

THE SWING BRIDGE

over the Tyne, and afterwards obtained a fine view of it in operation from the steamer as they proceeded to the works of the

THARSIS SULPHUR AND COPPER COMPANY.

At these works, which have been in operation about twenty years, they saw the process of the extraction of copper from burnt pyrites. This residue, treated with salt and calcined, and afterwards lixiviated in tanks, is treated for gold and silver, and then passes into vessels filled with scrap iron. The copper precipitate obtained is then taken to the smelting furnaces. The copper is chiefly sold in ingots, cakes, and wire bars. Messrs. C. Tennant and Co.'s Alkali Works were next visited. These were commenced in 1865, on a much smaller scale than now, and were worked as a branch of the older establishment at St. Rollox, Glasgow, where the manufacture of bleaching powder was first introduced into this country. The products are bleaching powder and soda, the total made at Hebburn being about 800 tons weekly. One of the special features of the works is that four of Mactear's salt-cake furnaces decompose the whole of the salt, hand labour having been abolished. About 700 men are employed in the various departments.

Lunch was served in the Drill Hall, the arrangements being under the charge of Mr. J. McCulloch.

There were no formal toasts, but Professor Roscoe proposed in a few sentences the thanks of the Society to the gentlemen who had so kindly thrown open their works to the visitors. This was seconded by Mr. J. C. Stephenson, M.P.

THE LEAD WORKS OF MESSRS. COOKSON AND CO.

were next visited. An exhibit of the raw materials and finished products of the works was shown, prominent being a block of silver computed to be worth from £2,200 to £2,300, and weighing over 6cwt. The works are for the smelting of lead and its desilverising; and it was stated that the furnaces when fully charged would hold 1,200 tons of lead.

After this visit, the party proceeded by the special steamer placed at the disposal of the Committee by the Tyne Commission, to the North Pier, Tynemouth, where its members separated.

Another excursion by members of the Society was made to the coke ovens at South Medomsley, where the

JAMESON COKING PROCESS

was seen in operation; and also to Crook to see the extensive set of coke ovens on the Simon-Carvès principle at

MESSRS. PEASE AND PARTNER'S WEST COLLIERIES.

The production of good metallurgical coke, with coal tar, and ammoniacal liquor, equal and similar to that furnished in any gas-works, was here witnessed.

CONVERSAZIONE AND RECEPTION.

On Thursday evening a reception was held in the Assembly Rooms, Westgate Road, by Mr. Walter Weldon, F.R.S. (retiring President of the Society of Chemical Industry), at eight o'clock. A most enjoyable and admirably conducted musical entertainment was given in the large room by a string orchestra and a chorus of men's voices (The "Antigone" Amateur Male-voice Choir), under the leadership of Mr. J. H. Amer. A selection from Mendelssohn's *Antigone* amongst other things, was given most effectively by the above-named excellent *Männerchor*, a kind of performance too seldom heard in this country. Refreshments were served on a large and liberal scale in the hall. The entertainment was a great success. The attendance of ladies and gentlemen

was very large, and the enjoyment of the evening rendered brilliant testimony to the indefatigable exertions of the Local Secretary (Mr. J. T. Dunn), and the Local Committee.

The Newcastle meetings as a whole have been pronounced among the most successful, not only as regards their general interest, but as regards the large attendance, the general goodfellowship created, and numerous new acquaintances formed amongst the members of the Society—surely one of the chief objects of meetings of this kind.

The Annual Meeting of the Society of Chemical Industry in July, 1884, will live long in the recollection of most members present, as a brief bright reminiscence in which many known to each other only by reputation, now came face to face, and engaged in friendly converse.

London Section.

Chairman: David Howard.

Committee:

Sir F. A. Abel.	B. E. R. Newlands
H. E. Armstrong.	B. Redwood.
W. Crowder.	T. Royle.
C. Graham.	John Spiller.
S. Hall.	G. C. Trewby.
A. K. Huntington.	W. Weldon.
R. Messel.	J. Williams.

Local Sec.: Thos. Tyrer, Garden Wharf, Church Road, Battersea, W.

CHEMICAL SOCIETY'S ROOMS, BURLINGTON HOUSE
Monday, May 5th, 1884.

MR. DAVID HOWARD IN THE CHAIR.

ON THE PROCESSES CONCERNED IN
THE CONVERSION OF STARCH INTO
ALCOHOL, AND THEIR RELATION TO
BREWING AND DISTILLING.

BY W. S. SQUIRE, PH.D.

It is only in the last few years that the processes concerned in the conversion of starch into alcohol have been scientifically investigated. Owing to the complicated nature of the influences at work, experimenters are far from unanimous in the conclusions at which they have arrived. Still, many important facts have been elicited, and I thought that a short sketch of our present knowledge of this subject might interest the members of this society. Where there is a conflict of evidence, I have ventured to select that which is in accordance with my own experiments and practice, without at all wishing to imply that my own experiments are more trustworthy than those of others, or that they by any means set disputed questions at rest. Those who are bold enough to address the members of a society like this, must be prepared for a pretty severe cross-examination at the end of their discourse, and for that reason, if for no other, I must be prepared to vouch personally for the facts I adduce in support of the conclusions I venture to draw.

As is the case with all ancient industries, considerable perfection in the processes employed in the conversion of starch into alcohol has been arrived at in the course of ages by pure empiricism. The practical man, warned by failures in one direction or another, learnt by sheer practice that method of working which yielded him the best results, without troubling himself about the why and the wherefore. He knew what temperature was, at certain stages, of importance, but

he judged of this at first, either by the amount of steam coming off from his vessel, or by dipping his finger into the hot liquor. For a long time he sneered at the thermometer as a new-fangled concern unworthy of a practical man who knew his business, and was guided in his operations by all sorts of rough-and-ready rules and appearances, for which he had the most fantastical explanations, but more generally no explanation at all. In fact, the brewers and distillers may be said to have formed a close corporation of rule-of-thumbists of the first order.

As ignorance and credulity go ever hand in hand, so it was, and to a certain extent still is, in this great industry. Secrets which are no secrets at all are jealously guarded. Recipes for setting bad beer right, and for fortifying and tinkering up yeast, all perfectly worthless, are bought and sold, and there is scarcely any industry in which mystery-mongering and quackery do so good a trade.

It is curious how professors of the art of brewing hang on to these electrical notions. A book published in the last few days by a well-known author*, contains this passage, at page 63. Speaking of fermenting vessels the author says: "We are apt to have far too many metal fittings, and the circular coils of attemperating piping, with brass parachute pipe passing down the centre line forcibly reminds one of a Leyden jar arrangement, and in many instances seems to be one." Then, in a foot note, he describes a Leyden jar, and says, "in the arrangement spoken of, the parachute pipe would be the inner coat, the attemperating coils the outer, and the layer of beer between them, the intervening glass!"

I have here another book†. The author is a practical brewer, hailing from Burton-on-Trent. He says page 30, "that acetous fermentation will occur in the mash-tun from the application of mashing heats taken at too low degrees of heat, whereby the pores of the liquor are so much opened that they readily imbibe too large a portion of atmospheric air. Acetous fermentation also ensues when the mashing heats are taken too high, thereby in a great measure closing the pores of the worts to the fermentation matter or yeast."

I have here a book of much greater value‡—at least it is published at 10 guineas. He says at page 69: "Pasteur's discoveries, proving that air-borne germs are the cause of what was supposed to be spontaneous germination, although of the highest importance in surgery and general medical practice, are of little use to the brewer. If the malt has been properly cured and brewed, the conditions of life for these air-borne creatures are not in the wort, and the wort is safe." "Pasteur's work shews yeast cells in various conditions, and were he or others turning the microscope to the cleavages or granules of fractured malt, they might be able to detect and check in time the causes of these abnormal conditions in yeast." It seems from this that Pasteur has been using his microscope to small purpose.

As might be supposed, the author speaks with profound disdain of the Bavarian system of brewing. He says, "The Bavarians, as well as the Germans generally, are, to the mind of the author, quite astray, both with their malt-drying, and their mashing processes." "The author has conversed with German brewers, and seen the process on a large scale, and he believes these people would be glad to exchange their system

for ours." The German system is, in his opinion, "the result of notions of cleanliness following on loss of tradition, or perhaps of mere loose drifting about because of never having had proper charts for guidance." That cold has anything to do with bottom fermentation he positively denies. I could multiply instances, but enough has been said to shew the sort of literature offered, and, what is more, eagerly bought at fancy prices, by the brewing trade.

Distillers and brewers are, in the widest sense of the term, chemical manufacturers, but the number of those who have any notion of the chemical changes going on in their mash tuns and fermenting backs is extremely limited. I am not speaking of those great brewers who employ the highest scientific skill, but of brewers generally.

It must not, however, be supposed that empiricism had gone very far wrong. When science stepped in to investigate she could only confirm much of the experience of ages, and admit that practice was in many respects right. It generally happens so. Agriculturists had found out the value of farm-yard manure, before Liebig and Gilbert pointed out the constituents to the presence of which in the manure its value is due; and washerwomen spat on their flat-irons to ascertain the heat by the flying off of the saliva, long before the days of Leidenfrost.

As the subject is a very wide one, and the time at my disposal is limited, I propose to confine myself, on the present occasion, to the action of organic and organised ferments, reserving for a future communication those conversions which are effected by other means. For the same reason I cannot deal with the conversion of barley and other seeds into malt, but will assume the malting process to be completed.

Our starting point, starch, is a body of very complicated structure, and probably of very complicated composition. It occurs widely distributed through the vegetable kingdom, and consists of minute grains which differ greatly in size and form, according to the vegetable source from which they have been derived. The starch granules are so characteristic of the plants which furnish them, that when vegetable powders are examined under the microscope, the form and size of the starch granules (if any be present) are often the best indication of the nature of the plant from which the powder is derived. The diameter of the grains varies from 2 to 60 micromillimeters*. The starch granules are either simple or compound. The simple grains, when examined under the microscope, present the appearance of round, or more or less egg-shaped bodies, offering distinct evidences of concentric stratification grouped round a point which is sometimes central, and sometimes eccentric, in which latter case it is near to the small end of the granules, as for instance in potato starch. The layers are not formed by the deposition of one on the other proceeding from within outward like the rings of an exogenous tree, but the fresh deposits are formed at the centre of the grains, pushing out and condensing the previous layers, much in the same way as in the endogenous stem†. The compound grains present the appearance of rounded masses with a reticulated structure, as if minute hexagons or rather dodecahedrons of somewhat irregular shape had been agglomerated together. Portions of these compound grains are sometimes found detached, in which case they occur as angular bodies of very small size. Rice starch for example. Sometimes, as in the case of the cereal grasses, there are two kinds of starch granules, large and small. The diameters being generally as 1 to 4 or 5. The two kinds are quite

* The Theory and Practice of Modern Brewing, by Frank Paulkner, London, F. W. Lyon, 1881.

† The Art of Brewing India Pale Ale, by James Herbert, practical brewer, Burton-upon-Trent, fifth edition, 1872, pp. 66, published by the author, price 10/6.

‡ Selection of the Practical Points of Malting and Brewing, by James Steel, pp. 123, London, E. and F. N. Spon, 1881.

* Micromillimeter = $\frac{1}{1000}$ Millimeter = .001 inch.

† Nüggeli, Die Stärkekörner.

distinct, no intermediate sizes occurring. (Drawings of the various starches were exhibited on the walls of the room. Of these drawings the photographic reductions are exhibited on the adjoining page.)

The starch granule when thoroughly dry is capable of absorbing from 10 to 18 per cent. of water, of which it may be again deprived without altering its physical constitution. In other respects it is not acted upon by cold water. Starch consists of two bodies, which have received the names of granulose (constituting by far the greater part of the whole), and amylocellulose. It is of the latter that the external envelope of the granule consists.

When starch granules are heated with water they begin to swell. Cracks appear in them, the envelope becomes torn, and the whole is converted into the familiar starch paste. The following table* shows the temperature at which this change takes place in different starches :—

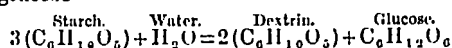
	Swelling up.		Commencement Gelatinisation.		Perfectly Gelatinised.
Rye	45°C.	.....	50°C.	.....	55°C.
Maize	50	.....	55	.....	62·5
Barley	37·5	.....	57·5	.....	62·5
Potato	46	.....	59	.....	62·5
Rice	54	.....	59	.....	62
Wheat	50	.....	65	.....	67·5

These figures hold good for the pure starches separated from the vegetable substance to which they belong. In some cases, however, the starch *in situ* requires a much greater heat to break it up, owing to the vegetable tissue in which it is embedded protecting it from the action of water. Crushed potatoes, rice and maize require long boiling with water, even under pressure, before the starch which they contain is completely gelatinised. The starch in crushed rye, barley and wheat breaks up nearly at the temperature given. A thin starch paste may be filtered through paper, and the solution, which is perfectly clear, contains the granulose, while the amylocellulose remains on the filter in the form of an opalescent jelly. Still it is very doubtful whether the granulose in the filtrate is really in solution, or only in a fine state of suspension. When porous bodies, such as fine linen cloth, are dipped into starch paste the water only is absorbed, the amylocellulose and the bulk of the granulose being left on the surface, and this is afterwards partially converted into dextrine by the hot iron of the washerwoman. Whether this be a true state of solution or not, it is certain that when starch is heated with water under pressure for some time, it is converted into a perfectly soluble body, known as soluble starch, and this solution, on cooling, no longer gelatinises. Starch heated in glycerine also undergoes this change. The amylocellulose differs considerably from ordinary cellulose. It is not soluble in ammonia and cupric oxide, and unlike cellulose, it is attacked by diastase. The well-known reaction of iodine with starch applies to granulose in all its modifications, but amylocellulose does not give the blue colour. It is coloured reddish or yellowish.

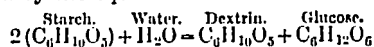
Important for us is the change which starch undergoes when acted upon by diastase. This body, which is very widely distributed in the vegetable kingdom, occurs in the largest quantity in germinating seeds, and possesses the property of converting gelatinised starch into saccharine matter. How this action is brought about, it will be convenient to study later on. For our present purpose a cold solution of malt may be regarded as a solution of diastase. This solution has no action whatever upon starch granules in the cold. The granulose of the starch is enclosed in

a membranous envelope, and as diastase is a perfect colloid it cannot get to the interior of the granule. If this envelope be broken by rubbing the starch with fine sand in a mortar, the granulose is exposed, and the diastase acts upon it even in the cold, though the granulose alone is attacked, the amylocellulose being unacted upon. Upon starch paste, diastase acts with great energy, even in the cold, though more rapidly if the temperature be raised to between 50° and 60°. In one or two minutes the paste loses its viscous character, the iodine reaction, which was at first dark blue, passes through violet to red, and in from 5 to 10 minutes disappears altogether. During this time the solution, which is quite limpid, has acquired a sweet taste.

The nature of this action has been studied by Dubrunfaut, O'Sullivan, Musculus, and Brown and Heron. Until about ten years ago it was supposed that the sugar produced from starch was grape sugar or glucose. Dubrunfaut*, it is true, pointed out in 1847 that the sugar produced was not glucose, but a sugar "*sui generis*," to which he gave the name of maltose. For some reason or other, this announcement excited no attention, and the thing was forgotten. So long ago as 1812, Vogel discovered that a gummy body was produced in addition to sugar. This body was examined by Biot and Persoz†, who gave it the name of dextrin, on account of its property of rotating to the right a ray of polarised light. Up to 1860 it was supposed that this body, dextrin, was the intermediate stage in the production of glucose, the starch being first converted into dextrin, and then, by the further action of diastase, into glucose. In 1860,‡ Musculus maintained that the dextrin and glucose were formed simultaneously, the starch taking up water and splitting into dextrin and glucose—



In 1870, Schwarzer§ called attention to the influence of temperature (of which, in a vague sort of way, brewers and distillers were quite aware), and shewed that at 60° (140° F.), and under, the reaction was expressed by the equation—



At temperatures above 60° he found that the action was represented by Musculus' formula.

In 1872, O'Sullivan|| rediscovered Dubrunfaut's maltose, and examined its properties. He found it to be a body totally distinct from glucose, having greater optical properties and a power of reducing from Fehling's solution only two-thirds as much cuprous oxide as is reduced by glucose. The composition of maltose was found by O'Sullivan to be $C_{12}H_{22}O_{11}$, and he proposed for starch $C_{18}H_{30}O_{15}$.

Under these circumstances the action would be represented thus :—

	Starch.	Maltose.	Dextrin.
At or below 63° (145° F.)	$C_{18}H_{30}O_{15} + H_2O = C_{12}H_{22}O_{11} + C_6H_{10}O_5$		
Percentage.....		67·85	32·15
Temperature 64° to 70° (147°-158° F.)	$C_{18}H_{30}O_{15} + H_2O = C_{12}H_{22}O_{11} + 4(C_6H_{10}O_5)$		
Percentage.....		34·5	65·5
Temperature 70° to 80° (158°-176° F.)	$4(C_{18}H_{30}O_{15}) + H_2O = C_{12}H_{22}O_{11} + 10(C_6H_{10}O_5)$		
Percentage.....		17·4	82·6
Reducing power :—	Maltose, 65 ; Dextro-glucose = 100.		

* Ann. Chem. Phys. [3], 21, 178.

† Ann. Chem. Phys. [2], 52, 72.

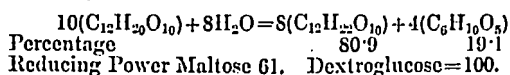
‡ Compt. rend. 54, 191.

§ Journ. f. prakt. Chemie. (1870), I., 212.

|| Journ. Chem. Soc., 1870, I., 173, and II., 25.

* E. Lippmann, Chem. Centralblatt (1861), p. 850.

Brown and Heron,* in a very elaborate investigation of this subject, find that the quantity of maltose produced is greater than that stated by O'Sullivan, and propose the following formula as expressing the normal action of diastase on gelatinised starch at 60° (140° F.) and below:—



When the reactions took place at higher temperatures the action was retarded, and the quantity of maltose produced was less. Brown and Heron's results are best shewn by the following graphic table which I copy from their paper:—

the optical power diminishes, while the cupric oxide reducing power increases until at last both correspond to the properties of pure maltose. Thus—

No. of Transformation	Sp. Rotation.	Cu ₂ O reduced.	Resulting Dextrin.
Soluble starch...	216.0	0	
1.....	209.0	6.4	...Erythro-dextrin α
2.....	202.2	12.7	... " β
3.....	195.4	18.9	...Achroo-dextrin α
4.....	188.7	25.2	... " β
5.....	182.1	31.3	... " γ
6.....	175.6	37.3	... " δ
7.....	169.0	43.3	... " ϵ
8.....	162.6	49.3	... " ζ
9.....	156.3	55.1	... " η
Maltose	150.0	61.0	

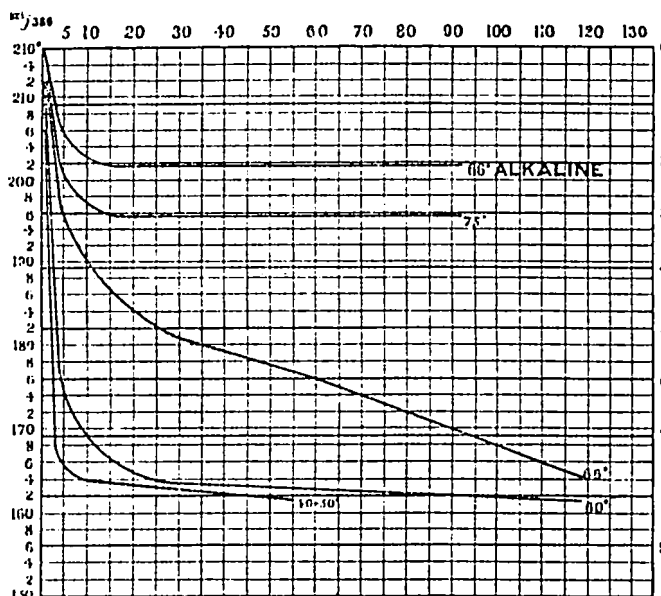
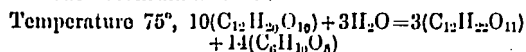


FIG. 1.

They give no formula for the reactions at the higher temperatures, but the re-action at 75° (167° F.) which seems to be tolerably constant, would be expressed by some such formula as this:—



Percentage 31.15 68.85.

The dextrin produced in this case is an achroo-dextrin, giving a colourless reaction with iodine. If the temperature of the reaction be higher than 75°, or if the mixture be rendered slightly alkaline, then the quantity of maltose produced is still less, and the dextrin is an erythro-dextrin, giving a red reaction with iodine.

It will be noticed that in the presence of much malt extract the re-action at 66° (150° F.) after two hours comes very near to the normal. Brown and Heron suppose that starch consists of a compound molecule $10(C_{12}H_{20}O_{10})$ and that, as hydration proceeds under the influence the diastase, one molecule after another splits off in the form of maltose, leaving dextrans of less complicated composition. (I have a model here to illustrate this.) As the action proceeds

The results obtained by Brown and Heron differ considerably from those of O'Sullivan, though both point in the same direction. Both adopt 150° as the specific rotatory power of maltose, but while O'Sullivan states that the cupric oxide reducing power of maltose is 65 as compared with glucose 100, Brown and Heron give it at only 61. Such a difference will considerably affect the analytical results. As it turns out maltose may be made to reduce either the one quantity or the other, according to circumstances. Soxhlet* has recently pointed out that the quantity of copper reduced is not a fixed quantity, either for maltose or glucose. It depends on the concentration of the solutions employed, and curiously enough the dilution of the solution has the effect of diminishing the reducing power of glucose, and increasing that of maltose. Accordingly the reducing power of the one substance cannot be expressed in terms of the other; indeed there is no reason for doing so. When a one per cent. solution of maltose is added to undiluted Fehling solution in excess, and the mixture is boiled for four minutes, an equivalent of maltose separates 6.1 equivalents of copper suboxide. If the Fehling solution is diluted four times and is not in excess, the reducing power rises to 6.4, but if the

* Journ. Chem. Soc. (1879), II., 699

† A model was exhibited consisting of 10 superposed blocks each bearing the formula $C_{12}H_{20}O_{10}$, the formula being printed on a blue ground to indicate the iodine reaction. A molecule of water H_2O was attached to the top block, to illustrate the first hydration of the starch molecule. The upper block was then removed, with its attached molecule of water, representing a molecule of maltose, the formula of which $C_{12}H_{22}O_{11}$ was on a white ground. At the same moment, by a mechanical

arrangement, the whole of the remaining nine blocks suddenly changed to a red colour indicating erythro-dextrin. The top remaining block was then hydrated, and removed changing to maltose, and leaving behind the second erythro-dextrin. The third block was in like manner hydrated, and on its removal the remaining seven blocks changed to white, indicating the first achroo-dextrin. These were successively hydrated showing the stages in the conversion of the starch molecules.

* Journ. f. Prakt. Chemie., 1880, 21, 227.

Fehling solution is in excess it attains 6.53. Two other sources of error are pointed out by Soxhlet, viz., that excess of Fehling solution permanently blues the paper of the filter owing to some compound of cellulose and copper being formed, and this, when the paper is burnt, will increase the amount of copper, and secondly that the determination of copper as oxide is not exact. To meet these difficulties he uses as a filter some asbestos which half fills the bulb of a chloride of calcium tube; on this the cuprous oxide is collected, and is then reduced to the metallic state by a stream of hydrogen. This reduction takes place at a very low temperature. According to Meissl* the determination of the maltose by the polarising saccharometer is liable to error owing to the fact that maltose exhibits the phenomenon of birotation. A freshly-made solution being about 18° weaker than one which has stood some hours.

My own experiments confirm the statement of Brown and Heron as far as their reaction (No. 8) is concerned, viz., that at 60° (140° F.), indeed, 63° (145°), and below, gelatinised starch undergoes, in the presence of malt extract, a definite process of hydration, which results in the production of a saccharine matter, consisting for all practical purposes of maltose, 80 per cent., dextrin, 20 per cent. I have not succeeded in obtaining any trustworthy evidence of definite reactions representing the other numbers. I could never obtain results sufficiently concordant to warrant the assumption that at any given temperature the reaction can always be represented by a definite formula. All that is certain is, that when the reaction takes place at temperatures above 60° (140° F.), the quantity of maltose falls off, and the quantity† of dextrin increases, until at 80° (176° F.), or thereabouts, the diastatic action is destroyed. I have endeavoured to put this in a graphic form on the diagram representing a thermometer. As you see the proportion of maltose and dextrin remains the same until 60° (140° F.) is reached. Even at 63° (145° F.) there is no practical difference; but from this point upwards the dextrin increases, until at 76° (169° F.) the proportion of maltose and dextrin are reversed. Up to this point the dextrin is one which gives no reaction with iodine. Above 76° (169° F.) the quantity of maltose produced is very small, and the dextrin gives a red colouration with iodine. At 80° (176° F.) the action ceases altogether, and iodine gives a blue colouration with the unaltered starch. What I wish you to observe is that the falling off in maltose is continuous, and does not advance by steps. The normal reaction by which 80 per cent. maltose and 20 per cent. dextrin is produced takes place, when sufficient malt is present, in about 20 minutes. After this reaction is complete the dextrin, in the presence of malt extract, undergoes hydration, and is ultimately converted into maltose; but this action is extremely slow, requiring a great many hours, and even then I have never seen a case in which the dextrin has completely disappeared. Here, again, the action is continuous. There is not the least indication of a halt corresponding to Brown and Heron's reaction No. 9. I think I am warranted in saying that there is no definite reaction, beyond the normal one, which will serve as a safe guide to the constitution of the starch molecule;

but as in the normal reaction, four-fifths of the whole is converted into maltose, it is evident that the formula, $C_{12}H_{20}O_{10}$ must be multiplied by 5 at least.

The most favourable condition for the action of malt extract on starch is a slight acid reaction (malt extract is always slightly acid). Brown and Heron have pointed out that a slightly alkaline reaction produces much the same result as a high temperature. I find that an increase of acidity beyond a certain limited amount has precisely the same effect. (I used for these experiments lactic acid, as that is the acid chiefly present in malt, and is also that chiefly produced during fermentation.) It will be seen later on that this has a most important bearing on the fermentation of distillers' worts.

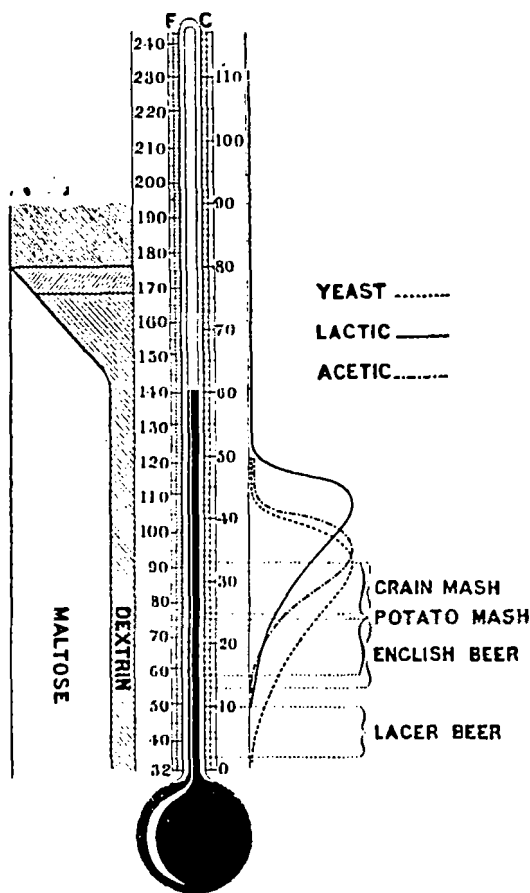


FIG. 2.

The body which brings about this remarkable action has received the name of diastase, but its nature and composition are very imperfectly understood, and it is doubtful whether it has ever been isolated. It occurs widely distributed in the vegetable kingdom. It is found most largely in germinating seeds, but also to a certain extent in seeds which have not germinated,* in the buds of many plants, and in the leaves of the oak and wild thorn.† Sometimes occurs where there is no starch to convert, just as emulsin occurs in sweet almonds which contain no amygdalin. It belongs to

* Journ. f. Prakt. Chemie., 1881, 25, 111.

† Mr. Southby (Brewing Practically and Scientifically Considered, by E. H. Southby, London, office of "The County Brewers' Gazette," 1877.) after speaking of mashing temperatures of 118° to 153° F., says "With porter and stout it is a common practice in many large breweries to use a much lower temperature in the mash, and where great fineness is required, this lower temperature is an advantage, increasing as it does the proportion of the dextrin to the sugar produced from the malt." This statement is precisely the reverse of the fact, and in direct contradiction to all that we know of the influence of temperature on diastatic action.

* In some parts of Russia, unsuited to the production of barley, but producing rye of excellent quality, this latter grain is treated in the mash tun without malt; the rye, without any preparation, whatever, containing sufficient diastase to effect the conversion of its own starch. The produce of alcohol by this process is, however, from ten to fifteen per cent. less than when malt is used, and the method is not now so much employed as formerly.

† Adolf Mayer. *Lehre von den Chem. Fermenten*, 1882.

the class of enzymes, the soluble or unorganised ferments, the other principal members of which are ptyalin in the saliva, pepsin in the gastric juice, invertin in the wash waters of yeast, emulsin or sinaptase in the almond, papain in papaya carica, rennet, etc. They are without exception destroyed when in solution at a temperature below the boiling point of water. Diastase loses its properties at 80° (176° F.); invertin and pepsin about 50° (122° F.). In the dry state they are much more permanent. Diastase can be heated to 120° (248° F.), pepsin to 110° (230° F.), invertin to over 100° (212° F.). They all act by bringing about hydration, though under very different circumstances. Thus the ptyalin of the saliva, which is also capable of degrading the starch molecule, requires an alkaline reaction, which is, as we have seen, almost fatal to diastase. Pepsin requires a very decided acid reaction, and under these circumstances degrades the molecule of albumin, much as diastase degrades starch. The resulting peptones weigh more than the albumins from which they are derived, owing to the hydration which accompanies the reaction.

Diastase is not diffusible, and for that reason starch is unacted on in the cold, unless the external membranous envelope be broken by trituration with some hard body. I rather insist on this point, as there seems to be a good deal of misapprehension about it. Mr. Lovibond* in his little book entitled "Brewing with Raw Grain," says at page 11: "Another method of forcing starch cells to give up their contents is to employ the osmotic or diffusive action of diastase. To accomplish this the ground grain is mixed with malt and water, and allowed to stand at as near 150° F. as possible, when the diastase of the malt finds its way through the cell walls, and converts the within contained starch into a solution of maltose and dextrin, which being very fluid readily escapes from the cells." This is quite a fancy picture of what does not, and could not happen. As long as the cell walls of the starch are intact no diastase can get in. But at 150° F. the cell walls are not intact. The diastase gets in at the crack, instead of diffusing through the membrane, that is all. I may mention another error based on a curious theory. A patent has been taken out by Mr. Kinder for rendering the action of the diastase on starch more complete by subjecting the mixture at 60° (140° F.) to a pneumatic pressure of about 80 lb. on the inch, just as starch is more easily converted by boiling with dilute acids, if the operation is performed under pressure. This is quite true in the case of dilute acids, but the pressure, *as pressure*, does nothing. The pressure is necessary only to get a higher temperature, which is not wanted for diastase, so that the analogy is altogether false. The action of compressed air was very carefully investigated by Paul Bert,† who found that while it retarded the development of the organised ferments, and in some cases even killed them, it had no influence whatever on the unorganised ferments, such as diastase, pepsin, etc.

A small quantity of diastase is capable of effecting the conversion of very large quantities of starch, probably 10,000 times its weight as a minimum. There is reason to believe, contrary to the generally received opinion, that the diastase itself undergoes no change, a very small quantity seems to do as much work as a large one, provided enough time is given, and this would hardly be the case, if the diastase was destroyed in doing the work. If this be the case the action is purely catalytic, and affords some clue to its nature. It is possible that the action of the enzyme

or soluble ferments is purely mechanical. In fact, that it is due to molecular vibration which causes the break-up of the molecules on which these ferments act. When solutions of albumin are heated to high temperatures, under pressure, they are peptonised, and undergo the same change which is brought about at lower temperatures by the presence of pepsin. Starch heated under pressure with water is converted into soluble starch. If this heating be continued at a pressure of 4 or 5 atmospheres, say at 150° to 160° (302° – 320° F.)—the conversion into maltose or glucose (it is not clear which) is almost complete. In these two cases a certain degree of heat produces the same result as the soluble ferments. Heat is nothing but molecular vibration, so that there is ground for supposing that the soluble ferments are bodies in such a state of molecular vibration, that they shake asunder, as it were, the fabric of the starch molecule, or of the albumin molecule as the case may be. Somewhat, though not altogether, comparable to the shaking asunder of dynamite, or gun-cotton, by the detonation of a small quantity of fulminate.

The action of the soluble or chemical ferments is specific. Diastase will not invert cane sugar. Invertin will not break up starch. The diastatic ferments are without action on salicin or amygdalin. It has been supposed that diastase exercises a peptonising action on the albuminous matters of grain, and this view is adopted by Mr. Faulkner in his recently-published book. This is certainly a mistake. It is well known that the peptonising action proceeds best in very acid media. In Germany, where no top yeast is to be had from the breweries, yeast, which the distiller requires to add to his wort, is artificially cultivated in very concentrated worts, containing as much peptones as possible. In order to effect this the worts are allowed to sour, until indeed they contain nearly two per cent. of lactic acid. In such a medium diastase is coagulated, and rendered inert, so that the peptonisation must be due to some other ferment, which acts, like pepsine, in an acid solution, and which has received the name of peptase, or vegetable pepsine.

That several bodies of the diastase class exist in malt can hardly be doubted. Those which are capable of most completely breaking up the starch molecule are those which are most easily coagulated by heat. When extract of malt is heated, say for 20 minutes to 75° (167° F.), it is still capable of acting on starch, but the action does not go far, the proportion of maltose produced is small. If the action is continued for a considerable time it does not make much difference. This effect is quite independent of the temperature at which the reaction takes place, which may be much lower than 75° . It depends solely on the temperature to which the malt extract has been heated. The kind of diastase which alone is able to carry the action further has been removed by the heat. If we bring it back again, which we can easily do, by introducing a small quantity of malt extract which has not been heated, a further action on the partially degraded starch molecule at once sets in, and the reaction is rapidly converted into the normal one, represented by maltose 80 and dextrin 20 per cent. As this reaction is of considerable practical importance, I shall try to make this evident to you by means of a beam of polarised light.

The experiment consisted in passing a parallel beam of light from the electric lamp through a large Nicol's prism A by which it was polarised. The beam then traversed a trough B provided with plate glass ends *bb*, and a thin plate glass removable partition C, so as to divide the trough into two unequal cells. The light next encountered a plate of quartz C made up of two semicircles *dd* fitted together, one of which consisted of dextro-rotary, and the other of laevo-rotary quartz;

* *Brewing with Raw Grain*, by Thos. W. Lovibond, London, E. and F. N. Spon, 1883.

† *Compt. rend.*, 1875, lxxx, 1579.

both plates having a thickness of 3.75mm. The light finally passed through a second Nicol's prism D, which served as an analyser, and a lense E, by means of which an image of the quartz plate C could be projected on a screen. Matters being thus arranged, the larger division of the trough was filled with a solution of the product of the action of malt extract at 70° (158° F.) on starch paste. The smaller division, which was 1-10th the size of the larger one, was filled with unheated malt extract. By rotating the Nicol's prism D on its axis, the double semi-circular image of the quartz plate was brought to an uniform greyish-blue colour (sensitive tint). On removing the glass partition in the trough, the two liquids were enabled to mix. In a short time a change of colour took place on the screen, the right-hand semi-circle became purple, inclining to blue, while the left-hand one became red, indicating a fall in the specific rotary power of the solution in the trough, owing to the conversion of products formed at the higher temperature into those characteristic of the lower temperature. The effect was to some extent obscured by the colour of the solution, which cannot be entirely removed.

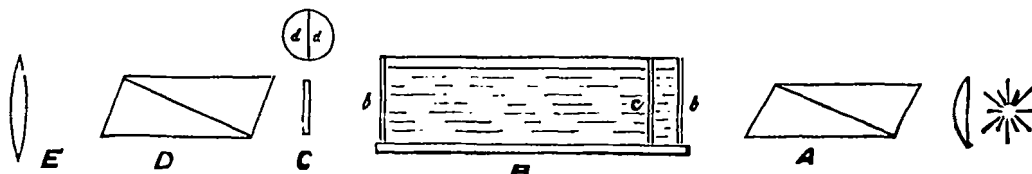


Fig. 3.

In brewing lager beer, hot water is not mixed directly with the malt, so as to produce at once, as in England, a mashing temperature of from 60° to 66° (140°-151° F.), but the malt is mixed with cold water. A portion of the mixture is run off, and is rapidly heated to the boiling point, to be returned to the mash-tun in order to raise the temperature of the whole. By this process the starch in the boiled portion is very completely utilised, but a considerable portion of it undergoes the saccharification corresponding to the higher temperatures, and ultimately the diastase is destroyed. This is of no consequence, for when the boiled portion is brought back to the cold malt and water in the mash-tun, the action is at once transformed into the normal one. The same thing happens in English distilleries where any starch not acted upon at the low temperature of the first mash, is transformed at the higher temperature of the first sparge into products corresponding with that temperature, and when this sparge is afterwards mixed with the first worts, containing unaltered diastase, the normal reaction ensues.

As we shall see presently, maltose is directly fermentable by yeast; dextrin is not. The distiller, whose object is to obtain the largest possible quantity of alcohol, is absolutely bound down to that mashing temperature which will give him the largest quantity of maltose. He may boil the rest of his grain to gelatinise the starch, but his malt must never go above the proper heat. Below the temperature at which barley starch gelatinises (57°-62°) he would lose the extract due to that starch, so he is obliged to work within very narrow limits. The brewer has more choice. Alcohol is not his only object, and he may vary the proportion of dextrin in his worts, and thus modify the character of his beer, by adjusting the temperature of his mashing. The distiller wishing to take advantage during his fermentations of the slow subsequent action of the diastase on the dextrin, must not exceed the temperature which would injure the diastase. The brewer has no further use for the diastase, and by boiling the worts destroys it.

FERMENTATION.

The starch having been converted into soluble saccharine matter, the next step is to convert this more or less completely into alcohol. This is accomplished by means of yeast, which consists of minute globules or corpuscles endowed with life, and capable of reproduction. This is added to the wort, and fermentation is set up. If yeast were a perfectly pure substance, containing nothing but the cells of *Saccharomyces Cerevisiae*, the matter would be a comparatively simple one, but it is not so. It is practically impossible to obtain yeast in a state of perfect purity. Other organisms are invariably present, each capable of setting up its own particular fermentation, and capable of reproduction at an alarming rate. Added to this, there are always minute organisms of various kinds adhering to the malt, and the different kinds of grain; and even the air which comes in contact with the worts is charged with the spores of all kinds of organisms, which are capable of development in the excellent conditions for their growth which all grain worts present. This is particularly the case with the air found in distilleries and breweries, especially if

the most scrupulous regard to cleanliness be not observed. Before we consider the conditions to be observed in order to obtain the maximum of alcoholic, and the minimum of secondary fermentations, we must study the peculiarities of the various organisms with which we have to deal. It would be quite impossible, in the time at my disposal, to deal with the immense number of tiny organisms which may, and occasionally do, produce the most disastrous results. I must confine myself on the present occasion to the three most important ones, viz., the yeast plant, the lactic acid ferment, and the acetic acid ferment. It was found impossible to project these minute bodies on the screen directly by means of the microscope, but with the assistance of my friend, Dr. Maddox, who is *facile princeps* in the art of microscopic photography, I have succeeded in preparing some photographs which I will endeavour to project. The yeast, as you see (autotype reproduction of photographs), consists of single cells of an ovoid shape. They are filled with matter of a highly nitrogenous composition, and in this transparent matter you will notice there are minute bodies, usually two or three in each cell, which probably consist of drops of liquid bedded in the protoplasm. In the healthy state, the walls of the cell are very thin, and scarcely visible, but when they are thick the cells are dead, or at any rate in a moribund condition. The cell is propagated in two ways. Under certain circumstances when the cells are growing in contact with air, spores are formed in the interior of the cell. The envelope then bursts, and the spores are set free; but the usual method of propagation during fermentation is by budding. A small protuberance is seen on the surface of the cell; this gradually increases in size, until it becomes as large as the parent cell. The new organism is finally detached, and then leads a separate existence; but before this takes place the new cell often becomes a parent in its turn, and this may go on until a perfect colony of cells hanging together is produced. There are two varieties of *Saccharomyces Cerevisiae*. One

known as "top yeast," characteristic of distillers' fermentations, and those fermentations which take place in English breweries. The other, "bottom yeast," characteristic of the lager-beer manufacture. Though these two varieties may have had one source originally, they are not readily convertible one into the other, and are probably instances of the Darwinian hypothesis, the organism having been modified in the course of many generations by the conditions under which it has been forced to exist. (Both these were shewn on the screen.) For a sample of bottom yeast I am indebted to the Austro-Bavarian Brewery Company. There is another species of *Saccharomyces*, *Saccharomyces Mycoderma*, which, like the others, is propagated by gemmation. The peculiarity of this organism is that it forms a skin on the surface of worts after the alcoholic fermentation is complete. It is very frequently found on distillers' wash, and when floating on the surface it absorbs oxygen and produces acetic acid. When plunged below the surface it produces alcohol, but only in very dilute solutions. Natural yeast, which I may call "wild yeast," as it is not cultivated, is found in the fermenting juice of the grape, and some other kinds of fruit. It has received the name of *Saccharomyces Ellipsoideus*, from its shape. A specimen of this (the *apiculatus* variety), obtained from plum juice, was exhibited.

The lactic ferment is a very different organism, and belongs to the bacteria class. It consists of fine threads of variable length made up of rod-like cells united together. These threads are excessively minute, generally less than the $\frac{1}{100}$ of a millimetre in diameter, though of variable length. This organism is fissiparous, that is to say, it is propagated not by budding, but by the division of the cells into two smaller cells, each of which leads a separate existence, and becomes as large as the parent cell, when it divides again. The acetic ferment consists of minute spherical cells which have a tendency to unite into threads, forming the well-known vinegar plant, which consists of millions of these bodies. These organisms are also fissiparous. All these bodies multiply under favourable circumstances with great rapidity, but in order to build up the substance of which they are composed they require certain kinds of food. These are carbohydrates, such as maltose or glucose, certain salts, chiefly phosphate of potassium and magnesium, and lastly albuminous, or rather albumenoid substances, which must be in the state of peptones, the molecule of albumin being too large to pass through the pores of the membrane which constitutes the envelope of the organism. In fact, they are unable to assimilate any food which is not diffusible. I have here some solution of pure invert sugar, divided into two portions. To both I have added a small quantity of yeast, and some phosphate of potassium, but to the one I have added some white of egg without any preparation, while to the other I have added a similar quantity of white of egg which has been previously treated with pepsin, and a little lactic acid. You will see that the yeast in the former has made no progress, while in the latter it has developed, and the solution is now in active fermentation. In other respects, the conditions of growth of these bodies present marked differences. By the side of the thermometer I have represented the effect of temperature. (See thermometer diagram, Fig. 2.)

The regularly dotted line represents the yeast curve. This organism is as you see capable of inducing a slight fermentation at a temperature very little over the melting point of ice. As the temperature rises its activity increases, until the optimum is reached at about 33° (92° F.) when it diminished down to nothing again, and at 50° (122° F.) or thereabouts it

is killed. The activity of the acetic ferment represented by the irregularly dotted line begins about 12° (54° F.) reaches its optimum about 36° (97° F.) when it begins to fall off, and finally, like yeast, loses its vitality at 50° (122° F.) The lactic ferment represented by the even line, begins to be active at a slightly lower temperature, viz., 10° (50° F.). Its activity increases gradually with the temperature, until it reaches a maximum at 44° or 45° (112° F.) when, as in the other cases, the activity diminishes, but observe how the line of life runs up, for although this organism produces no lactic acid at a temperature above 50° (122° F.), its vitality resists even the temperature of boiling water, and it is not finally destroyed under 111° (232° F.).

These curves are intended to indicate only in an approximate way the effect of temperature, and, temperatures being equal, they are very considerably modified by other conditions, for example, acidity. A certain acid reaction is favourable to the growth of yeast, and as lactic acid is the principal acid generally present in fermenting worts, its action may be taken as typical. In the presence of this acid, to an extent not exceeding $\frac{1}{2}$ to 1 per cent., the yeast plant develops far more rapidly than in a neutral medium. On the other hand the lactic acid ferment is extremely sensitive to the product of its own action. In a solution containing one per cent. of lactic acid, this ferment develops with extreme difficulty, and when the acidity amounts to two per cent. or even a little less, the action is completely arrested, and the organism dies. For this reason the latter ferment is very rarely found in fermenting grape juice, on account of its great acidity. This organism grows best in a neutral solution, so that if we wish to prepare, by means of this ferment, large quantities of lactic acid from a saccharine solution it is necessary to add some substance, such as carbonate of lime, capable of neutralizing the acid as fast as it is formed. It sometimes happens in breweries and distilleries that, owing to slow cooling of the worts, they have remained too long at a temperature of about 40° to 45° (104° to 113° F.) which is especially favourable for the development of this ferment. In ordinary parlance, the worts have soured. It is a frequent practice to add whitening or some such substance to neutralise them. This is the worst thing that can be done. The ferment is not thereby destroyed, on the contrary it sets to work again with renewed energy. Acidity is favourable to the development of those organisms, which are known collectively under the name of mouldiness. If a mixture of yeast, bacteria, and mould be introduced into a neutral wort, the bacteria will gain the upper hand. If the acidity amount to one per cent. the yeast will predominate, and if the solution contain five per cent. of organic acids, the mouldiness will have pretty much its own way. It is a well-known fact that meat rapidly putrefies when subjected to the action of saliva, while it keeps a long time in gastric juice. The explanation is that the slight alkalinity of the former favours the growth of bacteria, while the acidity of the latter has the contrary effect.

As the lactic acid ferment is retarded and ultimately killed by the product of its own action, so also is yeast. When the liquid contains from 12 to 14 per cent. of alcohol, fermentation altogether ceases, and by still greater concentration the yeast plant is killed. Alcohol also exercises an unfavourable influence on all organised ferments, and it is chiefly to this circumstance, though not altogether, that fermented vegetable juices and worts, such as beer, wine, &c., and pharmaceutical tinctures owe their keeping properties. The action of the lactic ferment is very distinctly retarded by the presence of alcohol. The acetic ferment is not so sensitive. Many other

substances are antagonistic to the growth of these organisms. Benzoic, cinnamic, carbolic,* salicylic, boric, and sulphurous acids, mercuric chloride, and generally the salts of the heavy metals, and in a less degree chlorides of the alkalis and alkaline earths. Hence the preservative action of common salt. Oil of hops and the aqueous extract of hops have a similar effect, and are powerful factors in the keeping properties of the highly-hopped English beers. The acids of the fatty series also retard fermentation, and this action appears to increase as we ascend the scale, acetic acid having a very marked influence in this direction, while butyric, valerianic, and caproic acids, are powerful poisons for the yeast plant, and ferments generally. Our pickles would no doubt keep much better if prepared with valerianic or butyric acids, though the flavour might possibly suffer to some extent. On the other hand prussic acid and the poisonous alkaloids appear to have very little action.

Lastly, the various ferments interfere with each others' action. Even among these low organisms there is a struggle for existence, which does not always end in the survival of the fittest, or at least the fittest for our purpose. In a wort in active alcoholic fermentation containing abundance of healthy yeast growth the lactic ferment, for instance, develops much less slowly than it would under similar circumstances, in the absence of the yeast.

As a general rule yeast is less sensitive than the lactic and other organisms of the bacteria class to the influences I have named, particularly such as salicylic acid, hops, etc., so that the curves which I have laid down as approximately representing the action of yeast and lactic and acetic ferments, are very considerably modified according to the substances present in the medium in which they live and have their being.

Disregarding for the moment the other influences let us examine that of temperature. On the right-hand side of the thermometer diagram, I have indicated the range of temperatures incident to the two great systems of beer brewing, lager or bottom fermentation beer, and English or top fermentation beer. You will notice that within the lager beer range the lactic ferment, and the acetic ferment are for all practical purposes inactive, and the fermentation remains of necessity a purely or very nearly a purely alcoholic one, though, owing to the low temperature, it is very slow.

In the English beer range the conditions are altogether different. Although the action of the yeast is more energetic, we have got within the range of the other ferments, though their activity at this temperature is not great as compared with that of the yeast. Still, supposing the lactic ferment to be present in any quantity, the amount of lactic acid produced, as indicated by the curve, would result in a very sour beer. In practice this effect is considerably modified. Owing to the energy of the alcoholic ferment the lactic fermentation is to a great extent suppressed, and the abscissa of the lactic curve are from this cause alone considerably shortened. In addition to this, the much larger quantity of hops used in English breweries has a tendency to lower both the curves, but it affects the lactic curve more than it affects the alcoholic one, and still further changes the aspect of the diagram. Still, as a net result, the English beer contains more lactic acid than the German beers. Professor Graham, in a paper on the brewing of lager beer, which he read before the first anniversary meeting of this society, said "that hops are to the English beer what ice is to lager beer—a means of keeping out the secondary ferments, and so promoting the preservation of the

beer." With this I quite agree, but with a single reservation, which is this. In the manufacture of lager beer, from the nature of the operation, the ice *must* be used, while in English beer, not of the high-class bitter beers, the hops are occasionally a little deficient. This is particularly the case with what are known as running beers, so called, I fancy, because you must run and drink them as soon as they are brewed.

Let us turn now to the influence of temperature on distillers' worts. In this case the object of the manufacturer is to convert the whole of the extract, or at any rate as much as possible, into alcohol, a thing not at all contemplated by the manufacturer of beer. The maltose being directly fermentable by the action of yeast, while the dextrin is not, the distiller must in the first instance so regulate his temperature as to obtain the maximum of the former with the minimum of the latter. He is therefore tied down to a mashing temperature not exceeding 60° to 63° (140°-146° F.). Up to this temperature he must go to ensure, as far as possible, the gelatinisation of the starch. When its conversion is complete, he may go a little higher, but not much. He is generally working (unless he is really a manufacturer of pure malt whisky) with as much raw grain as possible, and the minimum of malt, and to him a further action of diastase at a later period is absolutely essential. He dare not, therefore, play any tricks with it. This diastase, by long-continued action on the residual dextrin, is capable of gradually hydrating it, and converting it into maltose, but the action is excessively slow. It is found in practice that, in fermenting worts whose temperature has never exceeded 60° to 64° (140°-147° F.), that the dextrin is tolerably completely converted into alcohol, and it was assumed that the diastase acquired a greater power of acting on the dextrin when the maltose present in the worts had been removed by fermentation. In other words, that the maltose present in solution exerted a retarding influence on the action of the diastase. Closer investigation makes this view very improbable. The fact appears to be that, though yeast by itself has little or no action on dextrin, and diastase by itself only a very slow one, in the presence of both of these agents the dextrin is fermentable, though much more slowly than maltose or glucose. As I have already pointed out, diastase requires for its efficient action a slightly acid reaction; but when the acidity passes a certain point, the diastase is coagulated and rendered inert, so that if the worts during fermentation become very acid, the action of the diastase in assisting the yeast to ferment the dextrin becomes seriously impeded, and may be altogether stopped.

In order to obtain the maximum effect of the yeast, it is necessary to work at higher temperatures than in the case of beer, and the distiller has found that the best results are obtained when the temperature during fermentation rises to about 33° or 34° (92°-94° F.), which, by reference to the thermometer diagram, you will see is about the optimum of the alcoholic fermentation. But this temperature—indeed, the whole range of the distillers' fermentation, as practised in England—although extremely favourable to the yeast growth, is also extremely favourable for the lactic fermentation, and the acidity may grow to such an extent as to interfere seriously with the subsequent action of the diastase. Here there can be no question of hops or of ice to remedy the evil. Of course the thing is not so bad as it looks on the diagram, on account of the preponderating influence of the yeast, which, owing to the fact that one fermentation suppresses another, keeps the lactic ferment to a certain extent in check. It is on an active healthy growth of yeast that the distiller must

* Benzoesäure, Carbonsäure, Salicylsäure, Zinnssäure. Dr. H. Fleck, München, Oldenbourg, 1875.

chiefly rely to keep the lactic ferment down, added to which extreme cleanliness, and care in the selection of yeast, as free as possible from lactic ferment, to start his backs. Notwithstanding all precautions, a considerable quantity of lactic acid is unavoidably produced, and as this is produced at the expense of the maltose, which would otherwise be converted into alcohol, a very notable loss ensues. Every week some hundreds, I should say two or three hundred tons, of pure lactic acid is run to waste in the spent mash, from which alcohol has been distilled, in the United Kingdom alone.

As long as the lactic acid present is under one-half per cent., not much harm is done to the diastase; but as soon as this limit is passed, the diastase is very seriously lamed, and as a result a considerable portion of the dextrin remains unfermented, causing much loss to the manufacturer.

In Germany, where alcohol is largely manufactured from potatoes, the conditions are somewhat different. The distiller there is not troubled with an excise attenuation charge, and is consequently not obliged to separate the solid matter from the wort. He ferments the entire mash, solid matter and all. Under these circumstances he is able to prepare a much more concentrated liquor. While the worts in English distilleries rarely exceed a gravity of 1050, and more commonly are under 1040, the German distiller prepares a mash of a gravity of 1080 to 1090. This enables him to begin his fermentation at a much lower temperature, for the heat evolved in the fermentation of such a concentrated wort ultimately carries the temperature to the same point as reached by the English distiller, viz., the yeast optimum. Owing to the low temperature, the fermentation is at first rather sluggish, and it is only when the higher temperatures are reached that violent fermentation sets in.

When speaking of the influence of various substances on fermentation, I pointed out that the presence of alcohol had a restraining effect, but that alcohol affected the ferments of the bacteria class, such as the lactic acid ferment, far more than yeast. The German plan therefore presents the advantage that at the low initial temperature of the fermentation, comparatively little lactic acid is produced, and when the higher temperatures are reached, the mixture then contains so much alcohol that the lactic acid ferment grows with considerable difficulty.

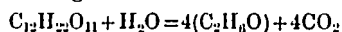
As long as the excise attenuation charge, which necessitates more or less clear worts, is imposed in England, this plan cannot be adopted here.

As the yeast rises to the surface of the fermenting wort, it is removed by the brewer, who obtains in this way much more than enough to start his new fermentations. The distiller cannot do this. As a general rule, distillers' worts, composed of the possible maximum of raw grain and the possible minimum of malt, contain such a small quantity of peptones, that in the later stages of the fermentation a portion of the yeast dies, and another portion lives on the substances, which pass into solution in consequence. As a result, the yeast contains a large quantity of dead cells. Even when the peptones are present in sufficient quantity, the lactic acid ferment has—especially at the end of fermentation, when the temperature is highest—developed to such an extent as to constitute a notable portion of the yeast collected. If this yeast were used to start the new backs, the result would be a great production of acidity, and consequent restraining of the action of diastase on the dextrin. In technical language the backs would "stick," and would refuse to attenuate beyond a certain point.

In this country the distiller, profiting by the excess

of yeast obtained by the brewer, draws his supply from that source, brewers' yeast being far freer from the lactic ferment than any the distiller can produce by the ordinary methods of working.

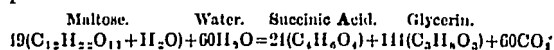
As to the nature of fermentation, more than one theory has been suggested. Pasteur observed that yeast, when growing in contact with air, and a proper supply of the salts, carbohydrates, and peptones, which constitute its natural food, rapidly absorbed oxygen, and under these circumstances produced comparatively little fermentation. He explained fermentation to be the result of the growth of the yeast cell, *in the absence of free oxygen*, a condition which compelled the cell to obtain its oxygen by the decomposition of the saccharine matter in the medium in which the cell is suspended. He pointed out that fermentation did not result in a simple splitting up of glucose (or maltose + water) into carbonic acid and alcohol, according to the formula



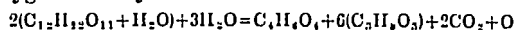
glycerin and succinic acid are always produced at the same time, and, according to Pasteur, 100 parts of glucose produce—

Alcohol	48.40
Carbonic acid	46.60
Glycerin	3.30
Succinic acid	0.61
Cellulose fat, etc.....	1.20

Supposing that the greater part of the sugar splits up into carbonic acid and alcohol, according to the simple formula, Pasteur explained the production of the succinic acid and glycerin by this very complicated formula.

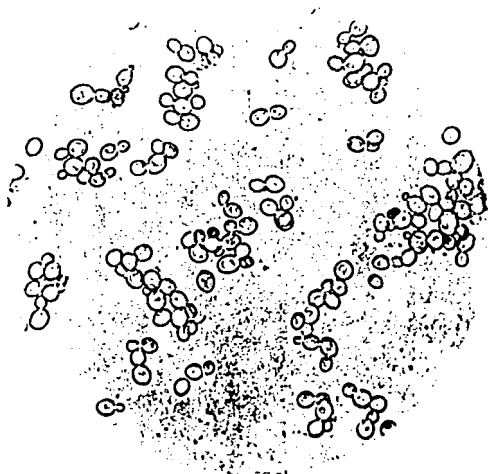


All this, however, does not explain precisely what is the source of the oxygen, in search of which the yeast is breaking up the saccharine matter. In order to meet this difficulty Monoyer* constructed a far simpler formula, which explains the formation of the succinic acid and glycerin, and furnishes a supply of oxygen to the yeast cell.

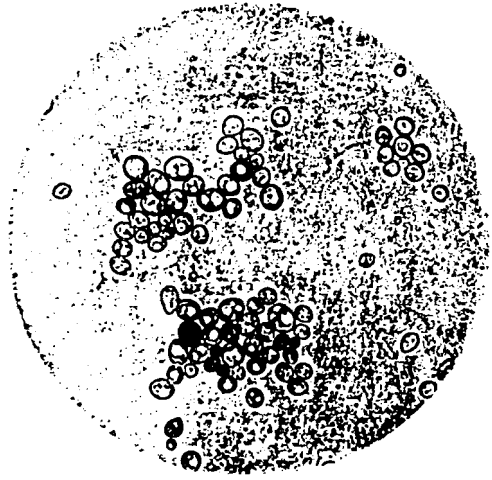


According to Nügel† the action of the yeast cell is due to molecular vibration of the protoplasm which it contains. In consequence of this molecular action, the decomposition of the sugar takes place outside, and not inside, the cell, as Pasteur's theory requires. This action is supposed to extend to a minute but sensible distance from the cell. The formation of acetic ether by the combined action of the acetic and alcoholic ferments is certainly a fact which tells strongly in favour of this view. Acetic ether is produced when acetic acid and alcohol are brought together in the *nascent* state. Now, if acetic acid be formed in the inside of the acetic ferment cell, and the alcohol is produced in the inside of the yeast cell, no acetic ether could be produced; but if a zone of molecular vibration, in which the work is done, surrounds each cell, it is evident that wherever these zones cut each other acetic ether would be produced. This theory also explains—what is not readily explicable otherwise—the suppression of one ferment present in small quantity by another ferment present in large quantity. More powerful vibrations tend to suppress less powerful vibrations, which are not in unison with them, and if we suppose each ferment to have a peculiar vibration of its own, in virtue of which it sets up a specific decomposition in the surrounding medium,

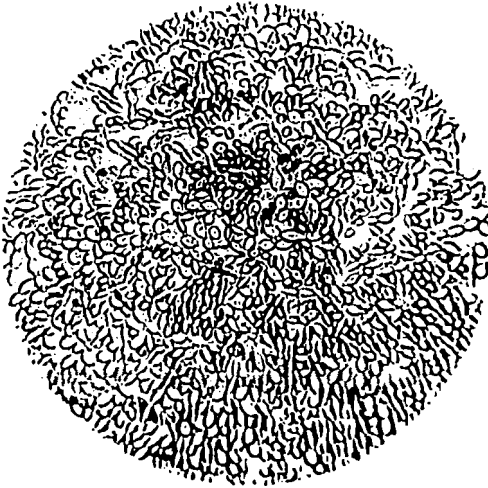
* Thèse de la Faculté de Médecine de Strasbourg.
† Nügel *Gährungs-theorie*.



Saccharomyces Cerevisiae (Var. Top Yeast)



Saccharomyces Cerevisiae (Var. Bottom Yeast)



Saccharomyces Ellipsoideus. (Var. Apiculatus)



Saccharomyces Mycoderma.



Acetic Acid Ferment



Lactic Acid Ferment.

we can easily understand how the predominating vibrations will tend to suppress the rest.

When speaking of diastase and the soluble ferments, I drew attention to the strong probability that their action is due to molecular vibration, and if Nægeli's views about the action of the organised ferments be correct, we have a common explanation for the two phenomena.

I have endeavoured to sketch, as fully as the time at my disposal would permit, the processes concerned in the conversion of starch into alcohol, and the modern theories of the changes which occur. I am quite aware that this sketch has been a most imperfect one. Many important points I have only glanced at, others I have passed by altogether. I have confined myself pretty much to what takes place when matters proceed smoothly, without attempting to deal with the derangements caused by a host of organisms which from time to time intrude themselves. To the charge, therefore, of many and important omissions, I at once plead guilty, but I couple with that plea "extenuating circumstances."

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Journal and Patent Literature.

I.—GENERAL PLANT, APPARATUS, AND MACHINERY.

A Hydrometer adapted to the Demonstration of Changes of Weight in Chemical Reactions. By Max Gröger, Berl. Ber., 17,568.

THIS hydrometer is constructed on the plan of Nicholson's. The description of the instrument is accompanied by figures. It is so constructed that the sensitiveness is independent of the load, and depends only upon the diameter of the upper rod which carries the scale-pan: this being 1mm., the depression is 1cm. per 0.00786grm. The hydrometer is specially adapted to the lecture demonstrations described by Rosenfeld (Ibid. V., 14 and 16).—C. F. C.

Pumps or Syphons for Drawing Acid from Carboys, &c. J. Longshaw, Salford. Eng. Pat. 4873, October 13th, 1883. Provisional protection granted only.

THIS invention is a combination of a pump and syphon. A tube fitting into the mouth of the carboy or vessel is provided at its lower end with a ball or other valve. Its interior is fitted with a piston, the rod of which is hollow and bent over to form the longer leg of a syphon, its end being sometimes provided with a cock. The syphon is brought into action by drawing up the piston so as to fill the lower tube; on quickly pressing it down again the liquid passes up the bent piston rod and fills the tube, syphoning being thus established.—C. C. H.

A New and Improved System of Evaporation and Distillation, and for Practical Application of the same. W. A. Barlow, London. Communicated by P. Callibures, Paris. Eng. Pat. 3309, February 14th, 1884.

THIS invention provides for the carrying into effect the above operations in a more economical manner than heretofore. The liquid operated upon is broken or pulverised into spray in the interior of a closed evaporating pan, and at the same time a current of air is forced through the spray so produced, which air has been previously purified and heated. The vapour carried off is condensed if desirable, and in processes of distillation the air discharged from the condensers is used through the apparatus again. The apparatus consists of: (1) A purifier, through which the induced current of air subsequently forced through the machine is filtered and washed. (2) A fan or other apparatus for forcing the air through the evaporator. (3) A heater, consisting of a vertical vessel provided with steam heated pipes, for heating the air to the desired point. (4) A pump for forcing the liquor under treatment through the pulveriser. (5) A domed evaporating pan containing the pulveriser, which consists of a cylindrical vessel provided with slits through which the liquid is forced, and striking against a hood breaks up the jets into spray. (6) The condenser, of which two or more may be employed in series, a pipe from the last of which communicates with the air-fan. The liquid in certain cases may be forced through the pulveriser by means of air, or a spray may be produced in a similar manner to an ordinary scent spray. Suitable apertures, provided with cocks, allow the material to be taken from the pan when required. The whole invention is covered by 12 principal and 9 minor claims, which include the combinations of the different apparatus, and also the evaporation of sugar, wine, beer, wort, grape juice, fruit syrups, milk, and the distillation of sea-water, alcohol, and petroleum, as well as the preparation of distilled water.—C. C. H.

Improved Means for Generating Steam by Chemical Agents. H. H. Lake, London. Communicated by H. Grünberg and G. Hardt, Cologne. Eng. Pat. 4295, March 3rd, 1884.

THE generation of steam by means of chemical agents has usually been effected by the heat given out during