

There is a great variety of citrus species: Tangerines/mandarins, grapefruit, lemons, limes and other exotic citrus fruits. Most of the processing operations described above for orange oil apply to the other citrus oils as well. Extrapolation is recommended within the whole citrus group. The extrapolation to or from oilseeds or oil fruits is not possible due to the different processes.

7.4.2.5. Comparison to industrial and/or household processing techniques

The representative processing studies selected for citrus oil production represent up-to-date technology in industry (JBT FoodTech, online). Regarding oil extraction by enzyme treatment essential oil producing companies inform that this type of pre-treatment is not commonly used and is not available on the German market (DVAI, 2018; VDC, 2018).

Domestic processing of citrus fruits into oil is of no relevance.

7.5. Palm oil and palm kernel oil

Palm oil is a vegetable oil processed from pulp of oil palm fruits. It consists of 50% saturated fatty acids, most of which are bound to palmitic acid. Additionally, palm kernel oil can be obtained from the kernels of the palm fruits. Palm kernel oil mainly contains lauric acid. Both oil types are used for food preparation, as additive in beauty products, as feedstuff, and as biofuel.

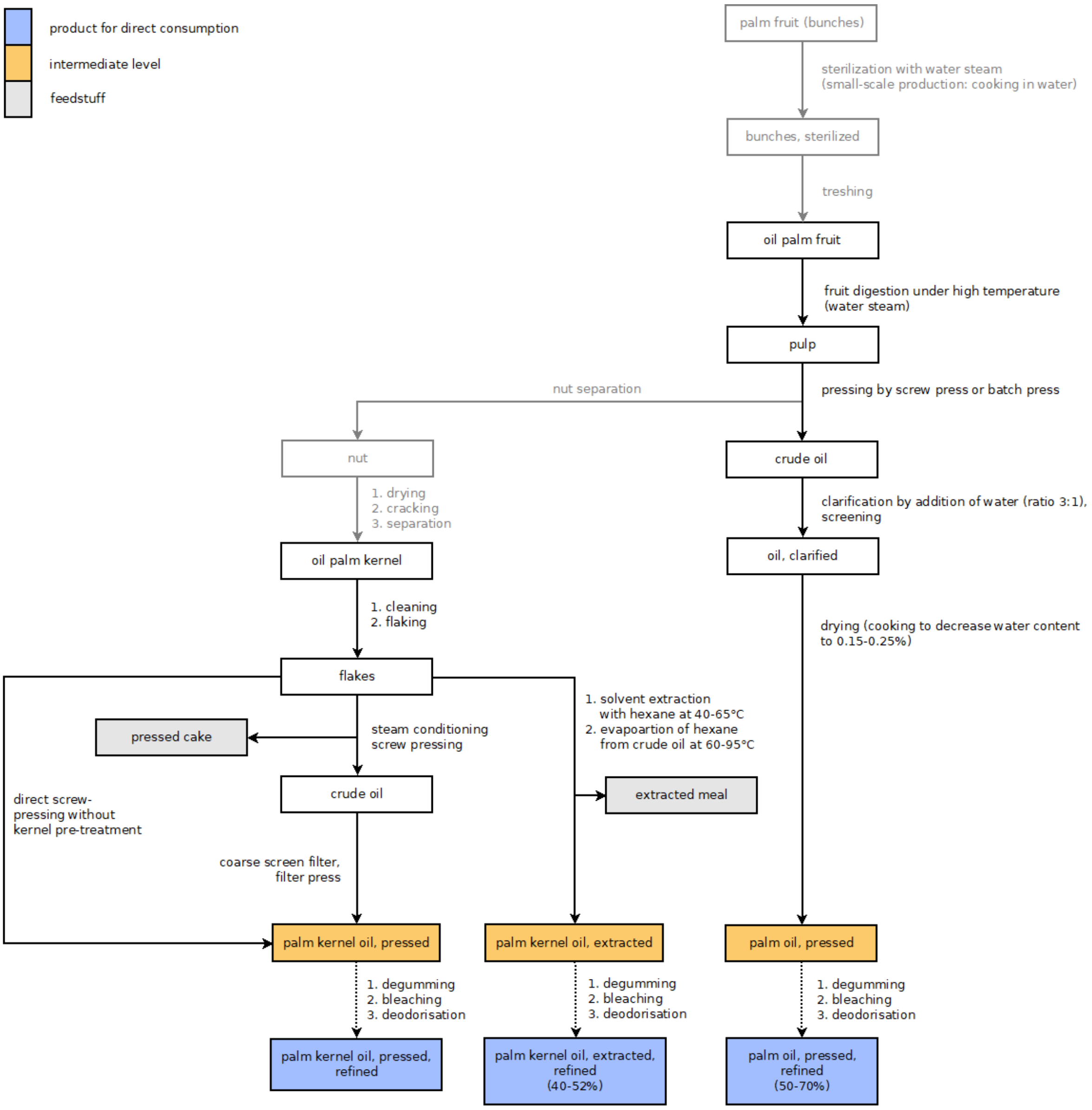
The fruits of the oil palm are arranged in bunches. The individual fruit consists of an outer skin (exocarp), the pulp (mesocarp), which contains the palm oil in a fibrous matrix, and a central nut consisting of a shell (endocarp) and the kernel from which palm kernel oil can be extracted. The kernel oil makes up about 10% of the total oil yield obtained from the palm fruit (Rimbach, 2015). To prevent the enzymatic decomposition of the fatty acids, the bunches are sterilised before processing. The pulp is pressed, whereby the nut is separated. After the oil has clarified, as much water as possible must be removed in order to prevent microbial processes. The nut itself is cracked, the kernel is separated and further processed into palm kernel oil (FAO, online-d).

There is no industrial processing of oil palm fruits in Europe. Palm oil and palm kernel oil are imported and processed further to food and cosmetic products.

7.5.1. Processing details

The production of oil from fruits of the oil palm can be performed in small-scale as well as large-scale processes. However, the majority of palm oil and palm kernel oil is produced in industry (large-scale). The focus of the following process descriptions is therefore on industrial production.

A flowchart of the production of palm oil and palm kernel oil is provided in Figure 31. The significant processing steps are explained below.



Yield factors are referenced in published literature (Frede, 2010).

Figure 40: Processing of oil palm fruits and oil palm kernels into oil (X-007).

Pre-treatment to obtain oil palm fruits (RAC)

Fruits of the oil palm are harvested in bunches. To prevent enzymatic decomposition of the fatty acids, the bunches are first sterilised under steam. This process has further advantages. The fruits separate more easily from the stems after the aqueous heat treatment. The oil-containing cells of the pulp are more easily broken down and the pulp is more easily detached from the nut. Water-soluble gums and resins are already separated.

Overall, it should be noted that the process takes place with the exclusion of air as far as possible in order to prevent oxidation of the oils.

The fruit is detached from the bunch with rotating drums or fixed drum equipped with rotary beater bars, leaving the spikelets on the stem (FAO, online-d).

Digestion

In palm oil production, digestion is the process in which the oil-containing cells are crushed or broken down to release the oil. Commonly, the digester consists of a steam-heated cylindrical vessel with rotating stirring arms. The fruits are mashed at high temperature. Thus, the viscosity of the oil is reduced and higher yields can be obtained (FAO, online-d).

Palm oil extraction

The oil is extracted from the broken cells by pressing. Depending on the volume of the processed fruits, batch presses (small-scale) or continuous systems (large-scale) are used. Screw presses are most commonly used. The fibres and the nut are separated. The nut can be further processed into palm kernel oil. This oil extraction is known as the 'dry method'. If the oil extraction takes place by adding hot water with which the oil leaches out, the process is specified as 'wet method' (FAO, online-d).

Clarification and drying

The crude oil consists of palm oil, water, cell debris, fibrous material and non-oily solids, which increase the viscosity of the mixture. Hot water is added in a ratio of 3:1. Furthermore, the addition of gums and resins under high temperatures facilitates the breaking of the emulsion. Non-oily solids fall down to the bottom of the container and the oil-water emulsion can be decanted. Subsequently, the diluted mixture is passed through a screen to remove fibrous material. The resulting oil-water emulsion is boiled for 1 to 2 hours and allowed to settle by gravity. Thus, the oil is located on the top of the vessel and can be separated from the water.

The clarified oil still contains traces of water, which can lead to an increased amount of free fatty acids caused by autocatalytic hydrolysis. Therefore, the moisture content of the oil must be reduced to 0.15 to 0.25% by re-heating the clarified oil and carefully skimming off the dried oil (FAO, online-d).

Separation of kernels

Nuts are separated from the pulp of the palm fruits as part of the press cake during the pressing process. The nuts are separated from fibres using a depericarper, and then dried. The kernels are cracked in centrifuge crackers and separated from their shells. Finally, the kernels are dried to a moisture content of 7% (FAO, online-d).

Kernel pre-treatment

Not all producers of palm kernel oil use the same procedure. Next to the complete pre-treatment (described in this subchapter), partially pre-treatment and direct screw pressing are possible production lines.

A pre-treatment of the kernels is necessary in order to extract the palm kernel oil efficiently. The kernels are cleaned and then mechanically broken into small fragments by swinging hammer grinders or breaker rolls (or a combination of both). The kernel fragments are flaked in a roller mill to a thickness of 0.25 to 0.4 mm. This progressive rolling initiates the rupture of the oil containing cells.

Subsequently, the flakes are steamed in a steam cooker. This intermediate step has several advantages: the meal gets an optimal moisture content so that it can be pressed efficiently; the cell walls are broken open optimally. The viscosity of the oil is reduced and the oil yield of the pressing process increases. In addition, proteins coagulate and can be separated from the crude oil obtained (FAO, online-d).

Extraction of palm kernel oil

The crude oil is obtained in a screw press. The de-oiled press cake is separated (FAO, online-d).

Oil clarification

Solid impurities have to be separated from the final oil. Therefore, the crude oil is passed through screens or pumped into a decanter (FAO, online-d).

Solvent extraction

The solvent extraction process uses hexane or other solvents to extract the oil from the prior processed flakes. This increases the yield significantly. For comparison, the oil content of the mechanically pressed cake is 5-12%, the press cake after solvent extraction contains only 0.5-3% oil (feedipedia, online). The procedure is comparable to the solvent extraction process for oil production from oil seeds. The press cake or flakes are brought into contact with hexane in a counter current process, whereby the solvent is sprayed over the solid material. The miscella (mixture of oil and hexane) is desolventised in a multi-stage evaporator/stripper elevating the temperature from 60 to nearly 100°C, obtaining the extracted oil. After final draining the solvent is removed from the de-oiled material in separated or integrated desolventising, drying, and cooling systems to yield the extracted meal. The pressed and extracted oils are blended for further refining or can be processed separately (FAO, online-d).

Refining

In order to obtain an edible product, raw palm oil or palm kernel oil must be processed further. Palm oil and palm kernel oil are refined to improve flavour, odour, colour and stability. For this purpose, processes like degumming, bleaching, deacidification, and deodorisation are applied to improve the oil. These procedures remove contaminants such as phosphatides, free fatty acids and pro-oxidants. The refining processes are also described in a comparable manner for maize and oilseeds. See chapter 7.2.1 and 7.3.1 for further information. The refining process takes place primarily in industrial scale processes (FAO, online-d).

7.5.2. By-products of oil production from oil palm fruits

Palm kernel meal (pressed cake) is the main by-product of the oil extraction process from palm kernels. It is commonly used as feedstuff. Further by-products are empty fruit bunches, nutshells and palm press fibres. Usually, these by-products are used to generate energy for steam generation during the sterilization of the palm fruit bunches. Oily residues of lower quality are used as bio fuel (feedipedia, online).

7.5.3. Scientific studies reflecting typical processing operations

There is only one study available, which describes the production of palm oil and palm kernel oil (Petrova, 2017).

The study was conducted in Malaysia. The palm fruit bunches were sterilised in an autoclave for approximately 20 minutes at 120°C and pressure of 0.14 MPa. The fruits were removed from the spikelets and immediately placed in a hydraulic hand press for extraction of the crude oil. The crude palm oil was then heated to 60°C to lower the viscosity, and decanted for removing solids and fibres. Finally, the clarified oil was passed through a filter paper containing anhydrous sodium sulphate to sufficiently remove water from the palm oil.

Before extracting the palm kernel oil, the fibres were removed by knife from the nut. After drying for 2 hours at 60°C, the nuts were cracked and the kernels separated from their shells. The kernels were crushed into smaller pieces and transferred into a Soxhlet extractor. The extraction of palm kernel crude oil was carried out with hexane. The organic solvent was removed by rotary evaporation.

The study is acceptable according to the quality criteria. It is referenced by EFSA in a Reasoned Opinion (EFSA, 2019).

7.5.4. Extrapolation to other commodities

No extrapolation to other commodities is recommended.

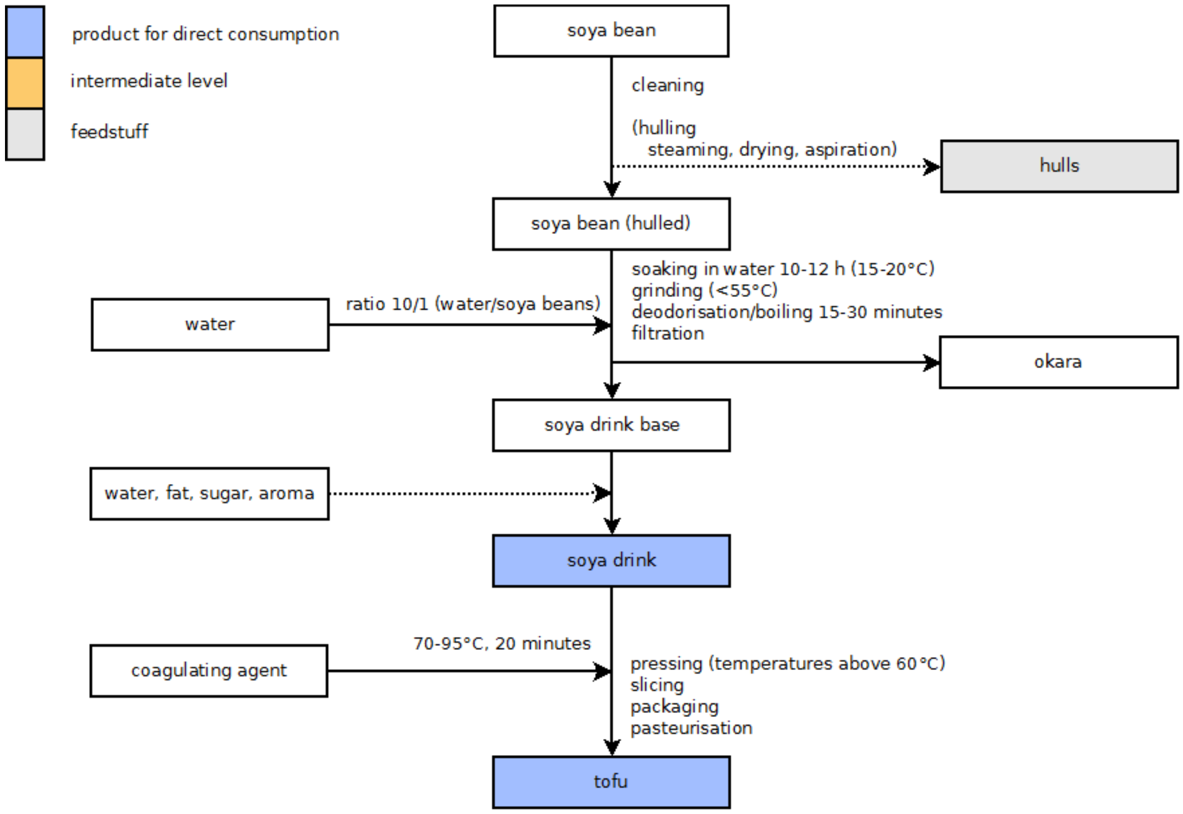
7.5.5. Comparison to industrial and/or household processing techniques

The production of palm oil and palm kernel oil is not a common household process in Europe. The production of palm oil and palm kernel oil is typically an industrial process. Small-scale procedures do not differ fundamentally from large-scale industrial production.

8. Soya drink and tofu production

Soya drink is an aqueous extract from soya beans. Tofu is made by coagulating soya drink and pressing the resulting curds. Both products are traditional foods in Asia. In non-Asian countries they are often used as an alternative to milk respectively meat.

8.1.1. Processing details



1 kg of soya beans typically yields 6.8-7.5 kg soya drink or 1.5-6.0 kg tofu, depending on the texture of the tofu (Erickson, 1995).

Figure 41: Processing of soya beans into soya drink and tofu (IX-006)

Cleaning and hulling

Soya beans are cleaned by aspiration to remove light impurities. Subsequently, the soya beans are screened to remove foreign particles. Hulling is an optional processing step and involves steaming, drying and aspiration. The advantage of hulling is a shorter soaking time in the following processing step.

Hydration and grinding

Cleaned soya beans, with or without hull, are soaked in water for 10 to 12 h. The soya bean to water ratio is 1:10. The soaked soya beans then undergo wet grinding.

Cooking/Deodorisation

The soya slurry is heated to temperatures around 100°C (boiling) or above (steam infusion) for 15 to 30 min to inactivate the trypsin inhibitors. This process is also called deodorisation because undesirable volatile off-flavours (beany flavour) are removed while heating.

Separation

The soya slurry is separated from any insoluble solids by filtration or centrifugation. The residue is called okara. Separation can be made before or after the cooking process.

The obtained soya drink base can either be processed to soya drink or to tofu. For soya drink, additional components are added to obtain the desired nutrient content (e.g. water, soya bean oil, sugar). Pasteurisation or sterilisation to extend shelf life is possible as well. For explanation of sterilisation and pasteurisation see introduction to chapter 3.

Coagulation

For tofu production, coagulating agents are added to the soya base. Possible coagulants are, among others, calcium sulfate, magnesium chloride or glucono delta-lactone. Coagulating time and temperature (usually between 70 and 95°C) depends on the used coagulating agent and the desired texture of the tofu.

After coagulating, the curds are pressed at temperatures above 60°C and are subsequently shaped. The obtained tofu is cooled in a refrigerated water bath. The finished tofu is packaged and subsequently pasteurised.

Different textures of tofu are distinguished. Soft tofu has higher water content than firm tofu and the texture is smoother. Firm tofu is pressed longer than soft tofu and the water content is lower.

Another tofu variety is silk tofu. Silk tofu is produced similarly to pressed tofu but the soya drink is coagulated without curdling the drink and the resulting tofu is not pressed. It has therefore a higher water content than pressed tofu.

8.1.2. By-products of soya drink and tofu production

The main by-product of soya drink and tofu manufacturing is okara. Okara is used in Japan as feedstuff (OECD, 2013), but is not relevant for feeding purposes in the EU.

8.1.3. Scientific studies reflecting typical processing operations

In several studies the term ‘soya milk’ was used instead of ‘soya drink’. The term ‘milk’ is defined in Regulation (EU) No 1308/2013[6] and in Europe it is not allowed to use the term for products of plant origin such as soya drink. Therefore, even when the term ‘soya milk’ was used in the studies it has been replaced by ‘soya drink’ in this document.

There is only one study available, which describes the processing of soya beans into soya drink and tofu (Mäyer, 2012c). The study is acceptable according to the quality criteria. It is referenced in a Conclusion (EFSA, 2015b).

The soya beans were cleaned by aspiration and screening. Cleaned soya beans were soaked in water for 12 h. Soaked beans were ground and subsequently filtered to separate the liquid (soya drink) from the solids (okara). Soya drink was then heated to 90-95°C for 9-11 min.

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[6] Regulation (EU) No 1308/2013 of the European Parliament and of the Council of 17 December 2013 establishing a common organisation of the markets in agricultural products and repealing Council Regulations (EEC) No 922/72, (EEC) No 234/79, (EC) No 1037/2001 and (EC) No 1234/2007. OJ L 347, 20.12.2013, p. 671–854

Tofu was produced by further processing of soya drink. The soya drink was heated to 75-85°C and mixed with a calcium sulfate solution. The soya drink coagulated and curd (tofu) was separated from the whey by centrifugation.

8.1.4. Extrapolation to other commodities

Extrapolation to other oilseeds is not recommended.

8.1.5. Comparison to industrial and/or household processing techniques

The processing in the available study reflects the industrial production of soya drink and tofu from soya beans. Domestic production of soya drink and tofu is of no relevance in the EU.

9. Beer brewing

Beer is an alcoholic beverage. Most commonly it is brewed with barley malt which is steeped in water and fermented with yeast, but other starch sources like wheat, rye, oats, millet, rice, maize or potatoes can be used as well. Hops are usually added in the brewing process to add bitterness and flavour. Beer brewing consists of a multitude of processing steps.

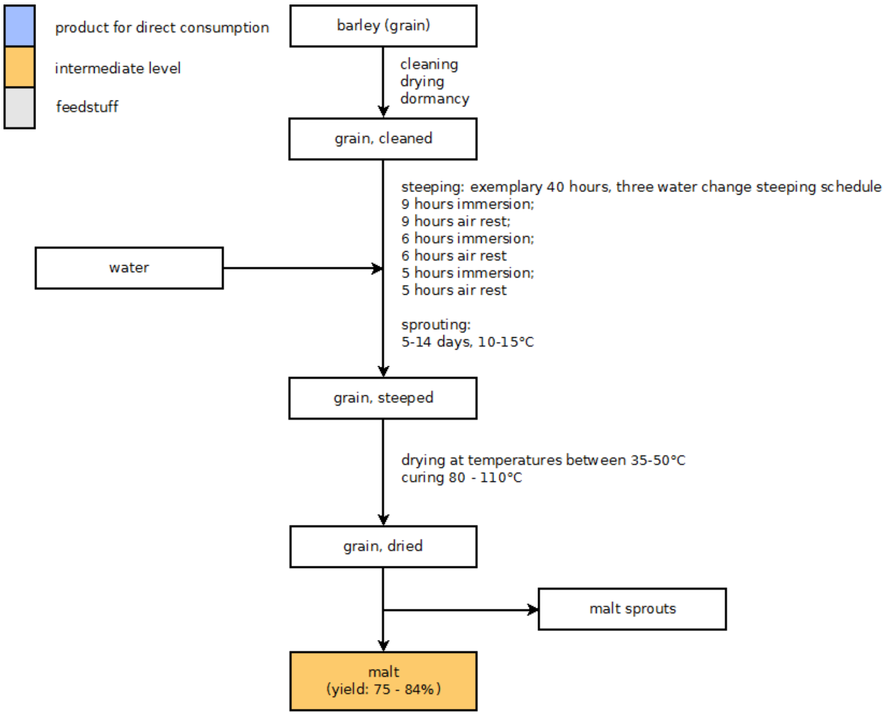
FoodEx2 considers beer as a composite food consisting of malt, hop extracts and water. Preliminary steps for the two most common ingredients (malt and hops) are presented in chapter 9.1 and 9.2. The beer brewing process is described in chapter 9.3.

9.1. Malt

9.1.1. Processing details

Malting is the germination of cereal grain under controlled artificial conditions. Though barley is the main grain used for brewing, beers are also made from wheat, spelt, maize, rice, sorghum and millet. The malting process is initiated by addition of water (steeping) to start germination. Main purpose is the development of amylolytic and proteolytic enzymes to break-down high-molecular substances in the cell walls of the endosperm. The sprouted grains are subsequently kiln dried and malt sprouts stripped. For beer brewing, barley is by far the most commonly used sort of grain in Europe. Further non-brewing end uses of malt in food industry are for example the utilisation as an ingredient for candy and confectionary products and as a supplement for bread flours.

Figure 42 shows a representative process of barley malt production. The significant processing steps are explained below.



Yield factors for malt are referenced in Narziß et al. (2017).

Figure 42: Processing of barley into malt (V-005)

Cleaning and conditioning

The pre-cleaned barley grain is dried to a moisture content of 14% and is subsequently stored for 6 to 8 weeks to overcome seed dormancy. Then another cleaning step is executed with the help of sieves and cyclones to remove impurities like straw particles, chaff, stones and dust.

Steeping and sprouting

Water (12-15°C) is added to cover the barley grain. The soaked water activates enzyme formation within the grain. Periods of wet steeping alternate with several hours of dry steeping. Steeping is complete when the barley has reached sufficient moisture content (between 44 and 48%). This process takes usually 24 to 48 h. During the subsequent sprouting process the grain is maintained at temperatures between 10 and 15°C and constantly aerated with fresh humidified air. The activated enzymes break down the cell walls and proteins, and open up the seeds' starch reserves. The sprouting period typically lasts between 5 and 7 days. The sprouted grain is known as ´green malt´ (Hornsey, 2013).

Kilning

The subsequent kilning process stops the sprouting, ensures a longer shelf life and affects the aroma and colour of the malt. Kilning can be divided into a drying phase and a curing phase. In the drying phase the green malt is gently dried without denaturation of the enzymes. For pale malts the drying temperature is low (between 35 and 45°C) and ventilation is high. For darker malts the temperature is higher (50°C) and ventilation is low.

After the drying phase the water content is between 5 and 10% and the malt can be cured at higher temperatures (4 h at temperatures of 80-90°C for pale malts and 90-110°C for dark malts) without causing a denaturation of enzymes. After kiln drying the malt seedlings are separated from the malt (Schuchmann and Schuchmann, 2005).

9.1.2. By-products of malt production

Malt seedlings (malt rootlets, germs, culms) are by-products formed at a rate of about 40 kg/t steeped barley (Briggs, 1998).

9.2. Hops

9.2.1. Processing details

Hops can be used directly in the brew to make a wet-hopped beer, but usually dried hop cones, hop pellets or hop extracts are used. Dried hop cones is the raw agricultural commodity (RAC). Therefore processing factors for hops refer to the processing of dried hops into hop extracts or beer.

Figure 43 shows a representative flowchart for processing of dried hops to hop extracts (ethanol extraction). The significant processing steps are explained below.

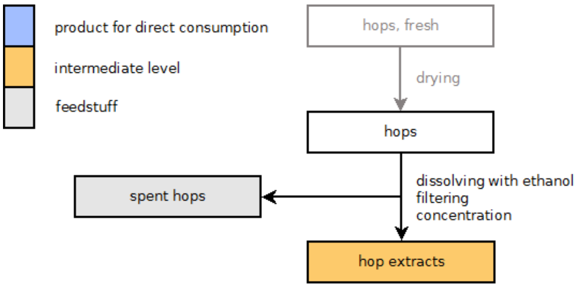


Figure 43: Processing of fresh hops into dried hops (= RAC) and further processing into hop extracts (V-006)

Hop pellets

Hop pellets are the most frequently used form of hops in the beer brewing industry (Eßlinger, 2009). Fresh hop cones contain about 80% water and are generally dried to a moisture content between 8 and 10%. Hop pellets are made from dried hops: The dried hop cones are shredded, then milled and the gained powder is pressed into pellets.

Due to the dehydration, the concentration of pesticide residues is expected to increase while fresh hops are dried. The processing from dried hops (RAC) to hop pellets is not expected to result in a change of nature or level of pesticide residues.

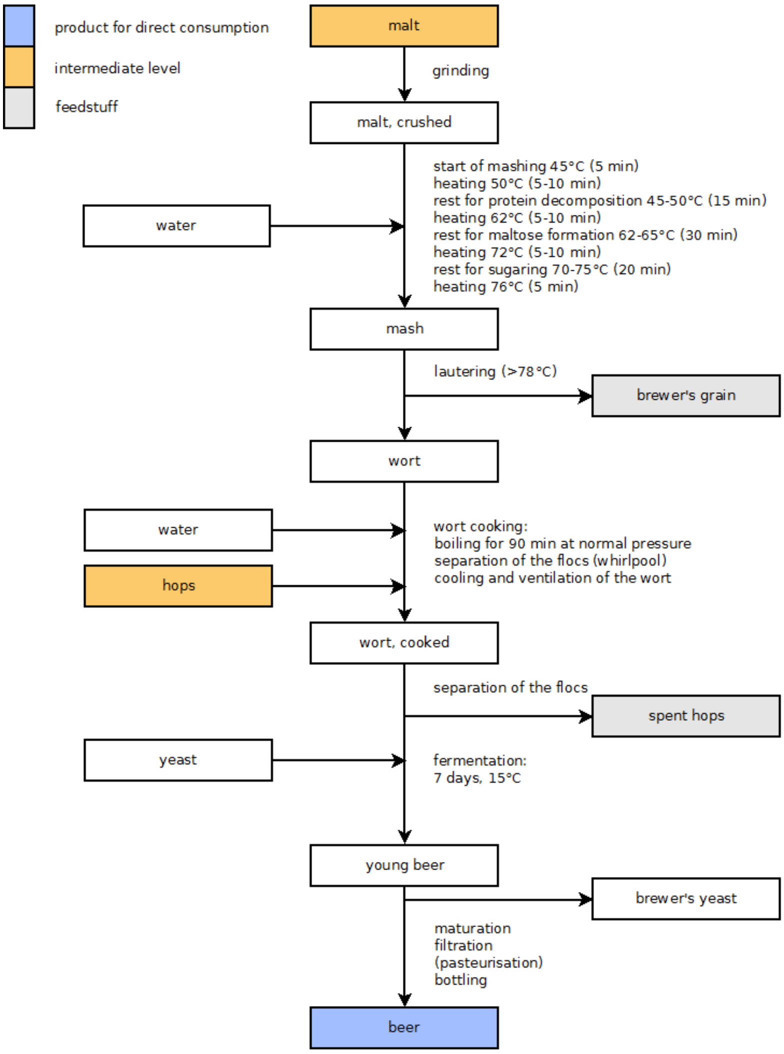
Hop extracts

Hop extracts are made from hop pellets. Ethanol or carbon dioxide can be used as extraction solvents. Ethanol dissolves a broader range of hop components and the extract needs further purification. Extraction with supercritical carbon dioxide is preferred because of its high selectivity for bitter and aromatic compounds (Bamforth, 2016). There is no processing study available which describes the extraction with supercritical carbon dioxide.

9.3. Beer brewing

9.3.1. Processing details

A flowchart of the brewing process is provided in Figure 44. The significant processing steps are explained below.



The yield factor for beer can vary greatly due to the different beer types. Exemplary amounts of ingredients for 1 L of beer are200 g barley and 4 g dried hops (Hamilton and Crossley, 2004).

Figure 44: Processing of malt, hops and water into beer (V-005, V-006)

Mashing

Before mashing, the brewing malt is dry milled. The ground malt is then steeped in brew water and subsequently heated. The main purpose of mashing is the dissolution and enzymatic conversion of ingredients. With regard to the optimal temperature range of the specific enzymes the mash is heated gradually with resting periods at different temperatures. Typical resting periods are at the following temperatures:

- 45 – 50°C for proteolysis and β-glucan degradation
- 62 – 65°C for maltose production (β-amylase)
- 70 – 75°C for saccharification (α-amylase)
- 78°C for inactivation of carbohydrate enzymes

Lautering

The mash is heated to approximately 78°C to terminate the enzymatic activity. In the subsequent mash liquefaction/filtration step the clear grain digestate, called wort, is separated from the insoluble malt components. The spent grain (remaining extract) is drained with hot water and the digestate combined with the first portion of the wort.

Wort cooking

The wort is boiled with hops which can be added either as fresh hops, dried hops or hop extracts. This process deactivates the malt enzymes, sterilises the wort and extracts and isomerises the essential components of the hops. Variety and amount of added hops have a significant influence on the bitterness and aroma of the beer. After the boiling process the clouding (trub) is separated.

Fermentation

Brewer´s yeast is added (pitching) when the wort has cooled down to a temperature favourable for the particular yeast variety. Warm fermentation at temperatures between 15 and 24°C and cold fermentation at temperatures between 5 and 12°C can be distinguished. The yeast transforms the sugar of the wort into ethanol and carbon dioxide. Following fermentation the so called ´green beer´ may be filtrated and further stored for maturation over a period of typically 1-2 weeks (Eßlinger, 2009) at cold temperatures (between -2°C and 0°C).

9.3.2. By-products of beer brewing

By-products of the beer brewing process are brewer's grain, brewer's yeast and spent hops. Brewer's grain represents the largest quantity of all by-products. Brewer's grain is collected at the end of the mashing process, once all sugars have been leached from the grain. The remaining product is a concentrate of proteins and fibre that is a valuable animal feeding stuff, particularly for ruminants (OECD, 2013). Dried and pulverised spent hops can be mixed with brewer's grain in a concentration not exceeding 3%.

9.3.3. Scientific studies reflecting typical processing operations

There are several studies which adequately describe the production of malt, dried hops and beer and a few studies which describe the production of hop extracts. No processing studies for beer or malt from cereals other than barley were made available.

The study of Ellis (2012a) reports the processing of barley grain into brewing malt and beer. Barley was cleaned and subsequently steeped. Steeping was done for 5 to 6 hours. In contrast to the described processing details above, the steeping duration is very short and no alternation between wet and dry steeping periods was made. The further processing was within the parameters described in the processing details (9.1 and 9.3).

The study is acceptable according to the quality criteria. It is referenced by EFSA (2015b) in a Conclusion.

The study of Braun (2011) reports the drying and extraction of hop cones and their utilisation in the beer brewing process. Hop cones were dried for approximately 7.5 hours at 58°C in a drying chamber. The dried cones were then milled with an impact cross mill. Subsequently, the dried hops were dissolved with ethanol using a soxhlet extractor. Spent hops were removed through filtration and the miscella was concentrated using a vacuum evaporator (temperatures above 50°C and vacuum between 0.5 and 1 bar). The hop extract was cooled down in a desiccator to ambient temperature. For the beer brewing process, dried hops were used. The beer brewing process followed the general process description. Pilsner beer was brewed.

The study of Braun is acceptable according to the quality criteria. It is referenced in a Reasoned Opinion according to article 10 by EFSA (2014c).

9.3.4. Comparison to industrial and/or household processing techniques

Given the high shares of water in the consumed end product both the malt and hops extracts, which may contain pesticide residues, are highly diluted in beer.

The basic processing steps in the studies correspond to the common industrial methods. Additional processing steps in the industrial production of beer can be clarification (with fining agents) and pasteurisation. Depending on the physical-chemical properties of the applied pesticides, clarification as well as pasteurisation can decrease pesticide residue levels in beer. For explanation of pasteurisation see introduction of chapter 3.

Malting, hop drying and hop extraction are normally not practised on a small scale.

The principal processing conditions of domestic brewing are corresponding to those in industry. The more recent trend of craft beer manufacturing is not reflected in any of the laboratory scale processing studies.

10. Milling processes

Cereal grains play an important role in the world's food supply. The major cereals are wheat, maize, rice, barley, sorghum, millets, oats and rye. Most of the grain for human consumption is milled to remove bran and germ. This is done to meet the sensory expectations of consumers but also to produce a more palatable product with a long shelf-life.

Residues of non-systemic pesticides are expected to decline when the outer layers of grains (bran) are removed in the milling process. When wet-milling is performed an additional loss of water soluble pesticides is expected.

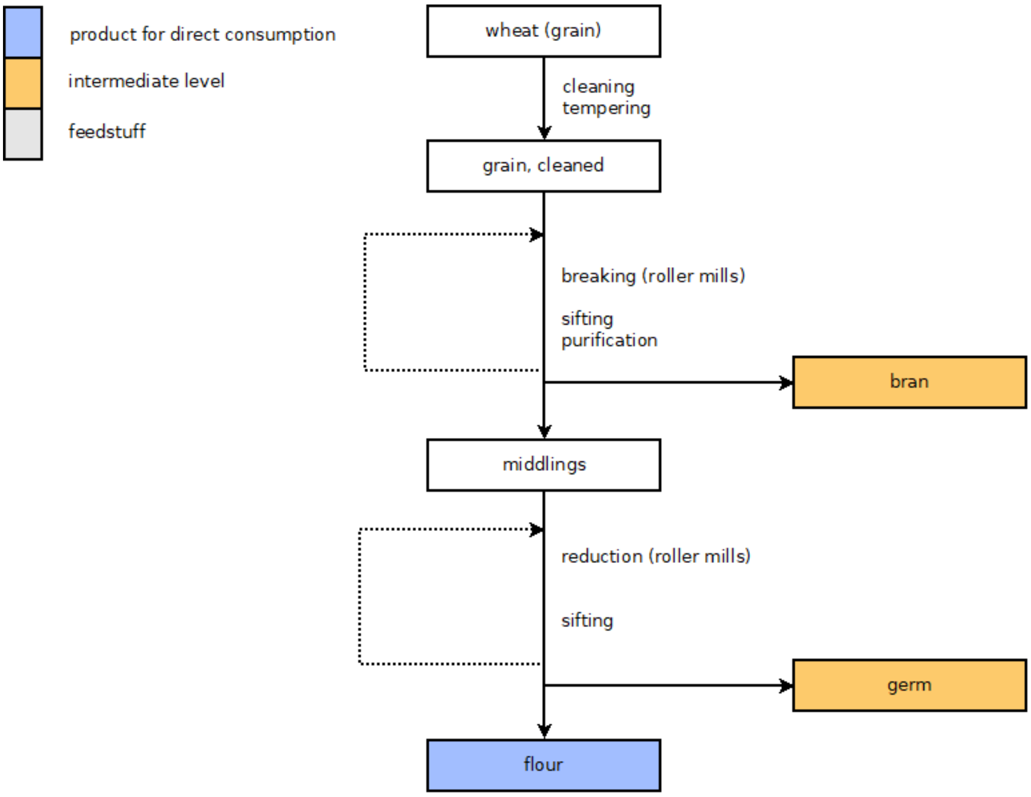
Wet-milling processes for starch production are described in chapter 11.

10.1. Wheat flour

Wheat is the second most produced cereal type after maize. It is a staple food worldwide and the main ingredient in bread (Rauter et al., 2010). Wheat flour is produced from soft wheat (Triticum aestivum), durum wheat (Triticum durum) and spelt wheat (Triticum spelta).

10.1.1. Processing details

Wheat milling is a gradual, stepwise reduction process, with repeated milling and sieving steps. The three main parts of the wheat kernel (bran, germ and endosperm) are more or less separated. Simultaneously, the endosperm is grounded into white flour. A simplified flowchart for wheat milling is shown in Figure 45 and is described below. It has to be pointed out that the flowchart cannot show all processing steps and milling products possible. This is because there is a huge variety of milling products and by-products, which differ in their composition. Additionally, every mill might have its own and slightly different sequence of processing steps.



Wheat kernels consist of 83% endosperm, 14% bran and 3% germ. Yield factors for flour depend on the flour type which is produced. Wholemeal flour uses all components of the wheat kernels, the yield factor is therefore nearly 100%. For white flour such as German flour type 550 the yield factor is between 64 and 71% (Heiss, 2004; Schuchmann and Schuchmann, 2005).

Figure 45: Milling of wheat into flour (XI-002)

Cleaning and conditioning

Before the grain is milled, it has to be cleaned. The cleaning process involves several machines (e.g. de-stoner, aspirator, separator, scourer, optical sorter and magnet) which remove foreign material and separate the grain by size, shape and weight.

After cleaning, the grain can be conditioned for milling by addition of water. The optimal moisture content depends on the hardness of the wheat (soft or hard wheat) and lies between 15 and 16.5% (Arendt and Zannini, 2013). The main objective of conditioning is to prevent breakup of the bran to smallest pieces in order to achieve a high separation ratio of the bran from the endosperm during the milling and sifting process.

Milling

After mixing, cleaning and conditioning, the wheat kernels are milled. The process consists of several breaking and sieving steps using roller mills and plansifters. A roller mill consists of one or two pairs of steel rollers set slightly apart from each other, with turned grooves.

The roller mills break the wheat kernels into pieces of different size and different quality. The differently sized particles of the broken wheat are sorted by plansifters. Beside bran particles the mixture contains also big particles of endosperm and adherent bran, medium and smaller sized particles of endosperm and bran, bigger particles of endosperm, smaller particles of endosperm, flour of endosperm and flour of bran.

Flour is defined by size: Flour consists of particles <112 µm or sometimes <125 µm. Flour is subsequently transported to a flour silo. The other particles are milled again on a roller miller with less deep and increasingly narrow cut grooves. Again particles of different size are produced and sorted by plansifters. Each plansifter provides four to five products. Flour is one of these products and is sorted out, the other, bigger particles separated by the plansifters are milled and sifted on different roller mills until there is hardly no endosperm left on the bran (VGMS, 2018).

The process of milling and sifting might be repeated up to 20 times depending on the equipment of the individual flourmill and the desired specifications. Hence, the flours produced throughout the whole milling process (so called passages) show different qualities resulting from the different parts of the wheat kernel and varying amounts of bran. Only in soft wheat mills, the wheat germ can be extracted after pressing and sifted by a special sifting passage from one of the plansifters. However, some soft wheat mills do not separate the wheat germ, but let the germ go away with the bran (VGMS, 2018).

Flours can contain larger or smaller quantities of the bran and the germ. Flours with only a small quantity of bran are therefore lightly coloured and flour with larger quantities of bran have a slightly darker, greyish colour (brown flour).

Blending

The various flour streams can be blended to make a variety of different flours with different characteristics. The terminology of the different flour types varies from country to country. In Germany and France, flour is labelled according to the ash content (in mg/100 g flour in Germany and in mg/10 g flour in France). The ash content increases when more outer layers of the wheat kernel are used for the flour.

The residue levels of non-systemic pesticides are usually concentrated on the outer layers (bran) of the wheat kernel. Therefore, flour with a low share of bran is expected to have lower residue levels than flour with a higher bran concentration. Hence, extrapolation is only recommended to flours with similar compositions. A rough differentiation in white, brown and wholemeal flour is possible. White flour has no or only a low share of bran, this corresponds to the German flour types 405-812. For brown flour, more than 80% of the grain is used (corresponds to German flour types 1050-1600). Wholemeal flour consists of all parts of the wheat kernel.

Wheat coarse meal/shred/grits are the hulled wheat kernels that retain the germ and bran. They are considered a wholemeal product. Extrapolation from wholemeal grain to other wholegrain products is possible.

10.1.2. By-products of wheat milling

By-products of soft wheat milling are different mixtures of bran, endosperm and germ. The majority of the milling by-products is sold as feed mainly for cattle and pigs (OECD, 2013). Smaller amounts are used for human consumption, for example as breakfast cereals. Each mill has its own bran by-products varying in particle size as well as in starch, fibre and protein content. Wheat germs have a very limited stability and are therefore mostly used as raw material for feed. In other cases, the germs can be further processed to extract its oil for use in cosmetics or food.

10.1.3. Scientific studies reflecting typical processing operations

Several studies are available on processing of wheat into flour. In most of them, flour type 550 was produced. Flour type 550 has a yield factor of approximately 64-71% (Schuchmann and Schuchmann, 2005).

In the study of Rice (2010) the processing of wheat into flour is described. Wheat was cleaned and subsequently moisture conditioned (moisture content 16.5%). The wheat kernels were then passed through breaking rolls. Material exiting the breaking rolls was sifted and separated into flour (break flour), middlings and bran. Middlings were further milled by reduction rolls and subsequently separated by sifting into flour (reduction flour) and shorts. Break flour and reduction flour was mixed. The study is acceptable according to the quality criteria. It is referenced by EFSA (2016b) in a Conclusion.

10.1.4. Extrapolation to other commodities

Rye as well as other wheat crops like triticale or spelt have a similar grain structure as wheat. Thus, extrapolation to flour from rye, triticale and spelt is possible due to comparable techniques used for flour production. However, the percentage of bran in the flour should be taken into account.

10.1.5. Comparison to industrial and/or household processing techniques

Processing of grain into flour is not a common household process. When it is done, usually wholemeal flour is produced. No change in the concentration of pesticide residues is expected when wheat is processed into wholemeal flour.

The processing studies adequately reflect the industrial production of wheat flour. However, the type and sequence of cleaning equipment and the number of breaking and reduction rolls can vary from mill to mill. This is however not considered to influence residue levels, which are expected to depend mainly on the percentage of bran left in the obtained flour in the end.

10.2. Pearl barley and barley flour

Barley is one of the most important cereal crops worldwide. It is primarily used as animal feed (70%) but is also an important source for malt (see Chapter 9) and other foods for human consumption (FAO, online-a).

Barley is milled to produce pot barley, the finer pearl barley and barley flour for human consumption. An important part of the milling process is the removal of the barley hull, which is largely indigestible. Due to the strong adherence of the hull to the pericarp, abrasive milling techniques are used.

10.2.1. Processing details

A flowchart of the processing of barley into pearl barley, pot barley and barley flour is given in Figure 46.

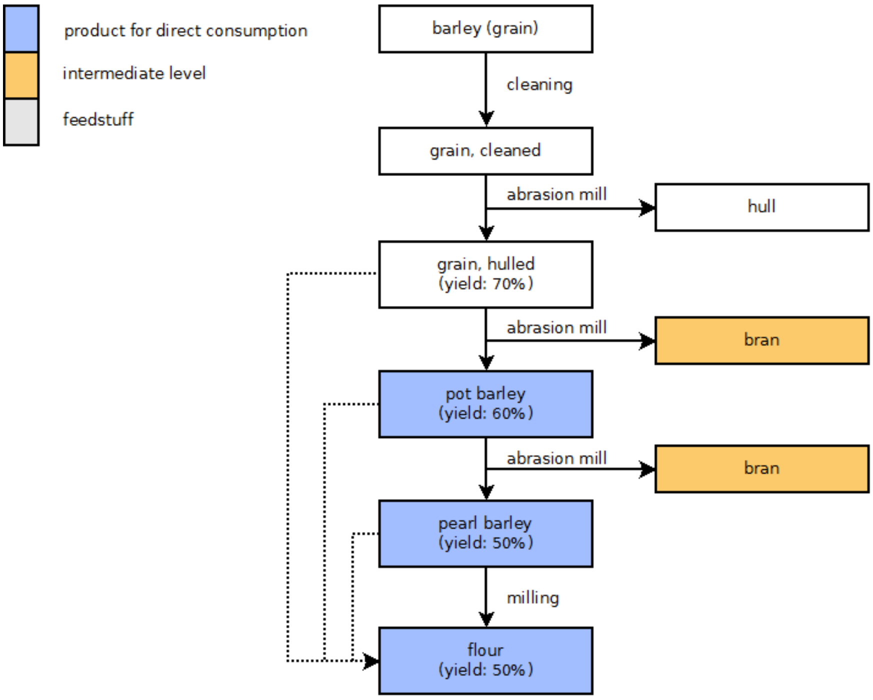
Cleaning and conditioning

Foreign grains, broken kernels and impurities are removed by sieves and/or magnets, screens, de-stoners and separators. The cleaned grains are then conditioned by adjusting the moisture content to approximately 15%.

Pearling

The cleaned barley grains are pearled, for example with a decorticator. This abrasion process removes the inedible hull (blocking) and polishes the kernel (pearling).

Hulled (blocked), pot and pearl barley is produced with the same process and the products only differ by the amount of abrasion. Hulled barley has only the tough inedible hull removed. For pot barley some of the bran is removed. The abrasion is around 35%. Pearl barley is polished longer and has therefore less bran and a higher degree of abrasion (45%) (Izydorczyk, 2004).



Yield factors are referenced in Izydorczyk (2004).

Figure 46: Processing of barley into hulled, pot and pearl barley and into barley flour (XI-003)

Milling

Pearl barley is often the end product but further processing into barley flour is also possible. Different milling systems, like stone, hammer, pin or roller mills can be used. Roller milling of hulled barley into barley flour is possible as well, but produces a less pure product.

10.2.2. By-products of barley milling

By-products of the different production steps in the dry milling process of barley are usually combined and used as feedstuff (OECD, 2015). Barley bran alone is not listed as feed in EFSA's User Guide to the PROFile (EFSA, 2016e).

10.2.3. Scientific studies reflecting typical processing operations

Several studies are available which describe the processing of barley grain into hulled barley, pot barley, pearl barley and/or barley flour. However, some studies do not distinguish between hulled, pot and pearl barley and use these terms as synonyms. The ratio of abrasion is also not always specified for every product.

In the study of Ellis (2012a) the processing of barley into pot barley, pearl barley and barley flour is described. The grains were cleaned, dried to moisture content below 15% and subsequently filled in a decorticator. The abrasion ratio for pearl barley was 29.4 - 44.6%. For pot barley the abrasion ratio was not specified. Pot barley was subsequently milled into barley flour by a hammer mill. The study is acceptable according to the quality criteria. It is referenced in a Conclusion (EFSA, 2015b).

10.2.4. Extrapolation to other commodities

Extrapolation to other cereals is not recommended.

10.2.5. Comparison to industrial and/or household processing techniques

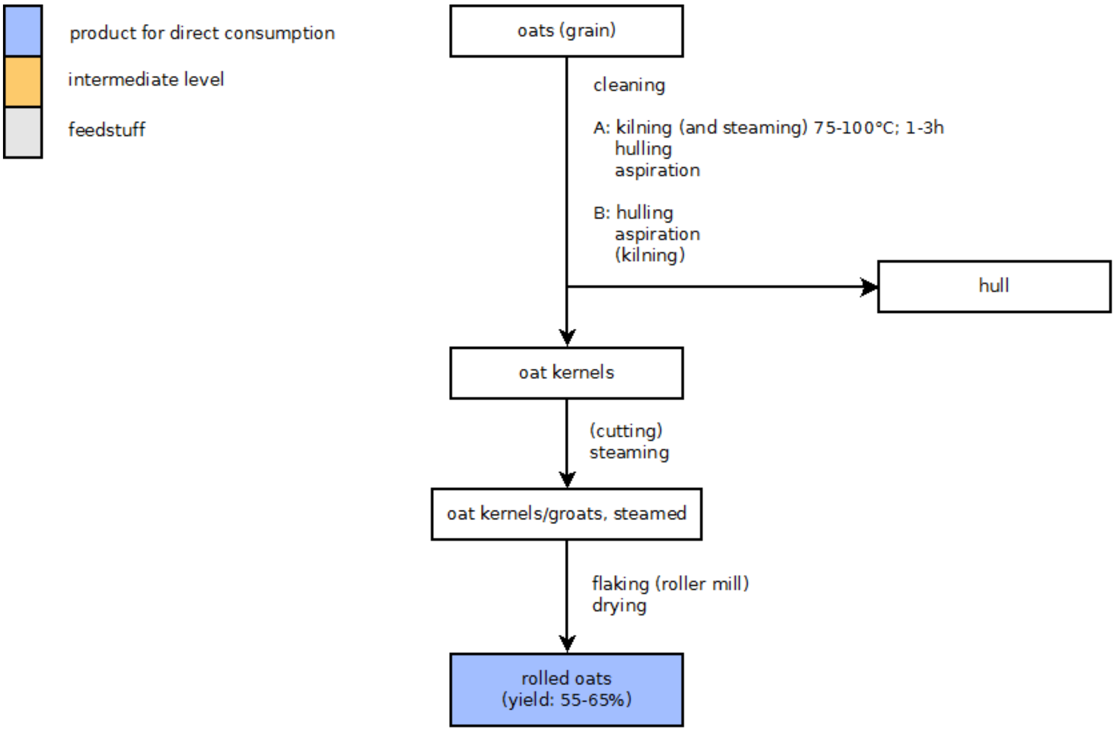
The processing of barley is not a common household process in Europe.

10.3. Rolled oats

Oats have a high nutritional value. Typical oat mill products for human consumption are rolled oats for usage in breakfast cereals or granola bars. Due to the low content of gluten, oats are rarely used as bread cereal.

10.3.1. Processing details

The production of rolled oats includes cleaning, drying, hulling, steaming, if necessary cutting and flaking. An example of typical processing steps is shown in Figure 47 and is described below.



Yield factors are referenced in Belitz et al. (2009).

Figure 47: Processing of oats into rolled oats (XI-005)

Cleaning

Impurities like stones, sand, chaff, other grains and other foreign material are removed. After cleaning, the oat grains can be sized and separated into different grades.

Steaming, drying and hulling

The oats are steamed and subsequently dried to a moisture content of 5-14%. Kilning is done at temperatures between 75 and 100°C for 60 to 180 minutes. The heat makes the oat more brittle which facilitates the following hulling step and gives a nutty flavour to the kernel. The hull is subsequently removed by aspiration (Belitz et al., 2009; Schuchmann and Schuchmann, 2005).

It is also possible to directly hull the oats without previous steaming or drying steps in an impact mill. In this type of mill, the grains are thrown against a hardened surface, e.g. hardened rubber. This results in the separation of the kernel (groat) from the hull (Heiss, 2004).

Steaming and rolling

The oat kernels are steamed for 20-30 min for softening and are subsequently rolled in a roller mill. Size and thickness of the rolled oats depend on the size of the groats. It is possible to cut the oats before steaming (for example with a rotary granulator) to produce smaller rolled oats. The rolled oats are dried to a moisture content of approximately 10-12%.

Oat flour

Whole oat flour is produced similarly as rolled oats. The oats are cleaned, dried and hulled. The groats are then steamed. The steamed groats are cut and subsequently grounded.

10.3.2. By-products of rolled oats processing

Oat hulls represent between 20 and 36% of the weight of the whole grain. They are the main by-product in the production of rolled oats and can be used as biomass for power generation (Welch, 1995).

10.3.3. Scientific studies reflecting typical processing operations

In the study of Scrimshaw and Milhan (2003) the oats were first dried at 60°C and then hulled. The oat kernels were steamed for 30 min and subsequently rolled on a roller machine. The study is acceptable according to the quality criteria. It is referenced by EFSA (2015e) in a Reasoned Opinion.

10.3.4. Extrapolation to other commodities

Extrapolation to barley flakes is possible.

10.3.5. Comparison to industrial and/or household processing techniques

The processing of oats is not a common household process in Europe.

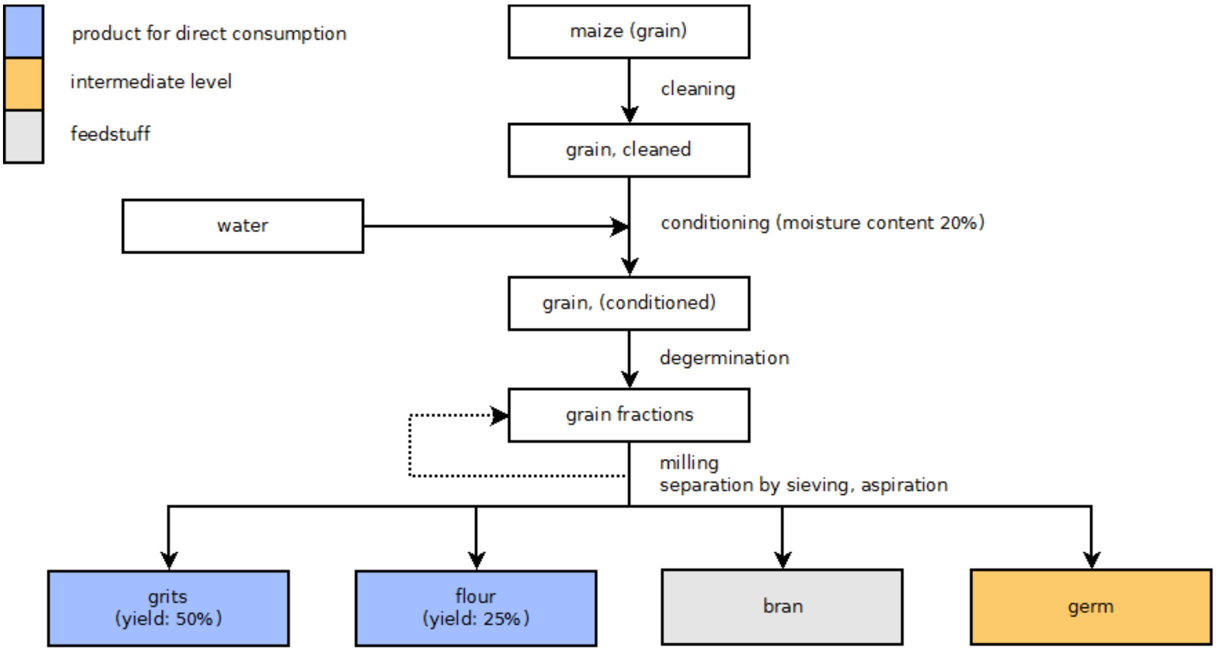
10.4. Maize flour

Maize is the cereal with the highest production worldwide and is a staple food in many parts of the world. In Europe, maize is primarily used for animal feed and biofuel. Typical maize products for human consumption are, among others, flour, maize grits (polenta), starch and maize oil.

Two different types of maize milling operations are applied: wet milling and dry milling. Dry milling produces maize flour and maize grits. Wet milling produces maize starch and is further described in chapter 11.1.

10.4.1. Processing details

A simplified example of the dry-milling process is schematically shown in Figure 48 and is described below.



Yield factors are referenced in Kent and Evers (1994).

Figure 48: Dry-milling of maize into flour, meal and grits (XI-004)

Cleaning

Before the whole maize grain is milled, it has to be cleaned. The cleaning process involves several machines (e.g. de-stoner, aspirator, separator and magnet) which remove foreign material and separate the grain by size, shape and weight.

Conditioning and de-germing

For better separation of bran and germ, the cleaned grain is moistened with water. The water is absorbed by the maize kernel, which provides greater elasticity of the seedling and the shell, and allows optimised separation of the germ.

The maize kernel is broken by attrition milling in a de-germinator. Different types of de-germinators (e.g. cone mill, hammer mill) can be used. The endosperm remains intact or in large chunks. A significant fraction of germ and bran can be separated by screening and aspiration after this first step.

Milling

Further separation of the remaining bran and germ is done by milling which consists of grinding (roller mill), sifting, classifying and aspiration. Grain fractions are recirculated to the milling process until they match the specification of the corresponding intermediate or end product.

The obtained endosperm products are classified by their size. There is no globally recognised terminology but commonly used terms include flaking grits (5800-3400 µm), coarse grits (2000-1400 µm), grits (1400-600 µm) and flour (less than 212 µm) (Kent and Evers, 1994).

Within the framework of the project, products of dry-milled maize are distinguished in grits and flour.

10.4.2. By-products of maize milling

By-products of the dry-milling of maize are maize bran and maize germ. Maize bran is usually mixed with broken kernels and germ residues after oil extraction and used as feedstuff (hominy meal). Germs can be further processed to maize oil (see 7.2).

10.4.3. Scientific studies reflecting typical processing operations

One study is selected as representative. The study adequately describes dry milling of maize (Johnston and Saha, 2009).

Maize grain was moisture conditioned to 21% and tempered for approximately 2 h. The maize was then milled in a disc mill to crack the kernel. The obtained maize stock was dried at temperatures between 55-70°C for 30 min. The dried maize stock was then screened in multiple steps to separate germ, bran and large grits. The remaining material was milled (disc mill) and screened in multiple steps to separate remaining bran and germ as well as grits and flour.

The study is referenced by EFSA (2016d) in a Reasoned Opinion and is acceptable according to the quality criteria.

10.4.4. Extrapolation to other commodities

No extrapolation to other cereals is recommended.

10.4.5. Comparison to industrial and/or household processing techniques

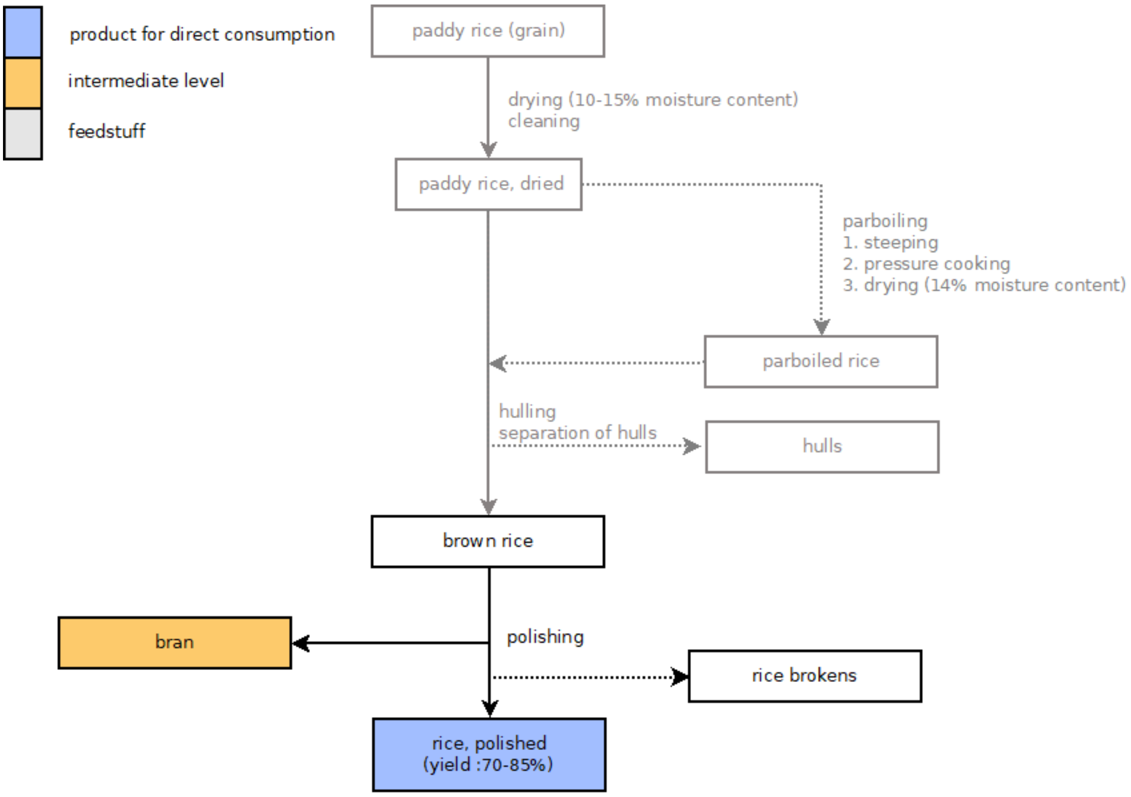
The available processing studies reflect well the industrial dry-milling process. Milling of maize is not a common household process.

10.5. Rice milling

10.5.1. Processing details

After threshing, the rice grains (paddy rice, rough rice) consist of the hull and the enclosed edible portion, which accounts for 80% of the total grain weight. When the hull is removed the product is called brown rice. Brown rice is defined as the RAC in Regulation (EU) No 2018/62. Additional removal of the bran layers creates polished rice, which is also called white rice.

The processing of rice is shown in Figure 49 and is described below.



Brown rice is the RAC. Yield factors of polished rice from brown rice depend on the degree of polishing and whether or not broken kernels remain in the polished rice (VGMS, 2018).

Figure 49: Processing of paddy rice into polished rice (XI-006)

Preliminary steps

After harvest, rice (paddy) has a water content of approximately 23%. In order to achieve good storage stability the rice is dried to a moisture content between 10 and 15%(VGMS, 2018). Subsequently, the dried rice is mechanically cleaned to remove foreign matter. The dried rice is subsequently hulled.

Hulling is the process of removing the outer hulls from rice grains with a minimum damage to the bran layers and without breaking the kernel. This can be achieved with a disc sheller, centrifugal sheller or a rubber-roll sheller (Bhattacharya and Ali, 2015). The rubber-roll sheller consists of two rubber surfaced rolls that are turning in opposite directions at different speeds. The shearing action strips off the hull from the paddy rice. Subsequently, a hull aspirator separates the detached hulls from the rice by air aspiration. The brown rice then passes into a paddy separator which removes any unhulled kernels from the brown rice which are returned for hulling. The resulting brown rice is considered the RAC and the starting point for calculation of processing factors.

Whitening/Polishing

The brown rice (RAC) is polished to remove bran layers. Suitable for this purpose are emery or metal polishers. The emery polisher polishes the grains by abrasion with emery. The metal polisher polishes by friction between the grains. The extent of the polishing varies according to the desired specification of the rice, ranging from still slightly brownish to white and almost opaque. During polishing, a certain percentage of rice kernels are damaged, leaving so called rice brokens. Rice intended for European consumption normally contains very few brokens. They may be further processed into rice starches, rice flours or rice proteins.

Further processing: Rice flour

Rice flour can be made from whole or broken kernels of brown or white rice. The rice is either dry-milled or wet-milled. Dry-milling is possible without further pre-processing on various types of mills. Wet-milling usually produces finer particles with less starch damage than dry-milled rice flour but requires more processing steps. The rice has to be soaked in water or sprayed with water before milling and is dried after milling (Kim, 2013).

Parboiling

Parboiled rice is obtained by steam (wet) milling. Rice grains are soaked in water, steamed and subsequently dried. While brown rice can theoretically be used for parboiling, the rice used for parboiling in Europe is paddy rice. Parboiling drives nutrients from the outer kernel into the inner parts of the rice kernel, but can also lead to an unwanted introduction of pesticide residues from the hull. The rice is milled analogously to polished rice (white rice).

Definition of the RAC as hulled rice renders it impossible to derive processing factors for parboiled rice which is obtained from paddy rice and not from the defined RAC. Therefore parboiling is not reflected in the flowchart. It might be considered to change the definition of the RAC to "paddy rice" in future in Annex I to Regulation (EC) No 396/2005.

10.5.2. By-products of rice processing

By-products of rice processing are rice hulls and rice bran. Hulls make up 20% of the rice grain by weight and are primarily used as biomass for power generation. Rice bran can be used as animal feed or can be further processed into rice oil. Heat treated bran may be used for human nutrition (Gunstone et al., 2007; OECD, 2015).

10.5.3. Scientific studies reflecting typical processing operations

One study was chosen as representative for polished rice. The study is referenced by EFSA (2010) and is acceptable according to the quality criteria. The study (Gimeno, 2010) describes the processing of paddy rice into brown and polished rice. The unprocessed rice grains (paddy rice) were cleaned and dried to a moisture content of 14.2-14.8%. Dried rice grains were passed through a huller mill to remove the hull and obtain the brown rice. Brown rice was further milled into polished rice by friction.

10.5.4. Extrapolation to other commodities

No extrapolation to other cereals is recommended.

10.5.5. Comparison to industrial and/or household processing techniques

The described processing of brown rice into white rice is consistent with standard milling practice and is not typically conducted on domestic level.

11. Starch production

Starch is the most common carbohydrate in human diets. In Europe, starch is mainly produced from maize, wheat and potatoes. Internationally, cassava, sorghum and rice are also important starch-supplying commodities.

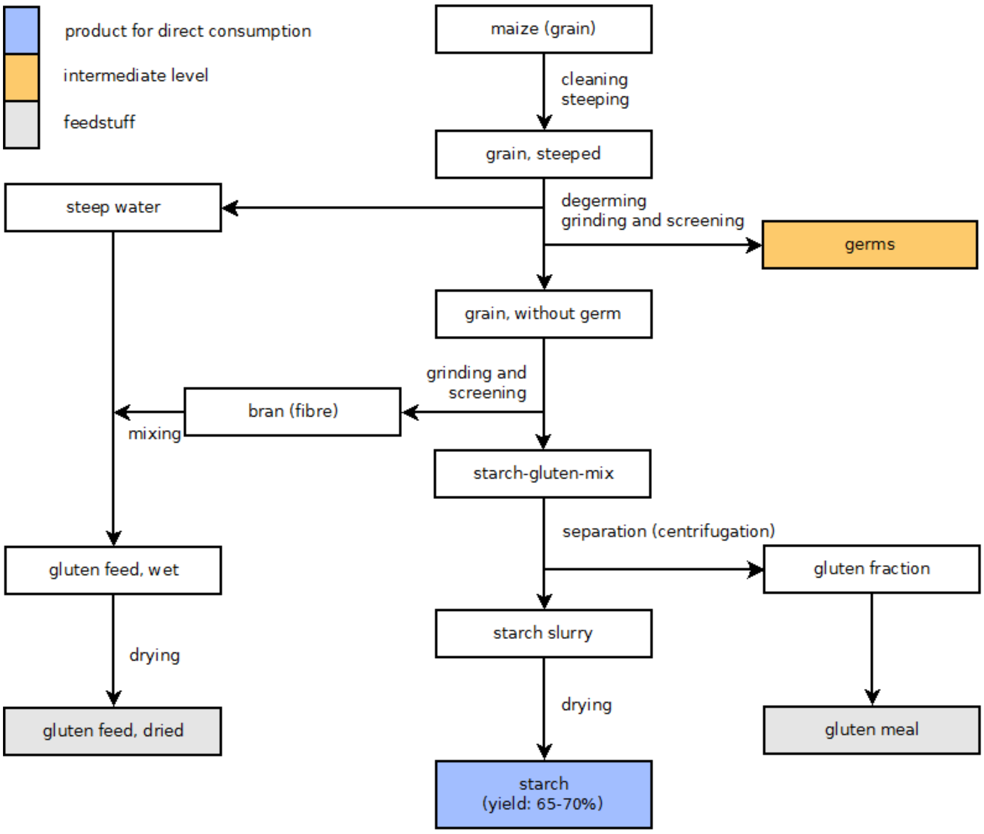
Extracted dried starch obtained in its natural granular form (e.g. without physical denaturation by heating) is called native starch. Further processing provides a variety of starch-derived food ingredients such as pre-gelatinised starches, maltodextrins, glucose syrups, dextrose, modified starches or other starch sweeteners.

11.1. Maize Starch

Maize is one of the most important raw materials for the production of starch. The starch content of maize kernels is between 65 and 75% (VGMS, 2018). The starch is obtained in a wet-milling process. By products are maize germs and protein-rich feedstuffs.

11.1.1. Processing details

The wet-milling process is shown in Figure 50 and described below.



Yield factor for maize starch is referenced in Brennan (2006); (VGMS, 2018).

Figure 50: Wet-milling of maize into maize starch (XI-007)

Cleaning and Steeping

The whole maize grain is dried and subsequently cleaned. Cleaning includes among others sieving, removal of metals by magnets and separation of particles by shape and density. The cleaned maize kernels are soaked in an aqueous sulphur dioxide solution (0.1-0.2%) for 30-50 h at temperatures around 50°C. During this process the maize kernels soften and double in size.

Separation of germ

The soaked maize kernels are coarsely grinded to loosen the germ from the rest of the kernel. The oil-rich germs are removed from the generated slurry using hydrocyclone separators. Further processing of the germ to maize oil is mostly done to produce refined maize oil and germ meal as animal feed (see 7.2).

Fibre separation

After germ removal the remaining fraction consists of starch, protein and coarse hull material (fibre). The material undergoes fine grinding and screening. The gluten and starch passes the screens and the fibre is retained.

The fibre is washed to recover remaining starch and gluten and is subsequently dried to a water content of approximately 10%. The fibre is mixed with steep water and is subsequently dried.

Starch washing

The starch-gluten mixture is separated by centrifugation into starch and gluten solution. The gluten solution is dried and used as feedstuff.

The starch solution is dried and sold as starch powder or can be processed further to maltodextrins, glucose syrups, glucose-fructose syrups, dextrose and modified food starches.

11.1.2. By-products of starch production from maize

The main by-products of the wet-milling of maize are maize gluten meal and maize gluten feed. Both products can be used as animal feeds (OECD, 2013).

Germs can be further processed to maize oil (see 7.2).

11.1.3. Scientific studies reflecting typical processing operations

One study is selected as representative. The study adequately describes the process of wet milling of maize (Johnston and Saha, 2009).

Whole maize was steeped for 22-48 h in water containing 0.1-0.2% sulphur dioxide at temperatures between 48 and 55°C. The maize kernels were then milled by a disc mill and a majority of bran and germ was removed by a hydrocyclone. The remaining material was then further grounded in a disc mill. Bran was removed by screening. Starch and gluten in the process water were separated by batch centrifugation. Subsequently, starch was dried at temperatures between 55 and 70°C.

The study is referenced by EFSA (2016d) in a Reasoned Opinion and is acceptable according to the quality criteria.

11.1.4. Extrapolation to other commodities

No extrapolation to other cereals is recommended.

11.1.5. Comparison to industrial and/or household processing techniques

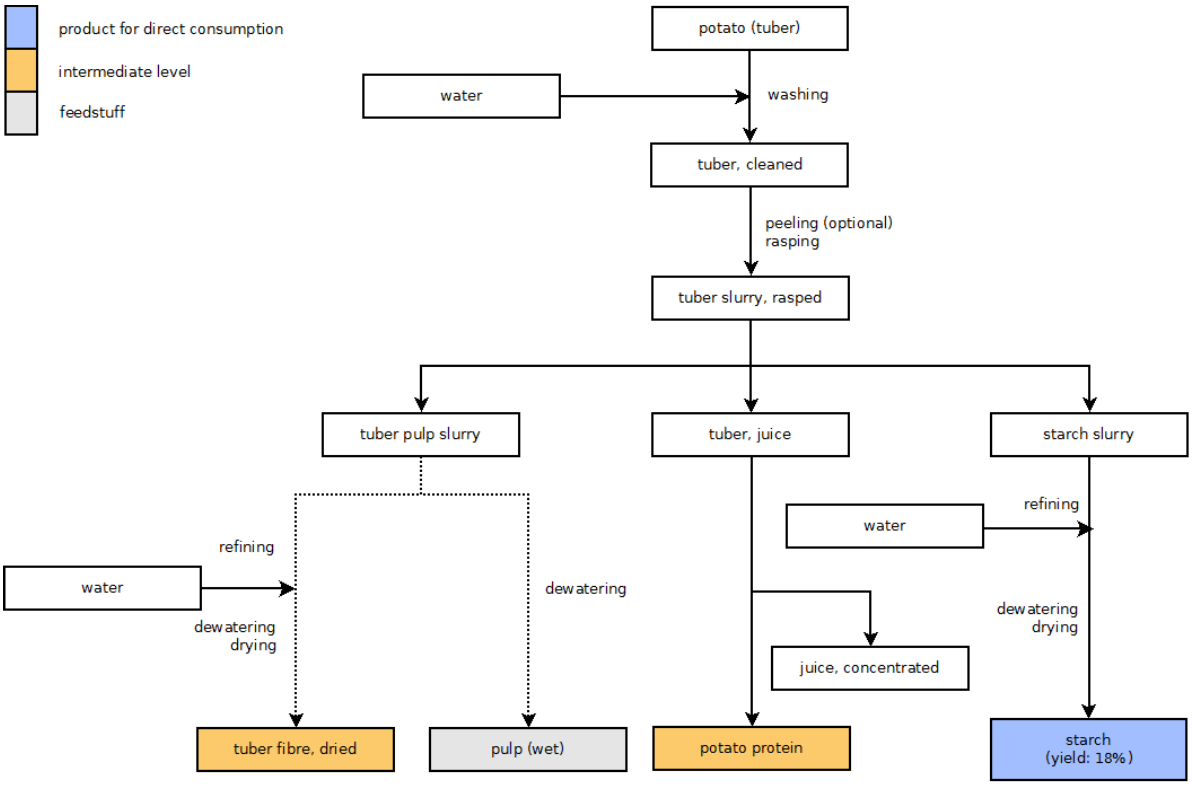
The available processing studies reflect well the industrial wet-milling process. Milling of maize is not a common household process.

11.2. Potato starch

Potato starch is a carbohydrate which is extracted from potato tubers. Potato starch is used in household cooking as well as in the food and feed industry. Potato starch is also the raw material for the production of modified potato starches.

11.2.1. Processing details

There are several methods to extract starch from potatoes. In all cases the potatoes are washed and subsequently rasped. The obtained slurry is then separated into three different components (tuber juice, tuber pulp slurry and starch slurry). The separation can be done in different order. A simplified example of the process is schematically shown in Figure 51 and is described below.



Yield factor referenced in BeMiller and Whistler (2009).

Figure 51: Processing of potatoes into starch (XI-008)

Rasping

The potatoes are washed and optionally peeled. The cleaned potatoes are then rasped. During rasping, the tuber cells are opened and the starch granules are released.

Potato juice and fibre extraction

The obtained slurry is then separated in three different components (tuber juice, starch slurry and the remaining potato pulp) for example with a decanter centrifuge. The separation steps can be done in different order. Starch is the most important product. The composition and yield of the remaining fractions depend on the manufacturing facility.

Starch refinery

The starch slurry contains small fibre particles and some soluble proteins. The fibre particles can be separated in a nozzle centrifuge. Soluble proteins are removed with hydrocyclones.

The refined starch slurry (also called ‘starch milk’) is dewatered, for example with a vacuum drum filter to a water content of approximately 40%. The obtained wet starch cake is then further dried to a water content of 20%.

11.2.2. By-products of potato starch production

By-products of the potato starch production are potato juice and pulp. The potato pulp slurry is dewatered to a certain extent. The resulting wet potato pulp may be used as cattle feed. Optionally, the potato pulp slurry can be washed and dried to potato fibre, which can be used as a food ingredient.

Potato juice can be further processed into potato protein and protein hydrolysates.

11.2.3. Scientific studies reflecting typical processing operations

One study is selected as representative. The study adequately describes potato starch production (Mäyer, 2012d).

Potatoes were washed and peeled. Green or bruised spots were removed. The peeled potatoes were then pulverised with a peeling machine. A continuous stream of water was added during the peeling. The mixture of water and pulverised potato which left the peeler was sieved with a 100 mesh sieve. Wet pulp which remained on the sieve was washed with water twice and then sieved again. Everything which passed the 100 mesh sieve was allowed to settle. The liquid portion (which contains the protein) was decanted. The starch fraction which settled on the bottom was centrifuged, water washed and then dried in a dehydrator to a moisture content of 15%.

The study is referenced by EFSA (2015c) in a Conclusion and is acceptable according to the quality criteria. For future studies, it is recommended to use the whole potato with peel for starch production. It is the more common process and reflects the worst case.

11.2.4. Extrapolation to other commodities

Extrapolation to starch from other commodities within the crop group of root and tuber vegetables, for example cassava, arrowroot and sweet potato, is possible.

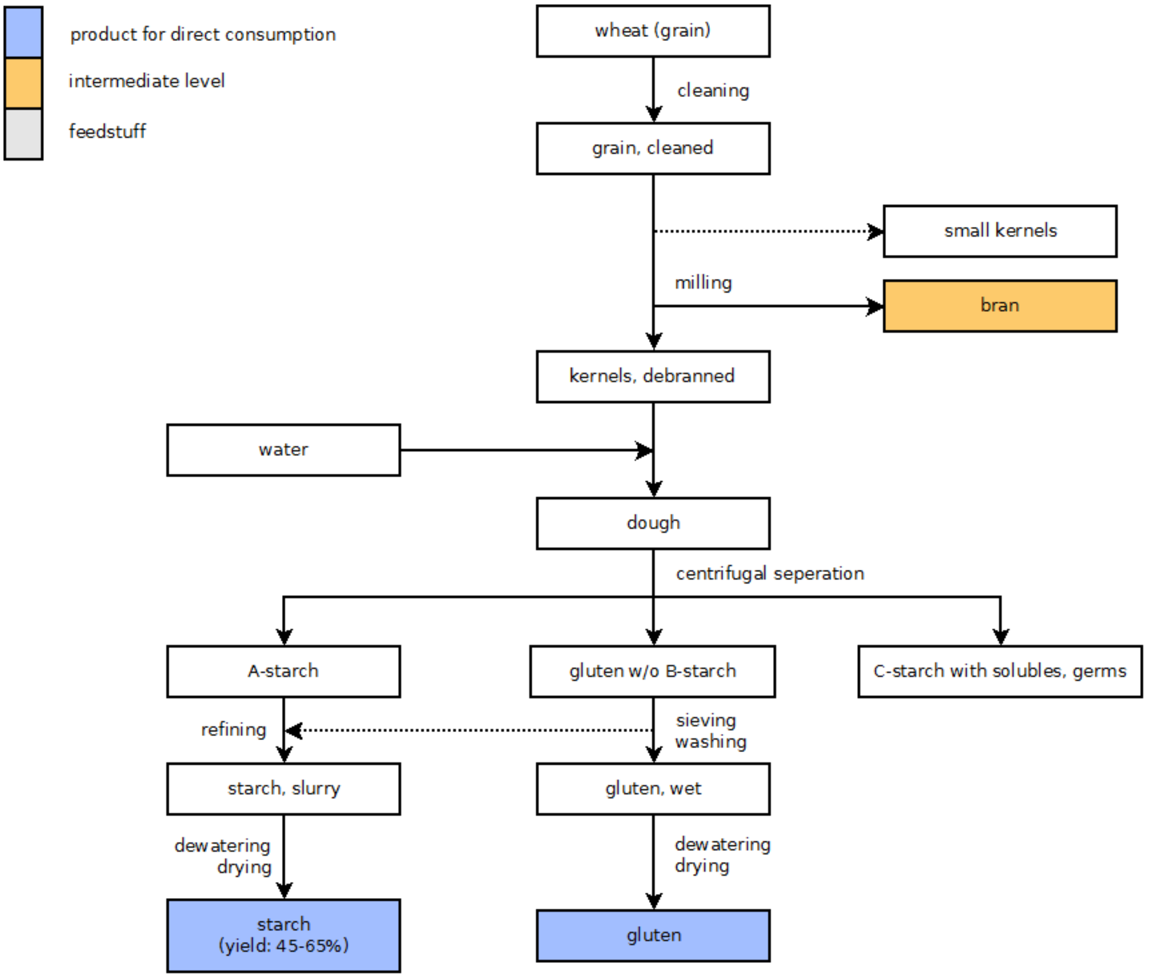
11.2.5. Comparison to industrial and/or household processing techniques

The described processing of starch production from potatoes is standard milling practice and is not typically conducted on domestic level.

11.3. Wheat starch

Apart from potatoes and maize, wheat is one of the most important raw materials for starch production. An important by-product is wheat gluten.

A simplified example of the wet-milling process is schematically shown in Figure 52 and described below.



Yield factor referenced by VGMS (2018).

Figure 52: Processing of wheat into starch (XI-009)

Cleaning

The wheat is cleaned to remove remaining chaff and non-wheat materials like soil and stones. Small wheat kernels may be sieved off, as they contain a significantly lower amount of starch relative to their surface.

Milling

The cleaned and sieved wheat kernels are tempered with water and subsequently milled. The bran fraction is separated by screening and can be either used as food (after refining) or feed. The crude wheat flour is fully moistened (dough preparation) or, alternatively, a batter is made. After further dilution with water the dough is centrifuged to A-starch, B-starch with gluten as well as pentosane-rich C-starch.

Separation and fractionation

A-starch is refined by washing with water. The starch slurry is subsequently dewatered and dried.

From the B-starch fraction gluten is obtained through sieves. The separated starch may be added to the A-starch or used for fermentation. C-starch with hemicelluloses is used for fermentation or animal feed.

11.3.2. By-products of wheat starch production

There are several by-products, like small wheat kernels, bran, or C-starch with hemicellulose which can be used as animal feed, for fermentation processes or for biogas production. According to industry, usage as feed is possible as well. No corresponding entry exists in the current OECD feeding table or in EFSA's User Guide to the PROFile (EFSA, 2016e; OECD, 2013).

11.3.3. Scientific studies reflecting typical processing operations

One study is selected as representative. The study adequately describes wheat starch processing (Ellis, 2012b).

Cleaned grain was steeped until it had a moisture content of more than 40%. The steeped grain was milled with a disc mill. The milled products were separated into wet starch, wet gluten and fibre by centrifugation. The wet starch fraction was refined by washing with water, centrifugation and sieving. Starch and gluten were dried at 50°C in a drying oven.

The study is referenced by EFSA (EFSA, 2015b) in a Conclusion and is acceptable according to the quality criteria.

11.3.4. Extrapolation to other commodities

No extrapolation to other cereals is recommended.

11.3.5. Comparison to industrial and/or household processing techniques

The described processing of starch from wheat is standard milling practice and is not typically conducted on domestic level.

12. Cocoa powder production

Cocoa powder is used as an ingredient in the food industry for a variety of products. It is used, among others, in chocolate flavoured beverages, ice cream and desserts.

12.1. Processing details

The RAC is defined as the fermented or dried seeds of the cocoa tree (cocoa beans). The processing of cocoa beans into cocoa powder is shown in Figure 53 and is described below.

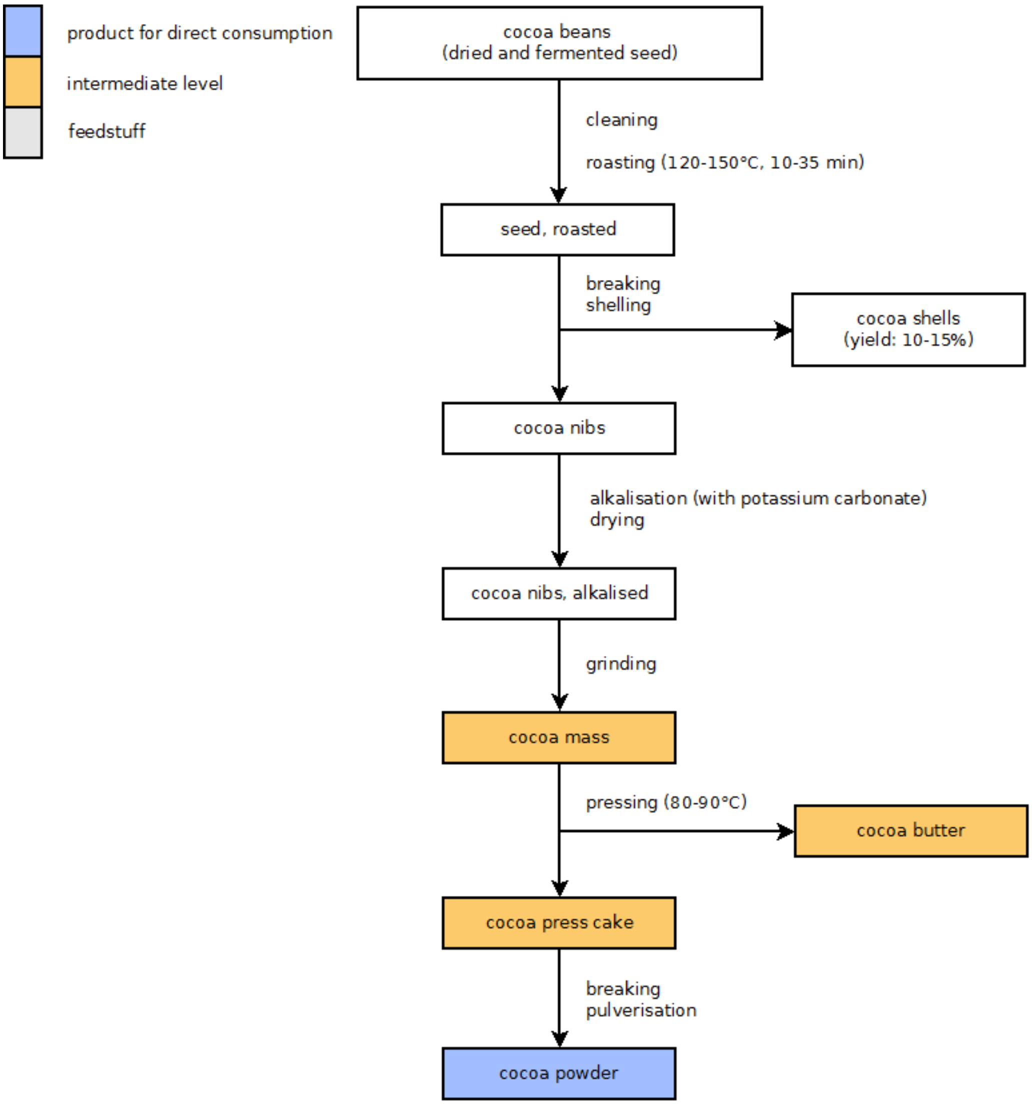


Figure 53: Processing of cocoa beans into cocoa powder (Heiss, 2004) (XIII-002)

Roasting

The water content of cocoa beans is approximately 6-8%. The beans are cleaned and subsequently roasted. Roasting time and temperature depends on the type of beans but is usually between 120 and 130°C and takes 10 to 35 minutes (Heiss, 2004).

After roasting, the cocoa beans are broken and the shells are removed from the cocoa nibs by airstream. The cocoa nibs are immersed in an alkaline solution (potassium carbonate). Thereby, the natural pH of 5 to 5.6 is raised to 7 - 8.

Another method involves roasting of the cocoa nibs instead of the whole cocoa beans. The cocoa beans are only heated to temperatures which allow removing of the shells. The cocoa nibs are subsequently alkalised, dried and roasted.

Pressing

The nibs are ground yielding cocoa mass. The cocoa mass is pressed at temperatures between 80 and 90°C to remove some of the cocoa butter.

The obtained cocoa press cake is then crushed and ground to cocoa powder. Two cocoa powder types can be differentiated by their fat content. Typical fat content for low fat cocoa powder is 10-12% and for high fat cocoa powder 20-22% (Heiss, 2004; Schuchmann and Schuchmann, 2005).

12.2. By-products of cocoa processing

By-products of the cocoa powder processing are cocoa shells and cocoa butter.

Cacao shells can be used as an ingredient for tea mixtures.

Cocoa butter is used in the food industry, for example in the production of nougat and some types of chocolate like couverture chocolate or milk chocolate. Other fields of application include cosmetics and pharmaceutical ingredients.

12.3. Scientific studies reflecting typical processing operations

No studies on processing of cocoa beans were available.

12.4. Extrapolation to other commodities

No extrapolation to other commodities is recommended.

12.5. Comparison to industrial and/or household processing techniques

The processing of cocoa beans into cocoa powder is not a common household process.

13. Sugar

Sucrose is a disaccharide (glucose and fructose) and the economically most significant sugar. The two most important sources for sucrose production are sugar cane and sugar beet. In 2017 the European Union was world's leading producer of beet sugar, with about 50% of total (EC, online-b). Cultivation and processing is operated in Europe. Furthermore, the EU imports raw sugar cane for industrial refining. The world's sugar production is composed of 80% sugar cane and 20% sugar beet processing.

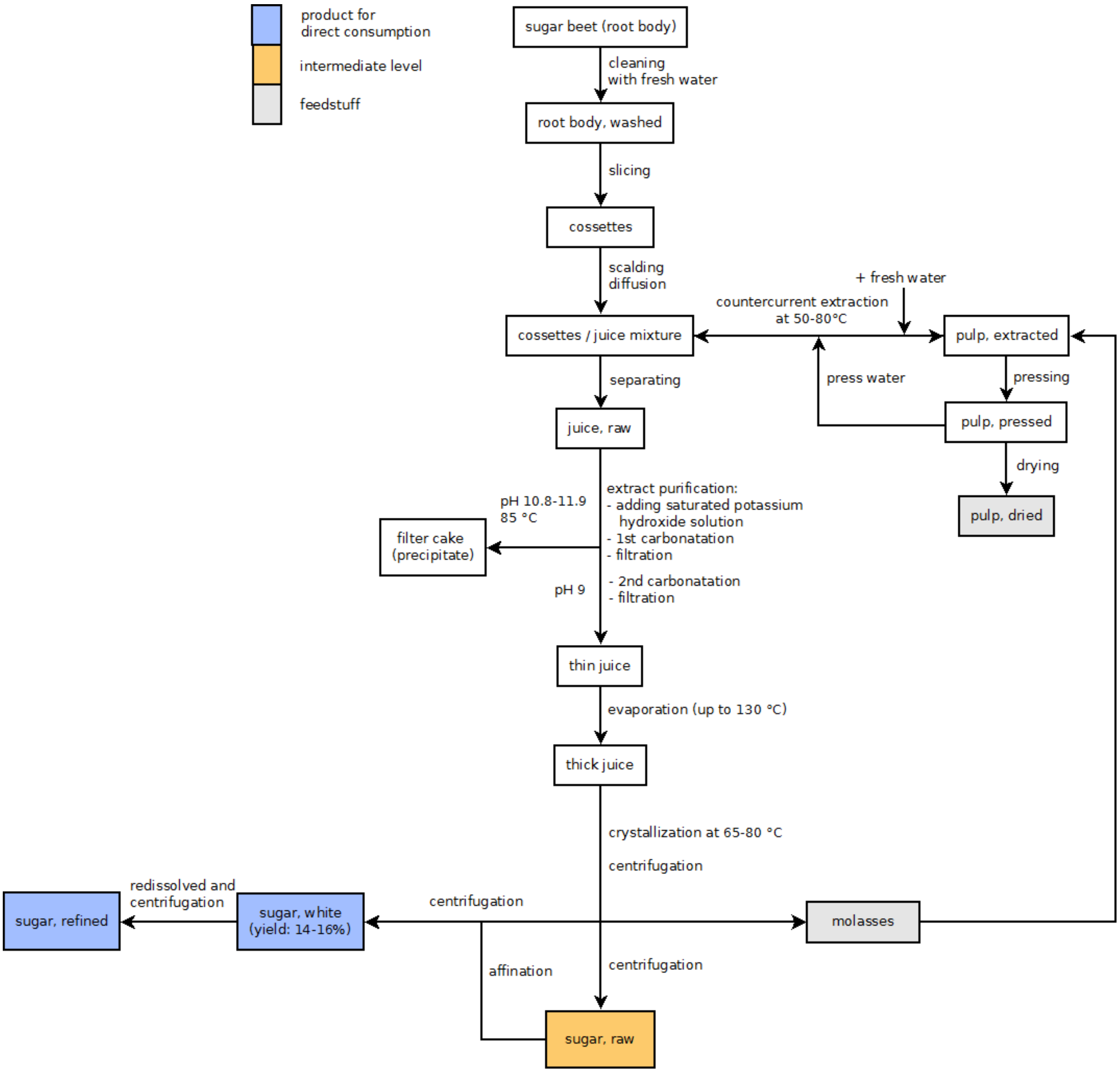
13.1. Sugar beet

The sugar content and the amount of non-sugar substances differ depending on the beet variety. Sugar beet contains about 17% sucrose (Heiss, 2004).

13.1.1. Processing details

Sugar production from sugar beets is depicted in Figure 54 and is explained below. The RAC is defined as the whole product after removal of tops and adhering soil by rinsing or brushing.

The sugar production is a highly optimised industrial process. Different key parameters have an impact on the residue level of pesticides such as temperature, boiling time, amount of water and physicochemical properties of the pesticide (e.g. volatility and hydrolytic stability). Some pesticides, depending on their water solubility, may be transferred from the RAC into the water. Heat-labile pesticides can degrade during evaporation. Molasses can contain a higher residue concentration than raw sugar. Normally, the pesticide residue concentration in sugar is negligible.



The sugar beets contain about 17% of sucrose (Heiss, 2004). Based on this content the sugar yield from beet to white sugar is about 14-16% (Agrana, 2014). The molasses contain the rest of the sucrose. The overall loss of sucrose during processing is only 0.4 – 0.6%.

Figure 54: Production of beet sugar (XII-001)

Washing and slicing

The sugar beets are washed with water and cleaned. The cleaned beets are mechanically sliced into shreds (about 2-3 mm thick and 4-7 mm wide), called cossettes.

Extraction

The solid/liquid extraction is performed by a continuous counter current process. The shredded sugar beets are leached in heated water or diffusion liquid, which is recirculated from the extraction process. The temperature is around 70°C (50-80°C)°C for thermal denaturation of the cells to release the sucrose (Belitz et al., 2009; Heiss, 2004; VDZ, 2018). The operation conditions are sterile due to short critical temperature times.

The industrial extraction is characterised by a production of "cold" juice and a complete press water recirculation. The extracted cossettes contain 10-12% dry substance (BMA, online) and are discharged, pressed and dried. The pressed water is recirculated to the extraction process. The processed cool raw juice (sugar extract) is a 15% sugar solution, which is subjected to the next step (Heiss, 2004).

Extraction is usually carried out between pH 5 and 7 (Poel et al., 1998; VDZ, 2018).

Purification of raw sugar extract

Purification is accomplished to clean the juice and to separate non-sugar compounds. Those components are precipitated by adding saturated potassium hydroxide solution and carbon dioxide. Raw juice has a pH of 6.2.

For pre-liming the raw juice is treated with 0.2-0.3% lime on juice for 20 min until pH 10.8-11.9. For cold main liming another 0.3-0.7% lime on juice is added followed by hot main liming at 80-85°C for 30 min (Belitz et al., 2009). For carbonation, carbon dioxide is added in two steps. In between the sludge is clarified by filtration. A final pH of 8.9-9.2 is reached and the remaining sludge is filtered off. The result is a clear light-coloured thin juice (Belitz et al., 2009).

During juice purification the pH ranges between 8 and 12 and temperatures around 70-95°C can be reached (VDZ, 2018).

Evaporation

The thin juice is concentrated by water evaporation (falling film evaporators, natural or forced circulation evaporators). High temperatures (up to 130°C) can be reached °C and the sugar content in the final thick juice ranges from 60-75 (Belitz et al., 2009; VDZ, 2018).

Crystallisation and Centrifugation

To isolate the sucrose from thick juice, a multistage crystallization is used. The following description is simplified. The thick syrup is reduced at temperatures of around 65-80°C (Belitz et al., 2009) in vacuum pans until slight supersaturation occurs due to evaporation. Sugar starts to crystallize at a certain concentration. To ensure a consistent crystallization a suspension with small sugar crystals is added. The crystallization process is interrupted when the crystal content reaches about 55% (VDZ, 2018). This intermediate product of crystals and syrup is mashed for homogenisation, continuously circulated and further passed to centrifuges.

To separate the crystals, the syrup (mother liquor) is centrifuged in batch centrifugals with high rotational speeds. The centrifugation process is a sequence of different crystallization stages. The obtained products are raw sugar, white sugar and molasses. Raw sugar is not suitable for direct use, thus it is processed in refineries to consumer sugar.

If the white sugar is re-dissolved and centrifuged again, a product of high quality and purity is produced, called refined sugar.

Remaining syrup is crystallized in a third crystallization step and molasses is obtained. Molasses is dark-brown syrup and still contains approximately 50% sugar (Heiss, 2004) and non-sugar compounds. The remaining sugar cannot be crystallized again.

Drying

The sugar is dried, cooled and stored in silos. Depending on the customers' requirements it is sieved and packed.

Types of sugar

Raw sugar from sugar beet is not suitable for direct use. Thus it is processed in refineries to consumer sugar.

Several types of granulated white sugar are produced. A few are only used in food industry and bakeries, others are available to consumers. The types differ in crystal size. Refined sugar is a white sugar with a higher quality and purity.

Commercial brown sugar is produced by adding molasses syrup to refined sugar. Depending on the percentage of molasses the sugar is light or dark brown.

Liquid sugar is a white granulated sugar which has been dissolved in water.

13.1.2. By-products of sugar production

Dried beet pulp, remaining from the extraction process, as well as ensiled pulp can be used for animal feeding (OECD, 2013).

Molasses is the dark-brown viscous syrup, which remains after the last crystallization step. It still contains sugar (Heiss, 2004), which cannot be crystallized again. Molasses can be used for animal feeding, alcohol and yeast production.

13.1.3. Scientific studies reflecting typical processing operations

The following study was chosen as representative for the processing of sugar beet into white sugar and is available to EFSA. Overall, the matrices “white sugar” and “refined sugar” are both traded commodities. No worst case could be identified with respect to pesticide residues.

The study of Schulz (2001) is acceptable according to the quality criteria and is referenced by EFSA (2007). Processing was performed in a pilot plant. The processing steps included washing, slicing, extraction, pressing, and purification of raw juice, evaporation, crystallization (with evaporation and cooling), centrifugation and affination.

All relevant data were reported. After slicing to cossettes the extraction started with pre-heating to 69-76°C and lowering the temperature to 55-56°C, while the cossettes stayed in the trough for 64-97 min. The extracted cossettes were pressed at 400 bars for 0.60-0.87 h. The raw juice was purified by two-stage cold liming and two-stage carbonation. Saturated potassium hydroxide solution was added until pH 11 and operated for 20 min. Remaining saturated potassium hydroxide solution was added and the mixture was heated to 80°C and reacted for 30 min. Afterwards carbon dioxide was added until pH 11 and the mixture was filtered. The obtained thin juice was evaporated at 0.25-0.35 bar and 68-76°C. For crystallization the resulting thick juice was concentrated under vacuum and seeded with seed material. For magma cooling a cooling crystallizer reduced the temperature to 31°C. The resulting syrup was centrifuged and molasses and raw sugar obtained. The raw sugar was mashed with water and centrifuged resulting white sugar.

13.1.4. Extrapolation to other commodities

The processing of sugar beet and sugar cane differs in a few steps. Therefore, an extrapolation from sugar beet to sugar cane is not recommended.

13.1.5. Comparison to industrial and/or household processing techniques

The production of sugar is a typical industrial process with a high level of automation. The available processing study adequately reflects the industrial production of sugar.

The processing of sugar beet for sugar production is not a common household process.

13.2. Production of sugar from sugar cane

Processing code XII-002 is assigned to the preparation of sugar from sugar cane.

Sugar cane is not cultivated in Europe but imported for refining. Sugar cane contains 12-14% sucrose (The Sugar Association, online). For human consumption, raw cane sugar and white sugar are produced. Furthermore, sugar cane molasses can be used for animal feeding (OECD, 2013).

13.2.1. Processing details

The processing of sugar cane differs in some steps from the beet sugar production, especially since a variety of techniques can be applied for juice extraction, clarification and refining. The extraction of raw sugar is shown in Figure 55.

The RAC is defined as the whole cane stalk after removal of tops, roots and adhering soil by brushing. Cane stalks are usually harvested by hand and processed quickly to prevent deterioration. Cane stalks are cleaned and washed with water before being shredded for juice extraction. There are two commonly used techniques for cane juice extraction. Extraction through high pressure milling is the traditional way of processing fresh cane stalks, while diffusion extraction is a process adapted from sugar beet juice extraction (Rein, 1995; Schiweck and Clarke, 2000). When squeezed, the produced sap contains 70% or more of sucrose. A sucrose yield of 93-97.5% can be achieved by repeating the squeezing (Belitz et al., 2009). The pressed cane is called bagasse. The raw extract (pH 4.8-5.0) is clarified and neutralised with lime and/or carbon dioxide, and crystallized. The extracted raw sugar is further processed into refined sugar, similar to beet sugar production, as shown in Figure 56.

For human consumption, raw cane sugar and refined sugar are produced. Furthermore sugar cane molasses can be used for animal feeding (OECD, 2013).

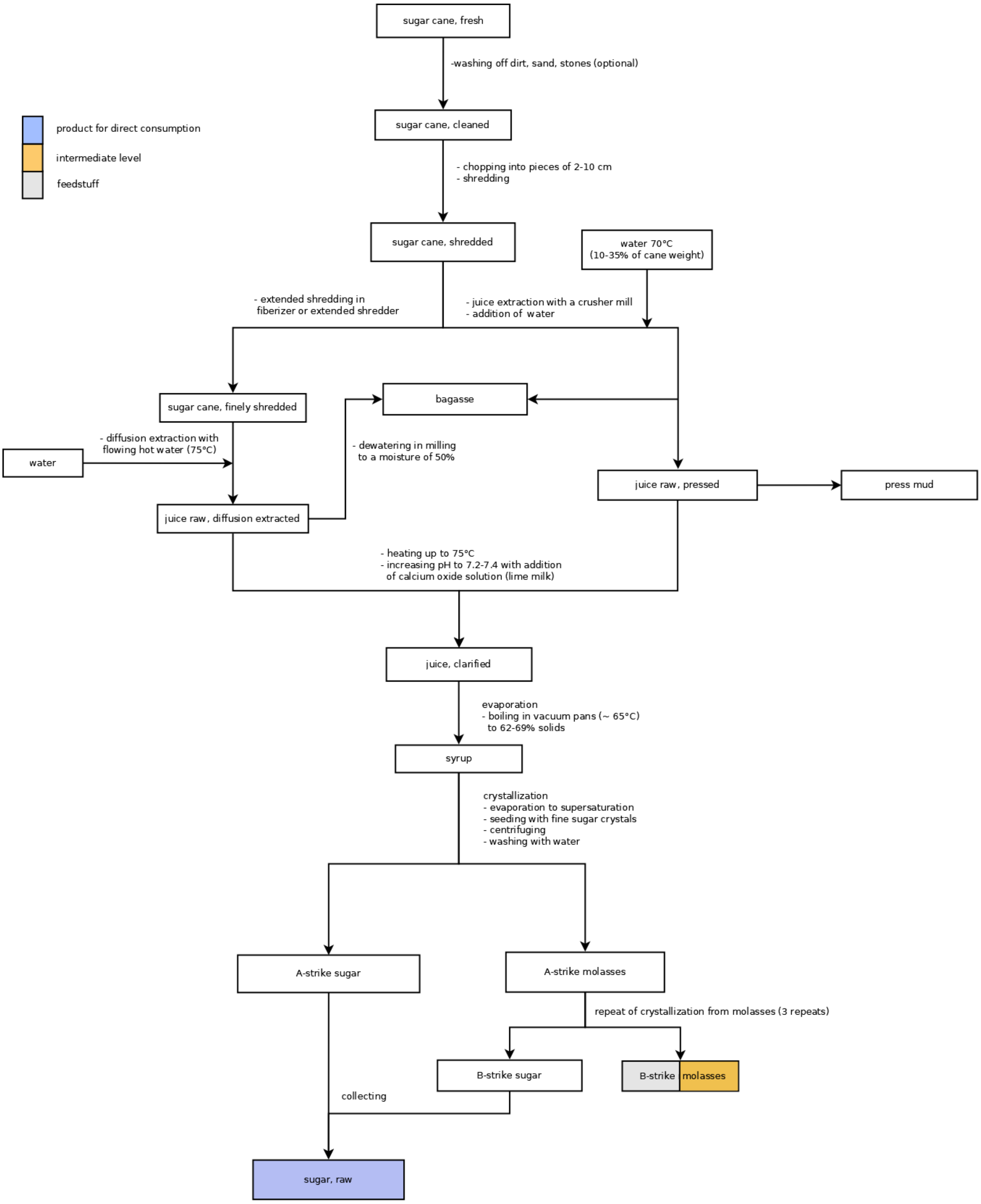


Figure 55: Raw sugar extraction from sugar cane (XII-002). A sucrose yield of 93 to 97.5% can be achieved by repeating the squeezing (Belitz et al., 2009).

Preparation after harvest

Sugar cane is commonly harvested by hand and processed within 24 hours after harvest. If necessary, sugar cane is dry cleaned from sand, rocks and soil and washed with water afterwards. To prepare the cane stalks for juice extraction, the stalks are first chopped into pieces of 2-10 cm with sets of revolving knives followed by shredding to rupture cells in the cane stalks for an increased extraction efficiency (Schiweck and Clarke, 2000).

Extraction by milling

The shredded cane is introduced into a milling train with multiple rolls to extract the raw juice. Water or recycled cane juice (70°C, 10-35% of cane weight) is added to the last roll in reverse direction to the cane. This process is called "imbition" and increases the juice yield. The raw juice with varying sugar content obtained from the multiple milling stages is collected and combined. The pressed cane, also called "bagasse", remains as a by-product of juice extraction (Schiweck and Clarke, 2000).

Extraction by diffusion

To extract the juice by diffusion, the shredded cane is further broken down in a fiberiser or extended shredder. The finely shredded material is placed in a diffuser and water (75°C) or recycled cane juice percolates through the cane matter and extracts the sugar from the bagasse. The by-product bagasse is dehydrated in a mill to 50% moisture (Schiweck and Clarke, 2000).

Clarification

To inactivate enzymes like invertase, the raw juice is heated up to 75°C for a few minutes and treated with calcium hydroxide solution (called lime milk) to increase the pH to 7.5 – 8.5. Heating and lime milk treatment lead to the precipitation of impurities and non-sugar substances that can be separated from the clarified juice through filtration (Prati and Moretti, 2010).

Evaporation

In a series of vacuum pans, the clarified juice is boiled from a solid content of 13-15% to one of 62-69%. Heat and pressure alternate during this processing step and the applied temperatures range between 65°C and 85°C (Eggleston et al., 2011; Schiweck and Clarke, 2000).

Crystallization

The syrup is further boiled in vacuum pans to super-saturation and seeded with fine sugar crystals to initiate crystallization. When the syrup reaches a concentration of 80-85% solids, raw sugar is obtained by centrifugation. The by-product of crystallization is a syrup called molasses, which is re-used for crystallization up to three times. The repeating process creates A-, B- and C-strike raw sugar and molasses. Raw sugar from different strikes is collected, washed with water steam, centrifuged and dried with hot air (42°C) to a moisture content of 0.2-0.5%. In contrast to raw beet sugar, extracted raw cane sugar is a product for direct human consumption.

Refining

Refining describes a purification process with the goal of obtaining pure sucrose from raw cane sugar. During washing, clarification and decolourization, impurities, colour and other non-sugar substances are removed, resulting in refined sugar.

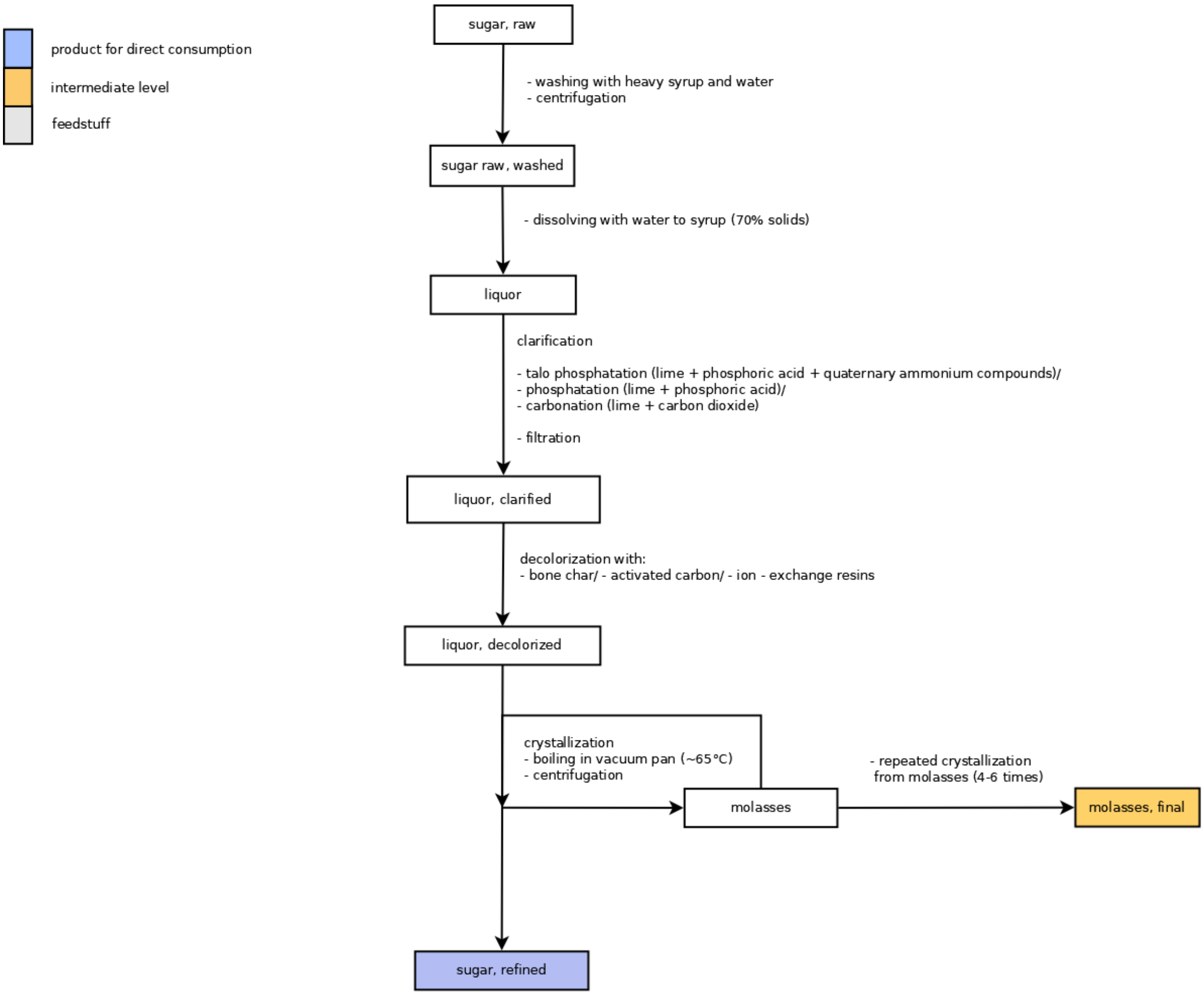


Figure 56: Process of refined sugar production from raw sugar (XII-002).

Washing

The raw sugar is washed by mixing it with a heavy syrup (80% solids), separation through centrifugation and subsequent washing with water (Schiweck and Clarke, 2000).

Melting

The washed sugar is dissolved in water (“melted”) into a liquor containing 70% solids (Schiweck and Clarke, 2000).

Clarification

Three ways of clarification exist to eliminate ashes, colour and turbidity from the liquor.

- Phosphatation: The addition of phosphoric acid (concentration up to 400 mg/kg solids) and calcium hydroxide to the liquor in an aerated floatation clarifier leads to the formation of calcium phosphate. Calcium phosphate precipitates while floating to the surface of the liquor. The clarified liquor is pumped from the bottom of the tank.
- Talo phosphatation: Resembles the process of phosphatation with the addition of quaternary ammonium compounds to increase precipitation.

- Carbonation: Calcium hydroxide and carbon dioxide are added to the liquor in a two-step process to filter out non-sugar substances (Schiweck and Clarke, 2000).

Filtration

Regardless of the type, any clarification is followed by a filtration step with pressure filters.

Decolourization

Decolourization usually is performed with one of the following three methods (Schiweck and Clarke, 2000):

- Ion-exchange resins: Treatment with basic macroporous anion exchangers at 80-85°C
- Activated carbon treatment
- Bone char treatment

Crystallization

Like in raw sugar factories, the decolourised or fine liquor is evaporated in a series of vacuum pans to 72-74% solids and seeded with fine sugar crystals to initiate the crystallization process. As with the crystallization of raw cane sugar, the by-product molasses is used for a repeated crystallization step. The repeated recycling of molasses creates multiple strikes of different quality sugars and molasses. Four to six strikes are common for white sugar (Schiweck and Clarke, 2000).

Conditioning

Trapped residues of water from the crystallization process can be removed by conditioning. Refined sugar is stored for four days under a dry air current to remove left-over moisture (Colonna et al., 2006).

13.2.2. By-products of sugar production

Molasses from raw sugar production are used for rum or ethanol production or animal feeding, while molasses from the refinery process can be further processed into molasses or syrup for human consumption (Schiweck and Clarke, 2000).

13.2.3. Extrapolation to other commodities

Extrapolation to other commodities is not recommended.

13.2.4. Scientific studies reflecting typical processing operations

One representative study is available reflecting sugar production from sugar cane. The study (Beasley, 1978) represents the previously described process of sugar production from sugar cane and is considered acceptable according to the quality criteria. It is not cited in any EFSA Conclusion or Reasoned Opinion, but was available from an authorisation procedure.

During sugar extraction, polar pesticides can concentrate in commodities along the process. Especially molasses from raw sugar extraction might contain increased residue levels compared to the RAC. Refined sugar in contrast is expected to contain low to no pesticide residues, due to the stripping characteristics of the refining process (Schiweck and Clarke, 2000).

Sugar processing was performed in a “processing mini factory” that was built to resemble industrial processing standards as close as possible. The study extracted refined sugar from frozen sugar cane including washing, shredding, juice extraction through pressing, clarification, evaporation, crystallization and refining.

The frozen, chopped sugar cane was processed in a cutter grinder into finely shredded sugar cane. Juice extraction was performed through hydraulic pressing in a cage plunger. After the first extraction, the plant material was macerated with the same volume of water that was extracted during the first press and was pressed again. The juice from both pressing steps was combined and filtered through a 100-mesh screen. To perform clarification, the juice was cold-limed to a pH of 7.4 and brought to the boil for three minutes. Non-sugar compounds were removed by transferring the juice into a settling tank and pumping out settlings from the bottom after 45 minutes. The clarified juice was evaporated afterwards for 15-20 minutes to a concentration of 65-70% solids at 71°C and 0.68 bar vacuum. During the crystallization step, concentrated syrup was further evaporated under changing vacuum conditions until a specific temperature was reached (~ 57.3°C). The next step involved seeding of fine crystals or shocking to initiate crystallization. Raw sugar and molasses were separated through a five-minute centrifugation step with the application of washing water from an atomiser. The refinery process started with dissolving the raw sugar in an equal amount of distilled water. The solution was heated to 60-65°C and treated with powdered carbon (2% based on sugar) for 15 minutes. After cooling down to a temperature of 50°C, the solution was filtered through a Hyflo Supercel pre-coated filter, which resulted in a clear and colourless filtrate. The filtrate was concentrated on an evaporator to a sugar content of 85% and seeded with a few crystals of refined sugar crystals while being stirred. The paste was transferred to a sintered glass funnel for separation of the mother liquid, after cooling down to 20°C. The filter cake was washed twice with a saturated sugar solution to remove the mother liquid and the refined sugar crystals were sucked dried in a vacuum oven at 60°C.

13.2.5. Comparison to industrial/ and or household processing techniques

Cane sugar extraction is not a common household process.

Glossary

Process	Explanation
Affination	Raw sugar is washed with hot water and steam. During centrifugation the syrup is removed from the sugar crystals. The end-product is white sugar.
Baking	Thermal process with heated air. Baking is commonly applied to cereals (bread baking) or vegetables such as potatoes.
Blanching	Heat treatment of an organic substance in order to denature natural enzymes, soften tissue and remove raw flavouring and followed by immersion in cold water to halt the cooking process. Two methods are applied: water blanching and steam blanching.
Brix	Content of soluble dry matter content (soluble solid).
Canning	Process to preserve a wide range of vegetable or fruit products (whole fruits or fruit sections). Depending on the pH, products are usually pasteurised or sterilised in closed package, to ensure longer shelf-life (preserves).
Dehydration (drying)	Content of water is decreased by different methods such as evaporation (sun drying or contact with hot air or heated surfaces) or sublimation (freeze drying).
Dehydration factor (generic)	Ratio of dry matter content in dried product divided by dry matter content in fresh product
Depectination	In order to gain clear juice, cloudy raw juice may be treated by pectolytic enzymes and clarification to remove the starch and pectins holding fine particulate in suspension. In addition, depectinases are used to increase the juice yield by enzymatic treatment of the mash.
Fermentation	Enzymatic conversion of organic substances into alcohol, gases and organic acids.
Flakes	Dried, grinded potato mash.
Frying	Heat is transmitted to food by effect of heated oil or fat.
Granules	Dried potatoes and water content removal.
Jam	Mixture of sugars, the pulp and/or purée of one or more kinds of fruit and water.
Jelly	Gelled mixture of sugars, juice and/or aqueous extracts of one or more kinds of fruit.
Juicing	Juicing of fruits and vegetables includes physical or enzymatic action or a combination of the two.
Malting	Controlled sprouting of cereal grain under artificial conditions.
Marmalade	Mixture of water, sugars and one or more products obtained from citrus fruit: purée, pulp, peel, juice and aqueous extracts.
Microwaving	Thermal heating by effect of microwaves to induce processes such as cooking, frying, pasteurisation or sterilisation.
Milling	Reducing to fragments, shreds or powder by passing through a grinder, crusher or mill. For example grain is separated into flour, bran and germ.
Must	Intermediate level during vinification and juicing. Unfermented juice extracted by pressing of mashed wine or table grapes.
Paste	Purée which is further concentrated by evaporation.
Pasteurisation	Heat treatment with a time-temperature combination that guarantees the inactivation of all pathogenic microbial flora and extends the product shelf-life. It does not kill spores or heat resistant bacteria.
Peeling	Removing of inedible or edible peel of fruits or vegetables. Mainly steam, lye and mechanical peeling methods are used.
Pickling	Preservation method in which the pH value of food is lowered.
Pomace	Remaining (stems, seeds, cores or peel) after pressing/extraction of fruits or vegetables.
Pulp	Synonymous to fruit flesh. Obtained after removing stones and inedible peels from fruit and vegetables.
Purée	Edible part of the whole fruit or vegetable is prepared (pulp), heated, sieved and concentrated by evaporation to the required consistency and desired Brix.
Purification (sugar)	Cleaning the juice and separating non-sugar compounds.
Refining (sugar)	White sugar is re-dissolved and centrifuged again. A product of high quality and purity is the end product.
Refining (oil production)	Removing of undesirable substances such as free fatty acids, phospholipids, coloured compounds and water.
Roasting	Cooking with dry heat
Slicing	Mechanical slicing into different sizes. Slices of sugar production are called cossettes.
Steaming	Water is boiled until it vaporises. Without direct contact of food with the boiling water.

Process	Explanation
Sterilisation	Heat treatment at temperatures of at least 120°C. Aiming a complete destruction of microorganisms.
Washing	Washing and sorting is a common initial step in food production. The washing systems consist of brush washer and/ or spray washer.

Abbreviations

Process	Explanation
BfR	German Federal Institute for Risk Assessment
BPI	Benaki Phytopathological Institute
EFSA	European Food Safety Authority
MRL	Maximum residue level (for pesticides). The maximum amount of a pesticide residue allowed in foods or animal feeds, expressed as milligram per kilogram.
OECD	Organisation for Economic Co-operation and Development
PF	Processing Factor
RAC	Raw agricultural commodity
RIVM	National Institute for Public Health and the Environment

Appendix A Tabular summary of recommended extrapolations

Processing procedure	OECD code	Example of typical RAC	Extrapolations
Cooking in water	VI	potatoes, beans (with pod), beans (without pod), beans (pulses), cabbages, celeries, spinach	potatoes → carrots, sweet potatoes, pumpkin (only cooking procedure) beans (with pod) → legume vegetables (with pod) beans (without pod) → legume vegetables (without pod) beans (pulses) → other pulses cabbage → head cabbage, other brassicas within subgroups celeries → other stem vegetables spinach → other leaf vegetables
Steaming	VI	potatoes	potatoes → carrots, sweet potatoes
Canned fruits	III	strawberries, apples, mandarins, peaches, plums	strawberries → other small berries apples → other pome fruits mandarins → other citrus fruits peaches → other stone fruits (processed peeled) plums → other stone fruits
Canned vegetables	VIII	tomatoes, beans, carrots, mushrooms, peppers, leeks	tomatoes → none beans → other legume vegetables (differ in with or w/o pod) carrots → other root and tuber vegetables mushrooms → other fungi peppers → other fruiting vegetables leeks → other leave vegetables
Jam	IV	currants, apples, plums, peaches	currants → other small berries apples → other pome fruits plums → other stone fruits peaches → other stone fruits (processed peeled)
Jelly	IV	table grapes, apples	table grapes → other small berries apples → other pome fruits
Marmalade	IV	oranges	orange → other citrus fruits
Purée	IV/VII	apples, strawberries, tomatoes	apples → all pome fruits strawberries → other small berries tomatoes → none
Paste	VII	tomatoes	tomatoes → none
Drying	XVI	fruits (banana, table grapes, plums, apples, small berries), vegetables (tomato, peppers, mushrooms, onions), herbs and spices	dried commodity → commodity with comparable water content
		potatoes (purée)	potatoes (purée) → none
	XIII	tea	none
Frying	IX	potatoes	potatoes → other root and tuber vegetables
Baking	IX	potatoes	potatoes → other root and tuber vegetables
Roasting	IX	peanuts	peanuts (roasted) → none
	XIII	coffee beans	coffee beans (roasted) → none coffee beans (instant coffee) → none
		chicory roots	root, roasted → none
Microwaving	XVIII	potatoes	potatoes → other root and tuber vegetables
Citrus juice	II	oranges	oranges → other citrus fruits
Pome juice	II	apples	apples (clarified juice) → other pome fruits (clarified juice) apples (unclarified juice) → other pome fruits (unclarified juice)
Grape juice	II	grapes	grapes → small berries
Stone fruit juice	II	peaches	peaches → other stone fruits

Processing procedure	**OECD code**	**Example of typical RAC**	**Extrapolations**
Tropical fruit juice	II	mangoes, pineapples	mangoes → other tropical fruits (with inedible peel)
Vegetable juices	VII	tomatoes, carrots	tomatoes → none carrots → other root and tuber vegetables
Wine production	V	wine grapes	wine grapes → other small berries wine grapes (red variety) → sparkling wine (red variety), rosé wine wine grapes (white variety) → sparkling wine (white variety)
Fermentation to sauerkraut	XVII	head cabbages	head cabbages → other fermented brassica cabbages
Fermentation of fruits/ vegetables	XVII	table olives, gherkins	table olives → none gherkins (pickled) → other fruiting vegetables (pickled)
Fermentation of soya beans	XVII	soya beans	soya beans (sauce) → none
Production of sake	XVII	rice	rice → none
Oil production - olives	Xa, Xb	olives	olives → none
Oil production - maize	Xc	maize	maize (wet/ dry milling) → other cereals (germ oils)
Oil production - oilseeds	Xa, Xb	peanuts, sunflower seeds, rape seeds, soya beans, cotton seeds, grape seeds, linseed	rape seeds → other oilseeds
Production of essential oils	Xa, Xb	peppermint, oranges	peppermint → other herbs orange → other citrus fruits
Oil production - palm oil - palm kernel oil	Xa, Xb	palm fruit, palm kernels	palm fruit → none palm kernels → none
Soya drink and tofu	IX	soya beans	soya beans (drink) → none soya beans (tofu) → none
Beer brewing	V	hops (dried), barley	hops (dried) → none barley → wheat, rye spirit → none
Milling	XI	wheat, barley, oats, maize, rice, sorghum	wheat (flour) → rye, spelt, triticale barley (pearl barley) → none barley (flour) → none oats (rolled oats) → barley (flakes) maize → none rice → none sorghum (flour) → wheat (wholemeal flour), rye (wholemeal flour), spelt (wholemeal flour), triticale (wholemeal flour), oat (wholemeal flour)
Starch production		maize, wheat, potatoes	maize (starch) → none wheat (starch) → none potato (starch) → starch from other root and tuber vegetables
Cocoa powder	XIII	cocoa beans	cocoa beans → none
Sugar	XII	sugar beets	sugar beets → none
	XII	sugar cane	sugar cane → none

Appendix B Overview of representative studies

Processing procedure	Commodity	Study	Author	Year	Study No/ Report No	EFSA Journal
Cooking in water	Potatoes	*Magnitude of 1,4-dimethylnaphthalene and 1-hydroxymethyl-4-methylnaphthalene (m21) residues in raw, boiled, microwaved, and fried potato samples.*	Van Hoven RL; Nixon WB	2012	535C-129	*EFSA Journal 2014;12(6):3735*
		Determination of the residues of glufosinate-ammonium in/on potato tuber for processing and the processed fractions after spraying of AE F039866 00 SL18 B7 (200 SL) in the field in Germany, the Netherlands and Belgium.	Melrose I; Eberhardt R	2006	RA-3079/05	*EFSA Scientific Report (2005) 27, 1-81*
		Magnitude of residues of Penthiopyrad and its metabolites in potatoes and potato processed fractions following applications of DPX-LEM17 20SC and 20EC at an exaggerated rate - USA and Canada, 2008.	Rice F	2009	DuPont-24499 ! ABC 63560	*EFSA Journal 2012;10(10):2948*
	Beans (with pod)	*lambda-Cyhalothrin: Residue study on beans with pods and processed fractions in Italy and Spain in 2010.*	Weir A	2011	S10-01575 ! T0025335	*EFSA Journal 2014;12(1):3546*
	Peas (without pod)	*Fluazifop-P-Butyl – Residue Study on Peas without Pods (Processing) in Germany and the United Kingdom in 2010.*	Langridge G	2013	FA-22-06-06	*EFSA Journal 2015;13(3):4059*
	Peas (pulses)	*Fluazifop-P-Butyl – Residue study on Dried Peas (processing) in Northern France and Germany in 2011.*	Devine C	2013	CEMS-4751	*EFSA Journal 2015;13(3):4059*
	Cabbages	*Chlorothalonil (R44686): residue study on head cabbage and cooked cabbage products in Switzerland.*	Gardinal P.	2006	05-6038	*EFSA Journal 2012;10(10):2940*
	Spinaches	*Lambda-Cyhalothrin: Residue levels in spinach and processed commodities from trials conducted in Northern Europe during 2000.*	Old J; Bruss J; Anthony S; Chapman S	2002	2001/1000942 ! IF-100/13960-00	*EFSA Journal 2014;12(1):3546*
Steaming	Potatoes	*Magnitude of residue of imidacloprid and its metabolites in potato raw agricultural commodity and processing fractions after one tuber treatment or one treatment in furrow with SeedOprid 600 FS (imidacloprid 600 g/L) – 6 trials (3 decline trials + 3 harvest trials) – Southern Europe – 2012*	Bastiani C	2013	BPL12/467/CL ! R-30299	*not cited*

Processing procedure	Commodity	Study	Author	Year	Study No/ Report No	EFSA Journal
Canning - fruits	Strawberries	*Lambda-Cyhalothrin - Residue levels in strawberry (field) and processed fractions from trials conducted in Southern France during 2001.*	Goodband T; Volle C	2002	PP321/1925 ! AF/5581/SY	*EFSA Journal 2014;12(1):3546*
	Peaches	*Determination of Captan and Tetrahydrophthalimide residues in peaches (RAC and processed fractions) following treatments with the preparation Captan 80 WG in Southern France under field conditions in 2005, Part 1 - Final Report*	Simek I	2007	R A5062	*EFSA Journal 2011;9(4):2151*
	Plums	*Magnitude of residues of Captan and THPI in plum processing products (follow up & baby food processings) following four applications of Captan 80 WDG - Northern Europe, Season 2007*	Wieser F; Klimmek A	2009	ARY-0707	*EFSA Journal 2013;11(7):3337*
	Apples	*Magnitude of the residue of thiophanate-methyl in apple raw agricultural commodity and processed fractions (Northern Europe - 2002)*	Grolleau G	2003	1014/01 ! CGA215944/4873 ! 4873	*EFSA Journal 2012;10(4):2685*
	Mandarins	*Determination of the residues of thiophanate methyl in/on oranges, mandarins and orange juice and marmelade and canned mandarins after post harvest application (drencher) of thiophanate methyl 500 SC*	Pollmann B	2007	20064082/S1-FPH ! 632-0301 ! RD-01293	*EFSA Journal 2014;12(12):3919*
Canning - vegetables	Tomatoes	*Isopyrazam and Cyprodinil: Residue tomatoes processed products in France (South) in 2009.*	Gemrot F	2012	S09-00358 ! T015542-04 ! A16934C_10026	*EFSA Journal 2015;13(1):3994*
	Gherkins	*Determination of the residues of BAS 510 F and BAS 490 F in gherkins and processed products following treatment with BAS 517 00 F under field conditions in Germany 2000*	Scharm M	2001	2001/1009069 ! 00/PF/003	*EFSA Journal 2014;12(7):3799*
	Beans	*lambda-Cyhalothrin: Residue study on beans with pods and processed fractions in Italy and Spain in 2010*	Weir A	2011	S10-01575 ! T0025335	*EFSA Journal 2014;12(1):3546*
	Carrots	*Determination of the residues of BAS 510 F and BAS 500 F in carrots and processed products following treatment with BAS 516 GA F under field conditions in Germany 2000*	Scharm M	2001	BN-713-010, 2002/7004459	*EFSA Journal 2014;12(7):3799*
Canning – jam, jelly and marmalade	Black currants	*Lambda-Cyhalothrin - Residue levels in blackcurrants and processed fractions from trials conducted in Northern France during 2002*	Ryan J; Richards S	2004	PP321/2231 ! RJ3419B	*EFSA Journal 2014;12(1):3546*
	Table grapes	*AE C656948 500 SC: Magnitude of the residue on grape processed commodities.*	Mackie SJW	2008	RAGMP042 ! M-298571-01-1	*EFSA Journal 2013;11(4):3052*

Processing procedure	Commodity	Study	Author	Year	Study No/ Report No	EFSA Journal
	Mandarins	*Determination of the residues of thiophanate methyl in/on oranges, mandarins and orange juice and marmelade and canned mandarins after post harvest application (drencher) of thiophanate methyl 500 SC.*	Pollmann B	2007	20064082/S1-FPH ! 632-0301 ! RD-01293	*EFSA Journal 2014;12(12):3919*
Canning - purée and paste	Apples	*SYN520453 - Residue study on apple and processed products in France (South) in 2008 - Final report.*	Oppilliart S	2009	A15149AC_11318!T009264-07-REG	*EFSA Journal 2013;11(4):3165*
	Tomatoes	*SYN545192 (A15457B) and SYN545192 + Azoxystrobin (A18126B): Magnitude of the residues of SYN545192 in or on tomatoes and peppers (representative commodities of crop group 8) following foliar applications USA 2011.*	Mäyer T	2012	A15457B_50059 ! 12SYN322.REP ! TK0058641	*EFSA Journal 2015;13(3):4043*
		Magnitude of DPX-E2Y45, IN-EQW78, IN-ECD73, and IN-F6L99 residues in processed fractions of tomatoes (fruiting vegetables, solanacea) following foliar applications of DPX-E2Y45 35WG- Europe, 2005.	Foster AC; Cairns SD; Davidson J; Hunter TM	2006	DuPont-16588 RV1	*EFSA Journal 2013;11(4):3143*
	Potatoes	*SYN545192 (A15457B) and SYN545192 + Azoxystrobin (A18126B) - Magnitude of the residues of SYN545192 in or on potatoes (representative commodity of crop group 1C tuberous and corm vegetables) following in-furrow and foliar applications USA 2011*	Mäyer T	2012	A15457B_50051 ! 12SYN321.REP ! TK0058640	*EFSA Journal 2015;13(3):4043*
Drying	Plums	*Magnitude of residues of Penthiopyrad and its metabolites in processed fractions of plums (stone fruit) following application of DPX-LEM17 20SC under maximum label rate - USA, 2007 - Revision no. 1*	Shepard E	2008	DuPont-22304 Revision no. 1 ! ABC 62397	*EFSA Journal 2012;10(10):2948*
	Table grapes	*SYN545192 150EC (A17056D): Magnitude of the residues in or on grape*	Mäyer T	2012	A17056D_50003 ! 11SYN294.REP ! TK0025158 ! 11SYN294.REP	*EFSA Journal 2015;13(3):4043*
	Apples	*BYI08330 150 OD: Magnitude of the residue on apple processed commodities*	Mackie SJW	2006	RAFNY014 ! M-276832-01-1	*EFSA Journal 2013;11(6):3243*
	Tomatoes	*Isopyrazam and Cyprodinil: Residue tomatoes processed products in France (South) in 2009*	Gemrot F	2012	S09-00358 ! T015542-04 ! A16934C_10026	*EFSA Journal 2015;13(1):3994*
	Potatoes	*SYN545192 (A15457B) and SYN545192 + Azoxystrobin (A18126B) - Magnitude of the residues of SYN545192 in or on potatoes*	Mäyer T	2012	A15457B_50051 ! 12SYN321.REP ! TK0058640	*EFSA Journal 2015;13(3):4043*

Processing procedure	Commodity	Study	Author	Year	Study No/ Report No	EFSA Journal
		(representative commodity of crop group 1C - tuberous and corm vegetables) following in-furrow and foliar applications USA 2011				
Frying	Potatoes	*Magnitude of residues of Penthiopyrad and its metabolites in potatoes and potato processed fractions following applications of DPX-LEM17 20SC and 20EC at an exaggerated rate - USA and Canada, 2008*	Rice F	2009	DuPont-24499 ! ABC 63560	*EFSA Journal 2012;10(10):2948*
		Magnitude of 1,4-dimethylnaphthalene and 1-hydroxymethyl-4-methylnaphthalene (m21) residues in raw, boiled, microwaved, and fried potato samples	van Hoven RL; Nixon WB	2012	535C-129	*EFSA Journal 2014;12(6):3735*
Baking	Wheats	*Determination of residues of trinexapac after one application of Trinexapac-Ethyl 250 g/L EC in winter wheat (outdoor) at 2 sites in Northern and Southern Europe 2010*	Fischer K	2011	S10-01352	*EFSA Journal 2012;10(1):2511*
	Potatoes	*Determination of the residues of glufosinate-ammonium in/on potato tuber for processing and the processed fractions after spraying of AE F039866 00 SL18 B7 (200 SL) in the field in Germany, the Netherlands and Belgium*	Melrose I; Eberhardt R	2006	RA-3079/05	*EFSA Scientific Report (2005) 27, 1-81*
Roasting	Coffee beans	*A17961: Magnitude of residues of SYN545192 and Metabolites, Azoxystrobin and R230310 in coffee beans and its derivatives - Brazil, 2011 -12*	Casallanovo, F	2012	A17961A_50005 ! M11173 ! TK0002522	*EFSA Journal 2015;13(3):4043*
Microwaving	Potatoes	*Maleic hydrazide residues in potatoes and microwaved baked potatoes treated with Antergon MH 180*	Patel NP	1994	M.6.2.6.27! AG/REP/15375/01	*EFSA Journal 2011;9(10):2421*
Juicing – citrus fruit	Oranges	*ADMIRE 2F - Magnitude of the residue on orange processed commodities*	Maloney AL	1994	106651 ! 106551 ! M-024942-01-2 ! MO-00-003134 ! AD19TO01	*EFSA Scientific Report (2008) 148, 1-120*
		Lambda-Cyhalothrin - Residue levels in oranges and processed fractions from trials carried out in Spain during 1999.	Brereton R; Volle C; Brown D	2000	PP321/0962 ! AF/4881/ZE	*EFSA Journal 2014;12(1):3546*
		BAJ 2740 240 SC - Magnitude of the residue in orange processed commodities	Krolski ME	2000	109726 ! BJ19OR02 ! M-136907-01-1 ! MO-01-013905	*not cited*
Juicing – pome fruit	Apples	*A17056D: Residue apple, processed products Germany and Italy 2010*	Eversfield S	2012	A17056D_10008 ! S10-02876-REG ! TK0030544	*EFSA Journal 2015;13(3):4043*
		Determination of the residues of BAS 500 F and BAS 510 F in apples and processed products	Schulz H	2002	2001/1015047 ! IF-101/14264-00	*EFSA Journal 2014;12(7):3799*

Processing procedure	Commodity	Study	Author	Year	Study No/ Report No	EFSA Journal
		following treatment with BAS 516 01 F under field conditions in Germany 2001				
Juicing – grape juice	Grapes	*Determination of residues of BAS 650 F in grapes and their processed products after four applications of BAS 650 00 F in Germany 2001*	Braun D; Altschuck A; Funk H; Klimmeck S; Klimmeck A	2008	2008/1022152 ! 249193	*EFSA Journal 2009;7(10):1367*
		Residue study (at harvest and processing) with IKF-5411 400 SC (IBE 4022) applied to wine grapes in Germany, Northern France, Southern France and Spain in 2011	Schäufele M	2012	JSM0210 ! OGV11-RE04 ! OGV11-RE05	*EFSA Journal 2015;13(10):4265*
Juicing – stone fruit	Peaches	*Lambda-cyhalothrin: Residue Levels in Peaches and Processed Fractions from Trials Conducted in Southern France during 2002*	Ryan J	2004	AF/5712/SY	*EFSA Journal 2014;12(1):3546*
		Determination of Captan and Tetrahydrophthalimide residues in peaches (RAC and processed fractions) following treatments with the preparation Captan 80 WG in Southern France under field conditions in 2005, Part 1 - Final Report	Simek I	2007	R A5062	*EFSA Journal 2011;9(4):2151*
Juicing – vegetables	Tomatoes	*SYN545192 (A15457B) and SYN545192 + Azoxystrobin (A18126B): Magnitude of the residues of SYN545192 in or on tomatoes and peppers (representative commodities of crop group 8) following foliar applications USA 2011*	Mäyer T	2012	A15457B_50059 ! 12SYN322.REP ! TK0058641	*EFSA Journal 2015;13(3):4043*
	Carrots	*Determination of the residues of BAS 510 F and BAS 500 F in carrots and processed products following treatment with BAS 516 GA F under field conditions in Germany 2000*	Scharm M	2001	BN-713-010, 2002/7004459	*EFSA Journal 2014;12(7):3799*
		Determination of residues of BAS 455 H (Pendimethalin) in carrots and their processed products after one application of BAS 455 48 H in Germany, 2012	Plier S	2012	2012/1271922 ! 426754	*EFSA Journal 2016;14(3):4420*
Wine production	Wine grapes	*Processing study with NC-224 200 g as/l SC applied to grapes in Germany and Italy in 2004.*	Blaschke U	2006	CGA219417/0861 ! OF95151/DE93 ! 861	*EFSA Journal 2009; 7(10):1349*
		Magnitude of the residue of KIF-230 in grapevine raw agricultural commodity and processed fractions after applications with mixture of KIF-230 (1.75%) + Mancozeb (70%).	Grolleau G	2000	EA980138 ! 9801EUV ! 8154	*EFSA Journal 2012;10(8):2872*

Processing procedure	Commodity	Study	Author	Year	Study No/ Report No	EFSA Journal
		Determination of residues of BAS 650 F in grapes and their processed products after four applications of BAS 650 00 F in Germany	Braun D; Altschuck A; Funk H; Klimmeck S; Klimmeck A	2008	2008/1022152 ! 249193	*EFSA Journal 2009; 7(10):1367*
Fermentation	Cabbages	*Determination of the residues of BAS 510 F and BAS 500 F in white cabbage and processed products following treatment with BAS 516 GA F under field conditions in Germany 2000*	Schulz H; Scharm M	2001	2001/1000939 ! IF-100/13959-00	*EFSA Journal 2014;12(7):3799*
	Olives	*Determination of Acetamiprid Residues in Olives (Rac and Processed Fractions) Following 2 Applications of Acetamiprid 20% SG under open Field Conditions in Southern Europe - 2012*	Simek I	2013	10/694 ! 2418/E694	*EFSA Journal 2016;14(2):4385*
		Combined processing and magnitude and decline of Cyantraniliprole and metabolite residues in olives following foliar application of DPX-HGW86 100 g/L SE - Southern Europe, 2009 initiation	Haigh I; Cairns S	2011	DuPont-27709 ! 694299 ! 48519711	*not cited*
	Gherkins	*Magnitude of the Residue of Acetamiprid in Gherkin Raw Agricultural Commodity and Processed Fractions after Three Foliar Applications of Acetamiprid 20 SG - Northern Europe - 2013*	Boissinot JC	2014	632-5001 ! RD-02699 ! R B2065	*EFSA Journal 2016;14(2):4385*
	Soya beans	*SYN545192 150EC (A17056D): Magnitude of the residues in or on soybeans*	Mäyer T	2012	A17056D_50011 ! TK0002561	*EFSA Journal 2015;13(3):4043*
	Rice	*Study on the residue behavior of BAS 500 F (Pyraclostrobin) and its metabolites in paddy rice processed fractions after treatment with BAS 500 23 F under field conditions 2014*	Woodard DL	2015	2015/7000583 ! 408324 ! 005SRL14R-06	*EFSA Journal 2018;16(11):5483*
Oil production - olives	Olives	*Fenoxycarb (CGA114597): Residue Study on Olives and Processed Fractions in Spain and Italy.*	Anderson L	2006	RA-2058/99	*EFSA Journal 2015;13(7):4202*
Oil production - maize	Maize	*Magnitude of BAS 700 F Residues in Processed Fractions and/or Aspirated Grain Fractions of the Cereal Grains Corn, Sorghum and Rice Following Applications of BAS 700 AE F*	Johnston RL; Saha M	2009	Saku 2P-6-177	*EFSA Journal 2016;14(3):4404*
	Maize	*ICIA0321 (Lambda-cyhalothrin) - Magnitude of the residue study on processed field corn products*	Grant CL; Francis PD	1991	RR 91-027B	*EFSA Journal 2014;12(5):3677*
Oil production – oilseeds	Rape seeds	*Magnitude of residues of picoxystrobin and its metabolites in processed fractions of canola following application of DPX-YT669 250SC (250 g*	Thiel A	2010	DuPont-24865	*EFSA Journal 2016;14(6):4515*

Processing procedure	Commodity	Study	Author	Year	Study No/ Report No	EFSA Journal
		a.i./L) at 5x maximum label rate - USA, Canada 2008				
		Determination of residues of Mepiquat-chloride in winter oil seed rape and its processing products after one application of BAS 134 00 W in Germany	Renner G	2005	2004/1015941 ! 03 10 47 023 ! 143773	*EFSA Journal 2015;13(8):4214*
	Peanuts	*Magnitude of residues of Penthiopyrad and its metabolites in peanuts and their processed fractions following applications of DPX-LEM17 20SC under maximum label rate - USA, 2007*	Thiel A	2009	DuPont-22296 ! ABC 62287	*EFSA Journal 2012;10(10):2948*
	Sunflower seeds	*The magnitude of Imazamox and Imazapyr residues in Clearfield sunflower and Clearfield sunflower processed fractions following application of BAS 723 00 H*	Norris FA	2009	RA-3191/01 ! MO-02-012234	*EFSA Journal 2014;12(6):3743*
	Soya beans	*SYN545192 150EC (A17056D): Magnitude of the residues in or on soybeans*	Mäyer T	2012	A17056D_50011 ! TK0002561	*EFSA Journal 2015;13(3):4043*
	Cotton seed	*SYN545192 150EC (A17056D): Magnitude of the residues in or on cotton*	Mäyer T	2012	A17056D_50034 ! 11SYN300.REP ! TK0025157	*EFSA Journal 2015;13(3):4043*
Production of essential oils	Oranges	*ADMIRE 2F - Magnitude of the residue on orange processed commodities*	Maloney AL	1994	106651 ! 106551 ! M-024942-01-2 ! MO-00-003134 ! AD19TO01	*EFSA Scientific Report (2008) 148, 1-120*
		BAJ 2740 240 SC - Magnitude of the residue in orange processed commodities	Krolski ME	2000	109726 ! BJ19OR02 ! M-136907-01-1 ! MO-01-013905	*not cited*
	Peppermint	*The magnitude of BAS 510 F and BAS 500 F residues in mint and mint processed fractions*	Versoi PL; Abdel-Baky S	2001	2001/5002467 ! 66700	*not cited*
Production of palm oil and palm kernel oil	Palm fruit/ palm kernels	*Report Amendment 1: Determination of residues of Chlorantraniliprole after two applications of Altacor 35 WG in oilpalm trees at 4 sites in Malaysia in 2015*	Petrova D	2017	MRID 50234701 ! S15-04277	*EFSA Journal 2019;17(11):5877*
Soya drink and tofu	Soya beans	*SYN545192 150EC (A17056D): Magnitude of the residues in or on soybeans*	Mäyer T	2012	A17056D_50011 ! TK0002561	*EFSA Journal 2015;13(3):4043*
Beer brewing	Barleys	*SYN545192 - Residue study on winter barley and processed products in Northern France, Germany and in the United Kingdom in 2010*	Ellis C	2012	A17056D_10011 ! S10-01049-REG ! S10-01049 ! TK0025362	*EFSA Journal 2015;13(3):4043*
	Hops (dried)	*Determination of residues of BAS 650 F and Dimethomorph in hops and its processed products after three applications of BAS 651 00 F in Germany*	Braun D	2011	2011/1101445 ! 308736 ! 08 10 47 026	*EFSA Journal 2014;12(10):3879*

Processing procedure	Commodity	Study	Author	Year	Study No/ Report No	EFSA Journal
Milling	Wheat	*Magnitude of residues of picoxystrobin and its metabolites in processed fractions of wheat following application of DPX-YT669 250SC (250 g ai/L) at 5x maximum label rate -USA, Canada 2008*	Rice F	2010	DuPont-25759	*EFSA Journal 2016;14(6):4515*
	Barleys	*SYN545192 - Residue study on winter barley and processed products in Northern France, Germany and in the United Kingdom in 2010*	Ellis C	2012	A17056D_10011 ! S10-01049-REG ! S10-01049 ! TK0025362	*EFSA Journal 2015;13(3):4043*
	Oats	*Pirimiphos-methyl - Magnitude of residues in oats and processed oat fractions resulting from a post-harvest admixture application of Actellic D.*	Scrimshaw O; Milhan C	2003	PP511/0808 ! AK/6859/SY	*EFSA Scientific Report (2005) 44, 1-53*
	Maize	*Magnitude of BAS 700 F Residues in Processed Fractions and/or Aspirated Grain Fractions of the Cereal Grains Corn, Sorghum and Rice Following Applications of BAS 700 AE F*	Johnston RL; Saha M	2009	Saku 2P-6-177	*EFSA Journal 2016;14(3):4404*
	Rice	*Magnitude of Imidacloprid Residues in Rice Following one Application with Imidacloprid (Imidacloprid 200 g/L SL)*	C. Gimeno	2015	2009/7000088 ! 1276-07	*EFSA Journal 2010; 8(4):1589*
Starch production	Maize	*Magnitude of BAS 700 F Residues in Processed Fractions and/or Aspirated Grain Fractions of the Cereal Grains Corn, Sorghum and Rice Following Applications of BAS 700 AE F*	Johnston RL; Saha M	2009	Saku 2P-6-177	*EFSA Journal 2016;14(3):4404*
	Potatoes	*SYN545192 (A15457B) and SYN545192 + Azoxystrobin (A18126B) - Magnitude of the residues of SYN545192 in or on potatoes (representative commodity of crop group 1C - tuberous and corm vegetables) following in-furrow and foliar applications USA 2011*	Mäyer T	2012	A15457B_50051 ! 12SYN321.REP ! TK0058640	*EFSA Journal 2015;13(3):4043*
	Wheat	*SYN545192 - Residue study on winter wheat and processed products in Northern France, Germany and in the United Kingdom in 2010*	Ellis C	2012	A17056D_10007 ! S10-01047-REG ! S10-01047 ! TK0025360	*EFSA Journal 2015;13(3):4043*
Sugar	Sugar beets	*Determination of the residues of Chloridazon in sugar beet and processed products following treatment with BAS 119 33 H under field conditions in Germany 2000*	Schulz H	2001	2001/5000050! 64420	*EFSA Scientific Report (2007) 108, 1-82*
	Sugar cane	*Glyphosate residues in sugarcane and related mill fractions following sugarcane ripener treatment*	Beasley RK	1978	MSL-026	*not cited*

Appendix C Processing codes (used to link processes described in the compendium to the coding in the EU Database on Processing Factors (Zincke et al., 2022))

Processing procedure	OECD code	RAC	Relevant figure/chapter in compendium	Processing code
Cooking in water	VI	potatoes	Figure 1 overview of cooking processes in water	VI-001
		carrots	Figure 1 overview of cooking processes in water	VI-001
		legume vegetables peas (with pod); peas (without pod)	Figure 3 The process of cooking green peas with and without pod.	VI-002
		beans (with pod); beans (without pod)	extrapolation Figure 3	VI-002
		pulses	Figure 4. The procedure of cooking pulses.	VI-003
		leaf vegetables (spinach)	Figure 1 overview of cooking processes in water	VI-001
		pumpkins	Figure 1 overview of cooking processes in water	VI-001
		stem vegetables (leeks, celeries)	Figure 1 overview of cooking processes in water	VI-001
		brassica vegetables (head cabbages, savoy cabbages, kale)	Figure 1 overview of cooking processes in water	VI-001
		fruiting vegetables (sweet peppers)	Figure 1 overview of cooking processes in water	VI-001
		cereals (rice)	Table 4	VI-004
Steaming	VI	potatoes	Figure 5: Processing of steamed potatoes.	VI-005
Canned vegetables	VIII	tomatoes	Figure 6: Canning of tomatoes.	VIII-001
		fruiting vegetables (gherkins, sweet peppers, chilli peppers, sweet corn)	Figure 30. Processing of gherkins into pickled gherkins.	XIX-001
		fungi (mushrooms)	Figure 7: Canning procedure of various vegetables.	VIII-002
		legume vegetables (peas, beans)	Figure 7: Canning procedure of various vegetables.	VIII-002
		pulses (peas, beans)	Figure 7: Canning procedure of various vegetables	VIII-002
		root and tuber vegetables (carrots, potatoes, beetroots)	Figure 7: Canning procedure of various vegetables.	VIII-002
		stem vegetables (asparagus)	Table 5: Overview of typically canned commodities	VIII-003
		brassica vegetables (head cabbage, kale)	Table 5: Overview of typically canned commodities	VIII-003
		bulb vegetables (onion)	Table 5: Overview of typically canned commodities	VIII-003
Canned fruits	III	pome fruits (apples, pears)	Figure 8. Canning procedure of various fruits.	III-001
		berries and small fruits (strawberries, currants)	Figure 8. Canning procedure of various fruits.	III-001

Processing procedure	OECD code	RAC	Relevant figure/chapter in compendium	Processing code
		stone fruits (peaches, plums, cherries, apricots)	Figure 8. Canning procedure of various fruits.	III-001
		citrus fruits (mandarins, oranges)	Figure 8. Canning procedure of various fruits.	III-001
		table olives	Figure 29. Pickling of table olives.	XVII-002
Jam	IV	berries and small fruits (strawberries, currants)	Figure 9: Processing of jam, jelly and marmalade.	IV-001
		stone fruits (peaches, apricots, plums)	Figure 9: Processing of jam, jelly and marmalade.	IV-001
		pome fruits (apples)	Figure 9: Processing of jam, jelly and marmalade.	IV-001
Jelly	IV	berries and small fruits (table grapes, currants)	Figure 9: Processing of jam, jelly and marmalade.	IV-001
		apples	Figure 9: Processing of jam, jelly and marmalade.	IV-001
Marmalade	IV	citrus fruits (oranges, mandarins)	Figure 9: Processing of jam, jelly and marmalade.	IV-001
Fruit purée	IV	pome fruits (apples, pears)	Figure 10: Processing of apples to apple sauce.	IV-002
		stone fruits (plum, apricot, peach, cherries)	chapter 3.3.4	IV-003
		berries and small fruits (strawberries and currants)	chapter 3.3.4	IV-003
Vegetable purée	VII	tomatoes	Figure 11. Processing of purée and paste from tomatoes.	VII-001
		carrots, potatoes	Chapter 3.3.4:	VII-005
		pumpkins	Chapter 3.3.4:	VII-005
Paste	VII	tomatoes	Figure 11. Processing of purée and paste from tomatoes.	VII-001
Drying	XVI	berries and small fruits (table grapes, currants)	Chapter 3.4.1: Dried fruits.	XVI-001
		stone fruits (plums, apricots, peaches)	Chapter 3.4.1: Dried fruits.	XVI-001
		pome fruits (apples, pears)	Chapter 3.4.1: Dried fruits.	XVI-001
		exotic fruits (bananas)	Chapter 3.4.1: Dried fruits.	XVI-001
		Fruiting vegetables (tomatoes, chili peppers)	Chapter 3.4.2: Dried vegetables.	XVI-002
		onions	Chapter 3.4.2: Dried vegetables.	XVI-002
		mushrooms	Chapter 3.4.2: Dried vegetables.	XVI-002
		potatoes	Chapter 3.4.2: Dried vegetables.	XVI-002
		fresh herbs and edible flowers	Table 8: Recommended generic dehydration factors for selected commodities used as dried herbs and for seasoning.	XVI-003
	XIII	green and black tea	Chapter 3.4.5: Further processing by dehydration	XIII-003
Potato flakes/ granules	XVI	potatoes	Figure 12. Processing of potatoes to potato flakes and granules.	XVI-004
Deep-frying (chips/ French fries)	IX	potatoes	Figure 13. Processing of potatoes to French fries by industrial and domestic procedures.	IX-001
		root and tuber vegetables (beetroots, sweet potatoes, carrots)	extrapolation Figure 13	IX-001

Processing procedure	OECD code	RAC	Relevant figure/chapter in compendium	Processing code
Deep-frying (crisps)	IX	potatoes	Figure 14. Processing of potatoes to potato crisps.	IX-002
		root and tuber vegetables (beetroots, sweet potatoes, carrots)	extrapolation Figure 14	IX-002
(Pan-)frying	IX	potatoes	Chapter 3.5. Frying	IX-003
Baking	IX	potatoes	Figure 15. Processing of potatoes to baked potatoes.	IX-004
Roasting	IX	peanuts	Figure 17. Processing of peanuts into roasted peanuts.	IX-005
	XIII	coffee beans	Figure 16. Processing of green coffee beans into roasted coffee and instant coffee.	XIII-001
Microwaving	XVIII	potatoes	Figure 18. Processing of potatoes by microwave cooking.	XVIII-001
Citrus juice	II	citrus fruits (grapefruits, lemons, limes, mandarins, oranges)	Figure 19. Representative processing of citrus fruits to citrus juice.	II-001
Pome juice	II	pome fruits (apples, pears)	Figure 20. Representative processing of apples to apple juice.	II-002
Grape juice	II	grapes	Figure 21. Processing of grapes into grape juice.	II-003
		berries and small fruits (currants)	extrapolation Figure 21	II-003
Stone fruit juice	II	stone fruits (peaches, plums, cherries, apricots)	Figure 22. Processing of stone fruit to juice.	II-004
Tropical fruit juices	II	tropical fruits (mangoes, bananas, pineapples)	Figure 23. Processing of mango juice.	II-005
Vegetable juices	VII	tomatoes	Figure 24: Processing of tomatoes to juice.	VII-002
		carrots	Figure 25: Two processing ways of carrot juice.	VII-003
		head cabbage, beetroots, celery, spinaches	Chapter 4.6.12: Further vegetable juices	VII-004
White wine production	V	wine grapes	Figure 26. Processing of grapes into white wine.	V-001
Red wine production	V	wine grapes	Figure 27. Processing of grapes into red wine.	V-002
Rosé wine production	V	wine grapes	Chapter 5.3: Rosé wine	V-003
Sparkling wine production	V	wine grapes	Chapter 5.7: Extrapolation to other commodities	V-004
Fruit wine production	V	berries and small fruits	Chapter 5.7: Extrapolation to other commodities	V-004
Distillates	V	wine grapes	Chapter 5.5. By-products of wine production	V-007
		barley grains		V-007
Fermentation to sauerkraut	XVII	head cabbages	Figure 28. Processing of cabbage to sauerkraut.	XVII-001
Fermentation of fruits	XVII	table olives	Figure 29. Processing of black olives into Greek-style olives and green olives into Spanish-style olives.	XVII-002
Pickling of vegetables	XIX	gherkins	Figure 30. Processing of gherkins into pickled gherkins (fermented).	XIX-001

Processing procedure	OECD code	RAC	Relevant figure/chapter in compendium	Processing code
Fermentation of soya beans	XVII	soya beans	Figure 31. Processing of soya beans and wheat into soya sauce.	XVII-003
Production of rice wine	XVII	rice	Figure 32. Processing of rice into sake (XVII-004)	XVII-004
Oil production - olives	Xa, Xb	olives for oil production	Figure 33. Processing of virgin olive oil and refined oil.	X-001
Oil production – maize dry milling	Xc	maize	Figure 34. Processing of maize to oil following the dry milling procedure.	X-002
Oil production – maize wet milling	Xc	maize	Figure 35. Processing of maize to oil following the wet milling procedure.	X-006
Oil production - oilseeds	Xa, Xb	oilseeds (peanuts, sunflower seeds, rape seeds, soya beans, cotton seeds)	Figure 36. Oil production for various oilseeds. Figure 37. Refining procedure for crude oils of various oilseeds.	X-003
Production of essential oils	Xa, Xb	herbs and flowers (mint)	Figure 38. Processing of mint to mint oil.	X-004
		citrus fruits (oranges)	Figure 39. Processing of citrus fruits to citrus oil.	X-005
Oil production - palm oil - palm kernel oil	Xa, Xb	palm fruit, palm kernels	Figure 40. Processing of oil palm fruits and oil palm kernels into oil.	X-007
Soya drink and tofu	IX	soya beans	Figure 41. Processing of soya beans into soya drink and tofu.	IX-006
Beer brewing	V	barley	Figure 42. Processing of barley into malt. Figure 44. Processing of malt, hops and water into beer.	V-005
		hops	Figure 43. Processing of fresh hops into dried hops (RAC) and further processing into hop extracts. Figure 44. Processing of malt, hops and water into beer.	V-006
Milling – flour	XI	wheat, rye	Figure 45. Milling of wheat into flour.	XI-002
		barley	Figure 46. Processing of barley into hulled, pot and pearl barley and into barley flour.	XI-003
		maize	Figure 48. Dry-milling of maize into flour, meal and grits.	XI-004
Milling – pearl barley	XI	barley	Figure 46. Processing of barley into hulled, pot and pearl barley and into barley flour.	XI-003
Milling – rolled oats	XI	oat	Figure 47. Processing of oats into rolled oats.	XI-005
Milling – rice processing	XI	rice	Figure 49. Processing of paddy rice into polished rice.	XI-006
Starch production	XI	maize	Figure 50. Wet-milling of maize into maize starch.	XI-007
		potatoes	Figure 51. Processing of potatoes into starch.	XI-008
		cereals (wheat, sorghum)	Chapter 11.3. Wheat starch	XI-009
Cocoa powder	XIII	cocoa beans	Figure 53. Processing of cocoa beans into cocoa powder.	XIII-002

Processing procedure	OECD code	RAC	Relevant figure/chapter in compendium	Processing code
Sugar	XII	sugar beet roots	Figure 54. Production of beet sugar.	XII-001
		sugar canes	Figure 55. Raw sugar extraction from sugar cane. Figure 56. Process of refined sugar production from raw sugar.	XII-002

Appendix D Industry contacts

Industry contact*	German designation	Process
German Federation for Food Law and Food Science	Bund für Lebensmittelrecht und Lebensmittelkunde e.V. (BLL)	all processes
Association of the German Confectionery Industry	Bundesverband der Deutschen Süßwarenindustrie e.V. (BDSI)	cocoa powder production, frying
German Association of the Fruit, Vegetable and Potato Processing Industry	Bundesverband der obst-, gemüse- und kartoffelverarbeitenden Industrie e.V. (BOGK)	potato products, dehydration, canned vegetables and fruits, fermentation and pickling, jam, jelly and marmalade, purée and paste
German Brewers�much Association	Deutscher Brauer-Bund e.V. (DBB)	beer production
German Tea Association	Deutscher Teeverband e.V.	dehydration
German Association of the Flavour Industry	Deutscher Verband der Aromenindustrie e.V. (DVAI)	oil production
Association of the German Spice Industry	Fachverband der Gewürzindustrie e.V.	purée and paste, soya sauce, dehydration
Geisenheim University	Hochschule Geisenheim	wine production
Starch Europe		starch production
Association of the German Fruit Juice Industry e. V.	Verband der deutschen Fruchtsaft-Industrie e. V. (FdF)	juice production
Association of the Cereal-, Mill- and Starch Production**	Verband der Getreide-, Mühlen- und Stärkewirtschaft e.V. (VGMS)	milling, starch production
Association of the Oilseeds Processing Industry in Germany e.V.	Verband der ölsaatenverarbeitenden Industrie in Deutschland e.V. (OVID)	oil production
German Bakers‘ Association**	Verband Deutscher Großbäckereien e. V.	milling
German Mills‘ Association**	Verband Deutscher Mühlen e. V. (VDM)	milling, starch production
Grain traders association of the Hamburg exchange	Verein der Getreidehändler der Hamburger Börse e.V.	milling, starch production
German Sugar Association**	Verein der Zuckerindustrie e. V. (VdZ)	sugar
Association of Companies participating in Drug and Chemicals Wholesaling and Foreign Trade	Vereinigung der am Drogen- und Chemikalien- Groß- und Außenhandel beteiligten Firmen (Drogen- und Chemikalienverein) e. V. (VDC)	dehydration, oil production
Waren-Verein der Hamburger Börse e.V.	Waren-Verein der Hamburger Börse e.V.	dehydration
Trade Association for Herbal and Fruit Teas	(Wirtschaftsvereinigung Kräuter- und Früchtetee e.V.)	dehydration

* National industry associations were contacted, which internally consulted their respective European partners

** This is not an official translation.

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