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A REVIEW ON THE USE OF SODIUM BENZOATE AS A PRESERVATIVE IN CARBONATED SOFTDRINKS

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Abstract:

One of the most compelling reasons for food analysis is to ensure that it is safe for both consumers and producers. Sodium benzoate is a widely used preservative that can be found in many foods and beverages. This study contains an overview on the properties, uses, safety, contraindications, adverse reactions and harmful effects of sodium benzoate. FDA accepted concentration is 0.1% and WHO accepted daily intake is 5mg/kg. From the available preservatives sodium benzoate is safer for consumption, however the continuous use may lead to harmful health hazards. It is safe to avoid over consumption of soft drinks and beverages in day-to-day life.

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INTRODUCTION:

Carbonated drinks or what is known as soft drinks become one of the favorite drinks as a thirst release because it tastes good and fresh. It is stored for a certain period of time. This drink is often given additional preservatives to maintain its quality. One of the preservatives that are often used is sodium benzoate. The salt form of benzoic acid is preferred because it is 200 times more soluble than its acidic form.

The Food and drug administration (FDA) includes benzoate as a commonly recommended ingredient with a maximum allowable concentration of 0.1%. The use of a higher benzoate of about 0.1% will change the taste in soft drinks.

Food preservatives have become an increasingly important practice in modern food technology with the increase in the production of processed and convenience foods. These preservatives are added to stop or delay nutritional losses due to microbiological, enzymatic or chemical changes of foods and to prolong shelf life and quality of foods. Preservation is aimed at achieving the self-life prolongation of foods. Present tendencies are based on the employment of certain methods which ensure qualitatively products, less preserved, with no additives, with nutritional value, but also safe from the microbiological point of view. Preservatives are defined as substances able to inhibit, stop or delay the growth of microorganisms or any deterioration of ailments due to microorganisms.
A preservative may be defined as any e substance that prevents or retards deterioration when added to food and drinks. It may inhibit or retard changes in appearance, odor, flavor and nutritive value. They inhibit the contamination/ growth of microorganisms such as yeasts, bacteria, molds or fungi in foods and drinks. Sorbates, benzoates, propionates and sulfites are used broadly in fruit processing. The principal mechanisms are reduced water availability and increased acidity. The principal mechanisms involved are reduced water availability, increased acidity and change in redox-potential. Many of these preservatives target microbial membranes and affect the viability of microbes.

Preservatives are classified as Class I & Class II.
Class I preservatives belong to natural sources which also exhibit preservative effects in foods. Examples of Class I preservatives are sugar, salt, vinegar, honey, spices, edible oils etc.

Class II preservatives are obtained by chemical derivation of compounds. Sorbates, benzoates, propionates and sulfites are used broadly as class II preservatives in fruit processing.

Benzoic acid:

Benzoic acid and its sodium salt (sodium benzoate) is permitted to the maximum level of 0.1%. Benzoic acid and its sodium salt are most suitable for preserving foods and beverages that naturally are low in pH (2.5 – 4.0). Sodium benzoate is more effective against yeasts and bacteria than molds. The narrow pH of its activity limits wider application of this preservative in foods. These are used to preserve carbonated at 0.03-0.05% and non-carbonated beverages at 0.1%, fruit pulps and juices. As an antimicrobial agent, benzoate acts synergistically with sodium chloride, sucrose, heat, carbon dioxide, and sulfur dioxide.

Sodium benzoate is a common preservative added to commercially available foods and beverages. Once dissolved in a polar solution, sodium benzoate dissociates into sodium ions and benzoic acid. Sodium benzoate is the sodium salt of benzoic acid and works well in acidic media to inhibit yeasts, molds, and bacterial growth. It is used in a variety of products, such as cosmetics and pharmaceuticals, but more commonly in foods like soda and fruit juice to preserve freshness. Benzoic acid is an effective antimicrobial agent for the purpose of preservation. Sodium benzoate is a very stable solid material, soluble in water at room temperature. It has antimicrobial activity against bacteria, fungi and yeasts, and shows most activity at pH below 4.5. It is recommended as a preservative for a number of food products consumed by humans at an optimum level of 0.1 %. The recommended limits in foods are 0.1 to 0.5 % for different countries.

SODIUM BENZOATE PROFILE

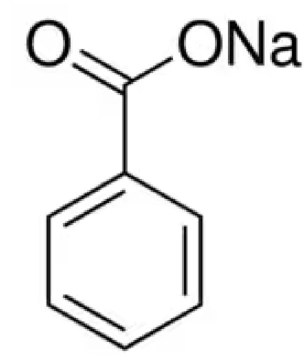


Fig no: 1 Structure of sodium benzoate

Sodium benzoate is best known as a preservative used in processed foods and beverages to extend shelf life, though it has several other uses. It is an odorless crystalline powder made by combining benzoic acid and sodium hydroxide. Benzoic acid is a good preservative on its own and combining it with sodium hydroxide helps it dissolve in products.

PROPERTIES

Molecular weight: 144.1g

Molecular formula: $C_7H_5NaO_2$

Category: pharmaceutical aid (preservative)

Definition: Sodium benzene carboxylate

Content: not less 99.0% and not more than 100.5% of dried substance

PHYSICAL PROPERTIES

Physical description:

Dry powder, pellets or large crystals; liquid

A white, almost odorless, crystalline powder or granules.

Odor:

Odorless

Boiling point:

>450^{0}C to <475^{0}C, decomposes with no boiling (OECD guidelines 103 (boiling point/boiling range))

Melting point:

For benzoic acid melting range of benzoic acid isolated by acidification and not recrystallized 121.5^{0}C to 123.5^{0}C, after drying in a sulfuric acid desiccator. 436^{0}C (OECD Guideline 102 (Melting point/ melting range))

Flash point:

>100^{0}C (>212^{0}F)

Solubility:

Freely soluble in water, sparingly soluble in ethanol. In water, 556g/L (temperature and pH not reported)

Density:

1.50g/cu cm (OECD Guideline 109 (Density of liquids and solids))

Relative density (water=1): 1.44

Vapor Pressure:

2.9×10-12mmHg at 25^{0}C

Autoignition temperature:

>500^{0}C

Decomposition:

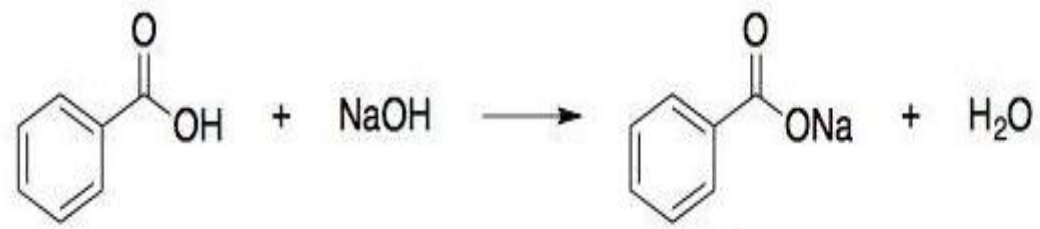
When heated to decomposition it emits toxic fumes of sodium oxide. It may emit acrid fumes when heated to decomposition (at 120^0 C/244^{0}F)

PREPARATION

Sodium benzoate is typically synthesized through the reaction of benzoic acid with sodium hydroxide. Here's a simplified description of the synthesis process:

- Preparation: Gather the necessary materials and equipment, including benzoic acid, sodium hydroxide, a beaker, a stirring rod, and a heat source.
- Mixing: In a beaker, add a measured amount of benzoic acid (C_6H_5COOH). Slowly add a stoichiometric amount of sodium hydroxide (NaOH) to the beaker while stirring continuously. The reaction equation is as follows:
  $C_6H_5COOH + NaOH \rightarrow C_6H_5COONa + H_2O$
  Ensure the reactants are well-mixed, and continue stirring until the benzoic acid has completely dissolved.
- Heating: Place the beaker containing the mixture on a heat source, such as a hot plate, and heat it gently. Apply moderate heat and maintain the temperature below the boiling point of the solution. Heating the reaction mixture helps to speed up the reaction and facilitates the formation of sodium benzoate.
- Evaporation: Continue heating the mixture until most of the water evaporates. As the water content decreases, the solution becomes more concentrated, and sodium benzoate will start to crystallize.
- Cooling and Filtration: Allow the solution to cool to room temperature or cool it further in a refrigerator or ice bath. The cooling process promotes further crystallization of sodium benzoate. Once the crystallization is complete, filter the mixture to separate the solid sodium benzoate crystals from the remaining liquid.
- Washing and Drying: Rinse the collected crystals with a small amount of chilled water to remove any impurities or residual reactants. Then, allow the crystals to dry thoroughly, either by air drying or using a desiccator.
- Storage: Store the dried sodium benzoate crystals in a clean, dry container, preferably an airtight container, to maintain their quality and prevent moisture absorption.

  It is important to note that this is a simplified overview of the synthesis process. The actual synthesis may involve specific reaction conditions, purification steps, and quality control measures depending on the desired purity and intended use of the sodium benzoate.



Benzoic acid **Sodium Hydroxide** **Sodium Benzoate**

Fig no: 2 synthesis of sodium benzoate

IDENTIFICATION:

To a 10% w/v solution add ferric chloride test solution; a buff-colored precipitate is formed. Add dilute HCl; a white crystalline precipitate is produced.

TESTS:

a) **Appearance of solution:**
A 10.0% w/v solution in CO_2 free water is clear and not more intensely colored than reference solution YS6.

b) **Acidity or alkalinity:**
To 20 ml of 5.0% w/v solution in CO_2 free water add 0.2ml of phenolphthalein solution. Not more than 0.2ml of 0.1M HCl or 0.2 ml of 0.1M NaOH is required to change the color of the solution.

c) **Arsenic:**
Mix 5.0g with 10 ml of bromine solution and evaporate to dryness on a water-bath. Ignite gently, dissolve the cooled residue, ignoring any carbon, in 50ml of water and 14ml of brominated HCl acid AsT, and remove the excess of bromine with 2 ml of stannous chloride solution AsT. The resulting solution complies with the limit test for arsenic (2 ppm).

d) **Heavy metal:**
2.0g complies with the limit test for heavy metals.

e) **Chlorinated compounds**
Dissolve 0.33g in 5 ml of 0.5M sodium carbonate, evaporate to dryness and heat the residue until completely charred, keeping the temperature below 400^0. Extract the residue with a mixture of 10 ml of water and 12 ml of dilute nitric acid and filter; the filtrate complies with the limit test for chlorides.

f) **Loss on drying**
Not more than 2.0%, determined on 1.0 g by drying in an oven at 105^0C.

STORAGE

Store protected from light.

ADVANTAGES

Sodium benzoate is a commonly used food preservative and additive with several advantages. Here are some of its key benefits:

- Antimicrobial Properties: Sodium benzoate exhibits strong antimicrobial properties, inhibiting the growth of bacteria, yeast, and fungi. It prevents the spoilage of food and beverages by effectively controlling the growth of microorganisms.
- Wide pH Range Stability: Sodium benzoate remains stable and effective over a wide pH range, from acidic to neutral conditions. This versatility makes it suitable for a variety of food and beverage applications, including acidic products like soft drinks, fruit juices, and pickles.
- Effective Against Mold and Yeast: Sodium benzoate is particularly effective in inhibiting the growth of mold and yeast. It prevents the development of visible signs of spoilage, such as discoloration or off-putting odors, in food and beverage products.
- Extended Shelf Life: By preventing microbial growth, sodium benzoate extends the shelf life of products. It helps maintain the freshness, quality, and safety of food and beverages, reducing waste and ensuring consumer satisfaction.
- Safe for Consumption: Sodium benzoate has been extensively studied and approved as a safe food additive by regulatory authorities, including the U.S. Food and Drug Administration (FDA) and the European Food Safety Authority (EFSA). It has a long history of safe use in a wide range of food and beverage products.
- Synergistic Effects with Other Preservatives: Sodium benzoate can work synergistically with other preservatives, enhancing their effectiveness. It is often used in combination with other additives, such as citric acid, to achieve a broader spectrum of preservation and optimize the overall product stability.
- Solubility and Stability: Sodium benzoate is highly soluble in water, making it easy to

incorporate into various food and beverage formulations. It also remains stable during storage and processing, ensuring consistent performance and preserving the desired product characteristics.

It is important to note that while sodium benzoate offers several advantages as a preservative, it is essential to follow regulatory guidelines and use it in appropriate concentrations to ensure food safety and maintain consumer health.

USES

Sodium benzoate is a commonly used preservative in various industries, including the pharmaceutical industry. It has antimicrobial properties and is effective against a wide range of microorganisms, including bacteria, yeast, and molds. In pharmaceuticals, sodium benzoate serves several purposes:

- Preservative: Sodium benzoate helps prevent the growth of microorganisms in pharmaceutical products, such as liquid medications, creams, and ointments. By inhibiting the growth of bacteria and fungi, it helps extend the shelf life of these products and maintains their safety and efficacy.
- pH adjuster: Sodium benzoate is also used as a pH adjuster in certain pharmaceutical formulations. It can act as a buffering agent to stabilize the pH of a solution, ensuring that the medication remains in the desired pH range for optimal stability and effectiveness.
- Disintegrant: In some oral solid dosage forms like tablets or capsules, sodium benzoate may be used as a disintegrant. It helps break down the tablet or capsule upon ingestion, allowing for efficient drug release and absorption in the gastrointestinal tract.

It's important to note that the specific use of sodium benzoate in pharmaceuticals, including dosage and application, can vary depending on the formulation and regulatory guidelines in different countries. Therefore, it is crucial to consult the product's labeling or consult a healthcare professional for specific information about the use of sodium benzoate in a particular pharmaceutical product.

MECHANISM OF FOOD PRESERVATION

The mechanism starts with the absorption of benzoic acid into the cell. If the intracellular pH falls to 5 or lower; the anaerobic fermentation of glucose through phosphofructokinase decreases sharply which inhibits the growth and surveillance of microbes that cause food spoilage.

SAFETY

WHO acceptable daily intake of total benzoate is 5 mg /kg of body weight.

REGULATORY STATUS

GRAC listed. Accepted as a food additive in Europe. Included in the FDA. Inactive ingredients guide (dental preparations, IM, and IV injections, oral capsules, solutions and tables, rectal and topical preparations). Included in the non-parenteral medicines licensed in the UK.

ADR

- Severe gastric irritation -Sodium benzoate is conjugated with glycine in the liver to yield hippuric acid which is excreted in the urine
- Anaphylaxis and urticarial reactions
- Irritant to eye and skin

CONTRA INDICATION

Caffeine and sodium benzoate injection should not be used in neonates.

HARMFUL EFFECTS OF SODIUM BENZOATE

- **Effect of Sodium benzoate on oxidative stress:** Oxidative stress occurs when there is an imbalance between the production of reactive oxygen species (ROS) and the body's ability to neutralize them with antioxidants. ROS can cause damage to cells and tissues, and chronic oxidative stress is associated with various health issues, including cardiovascular disease, neurodegenerative disorders, and cancer.
  Some studies have suggested that sodium benzoate may contribute to oxidative stress. Research conducted in cell cultures and animal models has shown that exposure to high concentrations of sodium benzoate can lead to increased ROS production and oxidative damage to cells. These effects may be mediated by the ability of sodium benzoate to deplete cellular antioxidants or interfere with mitochondrial function, leading to an increased generation of ROS.
- **Effect of Sodium benzoate on the embryos:** In research studies conducted on various organisms, including zebrafish and mice, high concentrations of sodium benzoate have been found to have adverse effects on embryo development. These effects may include developmental abnormalities, growth retardation, and even embryonic mortality. It is important to note that these studies typically use

concentrations significantly higher than what is commonly found in food products. However, its use should be limited, especially in pregnant women, due to its potential teratogenic properties.

- **Effect of sodium benzoate on hormone level:**
  It should be noted that benzoate was shown to affect the sperm motility (1 mg/kg b.w./day). It caused changes in the reproductive organs and affected the levels of sex hormones. Moreover, in another study, sodium benzoate affected the male reproductive system. The compound caused a 50% reduction in sperm count compared to the control group, as well as increased oxidative stress.
  In another in vivo study, the compound (0.01 mg/kg b.w.) also affected sex hormone levels (follicle-stimulating hormone (FSH), luteinizing hormone (LH), and free testosterone). A similar observation was related to the decrease in FSH, LH, and testosterone levels (sodium benzoate: 280 mg/kg/day). Additionally, a decrease in thyroxine and triiodothyronine and an increase in thyrotropin were observed. In contrast, another study reported a decrease in both thyroxine and thyrotropin (the dose of sodium benzoate was 50–200 mg/kg/day).
- **Effect of sodium benzoate in liver and kidney:**
  The sodium benzoate in animals affected the lipid profile and liver and kidney parameters. Moreover, there were observed histopathological and dose-dependent changes in the biochemical markers of liver damage (150–700 mg /kg b.w). It affected the histology of the kidney and liver. In addition, it was found that sodium benzoate may rather affect the kidneys than the liver. This compound (100 mg/kg b.w) was added to drinking water for 15 weeks. Similar to the previous study, the rats showed histological changes, including necrosis and atrophy of glomeruli and tubules, as well as increased urea and creatinine and decreased antioxidant defense. Another in vivo study confirmed its negative effects on the liver, as evidenced by an increase in the serum liver enzymes (alkaline phosphatase, aspartate aminotransferase (AST)) (the doses of sodium benzoate were 30, 60, 120 mg/kg b.w./day).
- **Effect of sodium benzoate on children's hyperactivity:**
  Attention-deficit hyperactivity disorder (ADHD) is mainly associated with symptoms of hyperactivity, inattention, and impulsivity. Beverages containing benzoate preservatives in their composition were given (45 mg/day) to 3-year-old children, who then experienced an increase in hyperactivity. These behaviors were reduced after the withdrawal. Another study showed a similar effect of sodium benzoate in 8-, 9-, and 3-year-old children. Furthermore, a survey was conducted among college students that examined the association between the consumption of sodium benzoate-rich beverages and symptoms associated with ADHD. Thus, it was shown that the consumption of such beverages was associated with a higher prevalence of symptoms of ADHD. However, it should be noted that due to the nature of this study (i.e., a survey), the feelings of the respondents were subjective.
- **Effect of sodium benzoate on gastric mucosa:**
  The effect of benzoate (oral provocation with 20 mg of sodium benzoate) on gastric mucosa was studied in a clinical trial. It was shown that it increased the release of allergic mediators, i.e., histamine and prostaglandins, from the mucosa compared to the control group. The same study suggested that benzoate-related allergic reactions may be mediated by prostacyclins and histamine.

- **Sodium benzoate with Vitamin C:**
  Although there are no studies that clearly confirm the harmfulness of these additives, it has been proven that when used as a preservative, sodium benzoate can react with vitamin C and thus form carcinogenic benzene. In practice, this combination is often used in colorful, sweetened drinks. In many studies, elevated levels of benzene were reported in carbonated beverages, fruit juices, and other products where benzoate was present in combination with vitamin C.
- **Effect of sodium benzoate on anxiety and memory loss:**
  Animals treated with these compounds experienced an increase in anxiety-like behaviors and impaired motor skills. The researchers suggest that this may be related to decreased levels of glycine in the body (it is consumed as a result of benzoate detoxification) and disruption of processes affected by this amino acid or disruption of zinc levels.

  In another study performed on rats treated with sodium benzoate, an increase in body weight and food intake and a decrease in memory scores and anxiogenic effects were reported.

CONCLUSION:

From our study we found that excessive consumption of sodium benzoate causes harmful health hazards. Its use should be limited, especially in pregnant women, due to its potential teratogenic properties. It is safe to consume compared to other preservatives. It is highly soluble in water that's why it is widely used as a preservative in food and beverages. However, it is safe, it also has hazardous effect on human body so it is safe to avoid the consumption of soft drinks or other beverages in day-to-day life.

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