Potential of Egg Shells as a Natural Food Preservative

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Abstract. Food preservatives are food ingredients that are added to food. Preservation aims to maintain the physical and chemical properties of food ingredients. Food preservatives are classified into two, natural and synthetic preservatives. Eggshells that can be used are chicken and duck eggshells. Several ingredients can be used as preservatives in food, such as sodium benzoate, nitrate, and sulphate, but in this case the main ingredient used in making natural preservatives in food is eggshells which are processed into flour for use in food preservation. Eggshells contain high levels of calcium carbonate so they can be used as a natural preservative. Apart from being easy to obtain, eggshells are also economically valuable and easy to apply. This review discusses and explains the function of eggshells as a natural preservative in food.

1 Introduction

Food preservation is a preservation method used to increase the shelf life of food. Preservation can also maintain its chemical and physical composition. When preserving food, it is necessary to consider the type of food being preserved, its state, the method of preservation, and the acceptability of the resulting product.

Food manufacturers often add food preservatives, both natural and artificial, to food products. Preservatives are essential for extending the shelf life of products. Manufacturers often choose synthetic preservatives such as formalin, borax, and others because they are more affordable, useful, and have more stable preservation. However, artificial preservatives have several drawbacks, especially their carcinogenic properties. Natural food preservatives have been developed in response to concerns over their adverse effects on human health [1].

People do not need to worry about the dangers posed by this material to health. Therefore, a preservative that is more natural and safer to use is needed. It seems that eggshells, which were previously considered as waste, can finally be used as a natural food preservative.

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2 Eggshell

Chicken eggshells account for about 10% of its weight [2]. The amount of eggshell waste generated each year continues to increase. Especially with the large number of chicken eggs produced each year, of which 30% are processed for food [3]. Most of the waste is dumped directly into landfills without any treatment [4-5]. The disposal of egg waste does not solve the problem of environmental pollution as the decomposing eggshell itself produces pollution [6].

The outer layer of the egg, known as the eggshell, serves to protect the entire egg from damage. In general, 9-12% of an egg's weight is made up of the chicken eggshell that encloses it. Chicken eggshells vary in colour from brown to yellowish white. Boiler chicken eggs have a white outer shell with some brown spots. Brown-coloured shells are thicker than white ones, which is a distinguishing factor in eggshell thickness [7].

The cuticle layer, sponge layer, and lamellar layer are the three layers that make up the general eggshell structure. The outermost surface that has a lot of protein on it is called the cuticle layer. Calcium carbonate-bound eggshell protein fibres combine with the sponge and lamellar layers to form a matrix. The composition of eggshells consists of 94% calcium carbonate, 1% calcium phosphate, 4% organic matter, and 1% magnesium carbonate. Eggshells comprise 11% of the total egg weight. The cuticle layer, foam sponge layer, and lamellar layer form the three layers that make up the shell of a chicken egg. The surface of the eggshell is coated with a transparent protein called the cuticle layer. This layer encloses the pores of the eggshell, but due to certain characteristics, gas can still pass through and cause the release of CO_2 and water vapor [8].

A matrix made of protein fibres bonded to calcium carbonate ($CaCO_3$), also known as calcite, in a ratio of 1:50 is formed by a foam layer and a flat sponge. Most eggshell layers consist of this foam layer. A protein and lime layer made of calcium carbonate, calcium phosphate, magnesium carbonate, and magnesium phosphate make up this layer. Most of the layers of the eggshell consist of a foam layer. Proteins and a lime layer made of calcium carbonate, calcium phosphate, magnesium carbonate, and magnesium phosphate make up this layer. The third layer of the eggshell is called the lamellar mammillary layer and consists of layers that are cone-shaped and have an oval or round cross-section. This very thin layer is made of an interweaving of minerals and proteins. Underneath the membrane layer, the deepest part of the eggshell, is the lamellar layer. The membrane layer, which covers the entire egg and is about 65 microns thick, consists of two membrane layers. The inner membrane layer and the outer membrane layer, both similar, form the membrane layer of the shell.

3 Eggshell content

Eggshells are mostly composed of calcium carbonate ($CaCO_3$), which makes up 94% of the shell weight, 1% calcium phosphate, 4% organic matter, and 1% magnesium carbonate [8]. Egg weight consists of 94% of calcium carbonate, 1% potassium phosphate, and 1% magnesium carbonate. The eggshell surrounding the chicken egg weighs 9-12% of the entire egg weight. Eggshell calcium is an ideal dietary supplement. For people with osteoporosis, the calcium found in eggshells helps increase their bone mineral density. Eggshells have a very high calcium bioavailability (93.80%).

In general, eggshells consist of 98.4% dry matter and 1.6% water. Eggshells contain trace amounts of mineral elements 95.1% and protein 3.3% of the total dry matter present. Composition of eggshell: $CaCO_3$ (98.34%), $MgCO_3$ (0.84%), and $Ca_3(PO_4)_2$ 0.75% are the minerals that make up the eggshell [9]. A 100 kg eggshell weighs between 8 - 11 kg; for every 100 kg of solid shell, there are 96 kg of inorganic material and only 4 kg of organic

material. Eggshells consist of 98% dry matter and 2% water based on their chemical composition. In contrast, 93% of the dry matter consists of ash, and 5% is crude protein [10]. Eggshells consist of 1.6% water, 3.3% organic matter (mainly protein), and almost 95.1% organic salts. Most of the organic matter consists of 98.5% calcium carbonate ($CaCO_3$) and 0.85% magnesium carbonate ($MgCO_3$) compounds. There are 2.21 grams of calcium, 0.02 grams of magnesium, and 0.25 grams of other minerals in the eggshell [11].

Magnesium carbonate ($MgCO_3$) makes up 0.85% of the organic matter, while calcium carbonate ($CaCO_3$) makes up about 98.5%. 2.21 grams of calcium, 0.02 grams of magnesium, 0.02 grams of phosphorus, and small amounts of iron and sulphur make up the 2.25 grams of minerals present in the eggshell [12].

The protein and calcium content is high in the eggshell, which is the outermost layer of the egg. The eggshell is composed of 98.4% dry matter and 1.6% water. Within the dry matter, there is 3.3% protein and 95.1% mineral elements. 98.43% $CaCO_3$, 0.84% $MgCO_3$, and 0.75% $Ca_3(PO_4)_2$ crystals can be found in eggshells, based on their mineral composition [9].

4 Natural preservative

Food preservatives are ingredients added to food to maintain its chemical and physical characteristics. There are two types of food preservatives: natural preservatives, which are derived from fresh food ingredients such as acids, sugar, salt, and garlic. Synthetic preservatives belong to the second group. A chemical synthesis process produces these preservatives. Artificial preservatives require less, are more concentrated, and are more stable.

The negative impact of synthetic preservatives is their weakness. Artificial preservatives contain carcinogenic compounds, so the use of these preservatives is thought to have adverse health effects, including promoting the growth of cancer cells. Types of synthetic preservatives include sodium benzoate, potassium sulphate, and nitrite. Natural preservatives are much better as they have less of a detrimental impact on health. Apart from the preservatives mentioned above, fresh food can also contain other preservatives such as sugar, tamarind, garlic, and kluwak. These ingredients can inhibit the growth of spoilage microorganisms.

Food additives known as preservatives are essential for extending the shelf life of food and enhancing its flavour. Preservatives have an antimicrobial function that helps regulate and stop food spoilage by protecting food from microorganisms (such as bacteria, yeast, and Mold) that can cause food poisoning, as well as botulism that can potentially cause death [13].

Food preservatives belong to a class of food additives that are pharmacologically inactive, which means they are safe and effective even in small doses. Preservatives are used in a variety of industries, including the food, cosmetic, and pharmaceutical industries. Food preservation is a technique used to extend the shelf life of food while maintaining its chemical and physical composition. When preserving food, it is necessary to consider the type of food being preserved, its state, the preservation technique, and the aesthetic appeal of the product. Modern industrial food preservation technology builds on ancient methods created to extend the storage life of foodstuffs [14].

Foodstuffs generally have a limited shelf life because they are easily damaged. If changes occur in foodstuffs that are no longer acceptable to consumers, then these foodstuffs can be said to be rotten or damaged. Food spoilage or decay can be caused by enzymes or microorganisms in food, but physicochemical changes can also affect it [15].

The need to extend the shelf life of food leads to the application of different food preservation techniques. Food additives (BTP), especially preservatives, are an increasing source of concern in terms of food safety these days. The use of preservatives has both advantages and disadvantages. Preservatives can remove pathogenic and food-damaging microbes from foodstuffs. This is one of the benefits of their presence. Chemical compounds, or foreign substances that infiltrate food, are essentially food preservatives. Users will suffer direct and cumulative losses from the use of preservatives if their use is not controlled [16].

The main purpose of food preservation is to increase the shelf life of food, prevent food from spoiling, and ensure its original quality is maintained for as long as possible [17]. Certain preservatives can also serve to improve the appearance quality of food. For example, nitrites can be added to processed meat to make it appear brighter red. Consumers are generally more interested in buying when something looks good [18]. Food preservation is based on three principles, which are as follows:

1. Discontinue or minimize microbiological damage. There are several approaches to stop or reduce microbial damage:
   - To prevent the entry of microorganisms, it is important to work aseptically (aseptic technique).
   - Eliminating microorganisms, e.g. by sterilization and radiation.
   - Preservatives, both artificial and natural, low temperatures, drying, anaerobic environments and other techniques can be used to inhibit the growth and activity of microorganisms.
2. Prevent or reduce the rate of food degradation (autolysis). The activity of food enzymes can be reduced or rendered non-functional, e.g. by boiling foods, and/or chemical reactions can be slowed down, for example by adding antioxidants to prevent oxidation reactions, to stop or slow down the rate of food degradation (autolysis).
3. Eliminate environmental factors that can cause damage, such as pest infestation. There are three categories that can be used for food preservation techniques based on the process:

1) Natural preservation. Natural preservation methods consist of heating and cooling. Both can be done using conventional or modern methods. For example, food is preserved using radiation methods today, whereas previously it was done by drying. These are some of the common and well-known standard techniques:
   a. Cooling.
      The cooling process involves storing food above freezing, which is between -2 and +10 °C. Freezing is the storage of foodstuffs in a frozen state to slow down the deterioration of quality and extend the shelf life of foodstuffs (low temperature preservation -12 and - 24 °C).
   b. Drying
      The drying process is carried out by utilizing heat energy to evaporate most of the water present in a material, thus removing some of the water. Microorganisms are usually prevented from growing in a foodstuff by reducing its water content to a certain point.
   c. Packaging
      Food processing includes packaging, which aims to preserve food, protect against mechanical damage, and maintain moisture content. Packaging technology is evolving at a rapid pace, especially about plastic packaging, which is significantly replacing other major packaging materials such as wood, cardboard, glass and metal.

d. Canning
The process of preserving food by keeping it in containers that are impermeable to air, water, bacteria, and other foreign matter is known as canning. The containers are then commercially sterilized to kill pathogenic (disease-causing) and spoilage microbes.

e. Salting
People have been preserving food with salt for a very long time. Since salt removes water from foodstuffs, it can act as a preservative by preventing the growth of spoilage microorganisms through the reduction of water activity.

2) Biological preservation. Fermentation is an example of a biological preservation method. This process works by converting carbohydrates into alcohol, which is called fermentation. Enzymes produced by the yeast cells themselves are the substances involved in this fermentation process. The food ingredients being fermented will determine how long the fermentation process takes. To speed up the fermentation process, more enzymes can be added to the fermentation or fermenting process. Enzymes are biological catalysts made by living cells that help speed up various biochemical reactions.

Enzymes obtained from food can be sourced from unprocessed foodstuffs or microbes present in food. Certain enzymes found in meat, fish, milk, fruit and grains are usually actively used in the digestion of these foods. Foodstuffs can also change due to enzymes. These changes can be beneficial, but also potentially harmful. Flavor, color, shape, calories, and other characteristics may change due to the influence of these enzymes. Papain, which is derived from the sap of papaya leaves or fruits, and bromelain, which is obtained from pineapples, are two examples of enzymes that are often used in meat processing.

3) Preservation of chemicals. Irradiation and fermentation are two examples of chemical preservation methods.

a. Fermentation Technique
The preservation principle of the fermentation method is based on:
i. Stimulates the growth and metabolism of microorganisms that produce organic acids and alcohol.
ii. Proteolytic and lipolytic microorganisms can be inhibited or controlled through the production of alcohol or organic acids, and if the population is large, through activity in the exchange of nutrients within the substrate.

b. Irradiation Methods
The process of irradiating materials, such as food, with radiant energy is called radiation. The technique of using radiation energy in a directed and planned manner is called irradiation. The process of utilizing energy to irradiate materials with artificial radiation sources is known as irradiation. Food can be preserved through the use of electromagnetic radiation or also called ionizing radiation, which is radiation that emits high-energy photons that can activate and ionize the material through which it passes [19]. Among the factors that can affect food preservation are:
i. Characteristics and types of food ingredients . Meat, milk, eggs and fresh fish are some of the foods that come from animals and are most susceptible to spoilage (perishable foods). One type of food that is highly perishable is fresh fruits and vegetables. Plant-based foods are a class of foods that survive storage at room temperature, including nuts and dried grains.
ii. Concentration of food preservatives. The longer the food is preserved, the higher the concentration of preservatives added; but this concentration should not exceed the recommended amount.

iii. Particle size of preservatives. The solubility and ability of food preservatives to react optimally in food is directly related to their particle size; smaller particles will facilitate faster food reactions.
iv. Different types of preservatives. Compounds known as preservatives come from a variety of sources and essentially prevent bacteria from growing in food. The use of various preservatives varies naturally depending on the food being prepared.

Preservatives are chemicals that come from various sources and essentially prevent bacteria from growing in food. Of course, there are various variations in the use of different types of preservatives when cooking.

Preservatives can come from various types of ingredients which basically can inhibit the growth of bacteria in food. Each type of ingredient will of course have a different dosage when applied in making food.

Preservatives can usually be found in powder form. Powder is the basic form of solid particles which have several sizes. According to the particle size, powder can be divided into six, namely colloidal powder (less than 1 μm), microscopic powder (1-100 μm), macroscopic powder (> 100 μm), fine granular powder (1-5 mm), coarse granular powder (5-10 mm), granulate grains (more than 10 mm). A material that has a large particle size when used in the pharmaceutical sector must first be milled with the aim of producing a smaller particle size, large surface area, and homogeneous particle size. There are several milling methods using certain tools. The simplest milling tool used in the pharmaceutical field is the mortar-stamper. Although it uses human power, it produces particles that are not too small. In other words, the particles produced are not micronized. Hammer mill, cutting mill, ball mill, and fluid energy mill are additional tools that can produce micronized powders. The crushing process, both physical and technical crushing, is carried out during the milling process [20].

It produces particles that are not too small, despite being powered by human power. In other words, the particles produced are not micronized. Additional equipment that can micronize powders include hammer mills, cutting mills, ball mills, and fluid energy mills. During the milling process, the crushing process both technically and physically is completed [20].

5 Application of eggshells as a presevative

Although it is powered by human energy, it produces particles that are not very small. In other words, the particles produced are not micronized. Hammer mills, cutting mills, ball mills, and fluid energy mills are some other equipment that can be used to make powders smaller. Technically and physically, the crushing process is completed during the grinding process.

6 Conclusion

Eggshells in this case are an alternative that can be used as a natural preservative in food processing to maintain food quality and economic value. It uses human energy to drive itself, but the particles it produces are not very small. In other words, the particles produced are not micronized. Additional equipment that can be used to reduce powder size include hammer mills, cutting mills, ball mills, and fluid energy mills. The crushing process is technically and physically completed during the grinding process.

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