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Encapsulation of aromatic coconut water with sodium alginate and calcium chloride

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ABSTRACT

The main goal of this study was to determine the best amount of sodium alginate needed to effectively encapsulate aromatic coconut water using sodium alginate and calcium chloride. Additionally, the study aimed to explore how physical and chemical factors influence the production of aromatic coconut encapsules. Finally, the research sought to evaluate consumer acceptance of encapsulated coconut aroma. The findings revealed that using 2 g sodium alginate per 200 g coconut water, 500 g clean water, and 3 g calcium chloride resulted in suitable viscosity of the encapsulated aromatic coconut. These encapsulations were able to dissolve into water when used in encapsulated or coated tablets. When incorporating varying amounts of sodium alginate (2, 2.5, and 3 g) into the aromatic coconut water, the colour and brightness value (L*) of the encapsulated product was found to be 45.18 ± 0.03, with a red value (a*) of -0.50 ± 0.01 and a yellow value (b*) of -3.12 ± 0.01. The pH value remained consistent at 5.20 ± 0.00, and the total dissolved solids (∘Brix) were 6.43 ± 0.00. No significant differences were observed in the sugar solid solution. Microbial analysis indicated that the quantity of microorganisms did not exceed the specified standard. In terms of consumer acceptance, 76% of the participants expressed satisfaction with the encapsulated coconut water.

Keywords: Aromatic coconut water, Encapsulation method, sodium alginate, Beverages.
Article type: Research Article.

INTRODUCTION

Derivation and the significance of the problem:

Coconut is a highly popular fruit in Thailand known for its versatility and usefulness in various applications (Pipatkanaporn 2016). It can be used to create both sweet and Savory dishes that promote health and address various symptoms or ailments (Rethinam & Krishnakumar 2022). Furthermore, coconut can be utilized for producing coconut oil, coconut milk, sugar, and even for inventing new products (Chaovanalikit & Itthisoponkul 2011; Sirirachana 2020; Kallapur *et al.* 2021; Montoya 2023). Encapsulation is a process that involves coating or enclosing one substance within another substance. It is commonly used to encapsulate liquids, solid particles, or gases. The substance being encapsulated is referred to as the core material or internal phase, while the substance doing the encapsulating is called the wall material, carrier, membrane, shell, or coating. Some examples of encapsulation include probiotics being encapsulated with hydrocolloids to maintain their viability, flavouring substances being encapsulated to preserve their flavour, and fluidized bed coating techniques being used for coating purposes. Various techniques can be employed for encapsulation, such as spray drying, extrusion, coacervation, liposome entrapment, and drying techniques (TAS 2023; TCS 2023). Encapsulation finds its application in various food products, with ingredients like acids, fats, lipids, enzymes, microorganisms, sugar substitutes, artificial sweeteners, vitamins, minerals, colorants, and salts being commonly encapsulated. The process of flavour encapsulation typically involves two steps: emulsifying the core material with a coating material such as polysaccharides or proteins and subsequently drying or cooling the emulsion. The choice of

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encapsulation technique will impact the distribution and stability of flavour compounds in the final food product during storage. In this context, the researchers were intrigued by the idea of developing aromatic coconut water in a new form by encapsulating it using liposome entrapment. The aim was to enhance the value of aromatic coconut water by employing scientific processes to benefit from its properties.

Research objectives

1. To determine the appropriate amount of sodium alginate required for encapsulating aromatic coconut.
2. To examine the physical properties and chemical composition of the encapsulated coconut.
3. To evaluate consumer acceptance of the encapsulated aromatic coconut.

Research Scope

This study will include the following:

1. Investigating the technique of encapsulating aromatic coconut water using liposome entrapment. The specific coconut variety used will be aromatic coconut water obtained from the Thewet Market in Bangkok, which is a mutation of the Green Shorty coconut or Green Pig variety.
2. Examining the physical, chemical, and sensory properties of the encapsulated capsules containing aromatic coconut. The physical properties will include characteristics such as size, shape, and appearance of the capsules. The chemical properties will involve analysing the composition, nutritional profile, and any changes in chemical attributes of the encapsulated coconut aroma.
3. Evaluating consumer acceptance of the aromatic coconut capsules through sensory tests and surveys to assess factors such as taste, aroma, texture, and overall satisfaction.

Expected Benefits

The expected benefits of this study are as follows:

1. Determining the appropriate amount of sodium alginate required for encapsulating aromatic coconut will enhance the efficiency and effectiveness of the encapsulation process. This will contribute to the development of a standardized procedure for encapsulating the aroma of coconut.

2. Analysing the physical properties and chemistry of the encapsulated coconut aroma will provide insights into its stability, shelf life, and potential applications in various food and beverage products. This information can be valuable for food manufacturers and researchers pursuing encapsulated coconut aroma in their products.

3. Evaluating consumer acceptance of the aromatic coconut encapsules will provide feedback on the overall liking, preference, and potential market demand for this product. This knowledge can guide product development, marketing strategies, and help identify potential niches or target markets for aromatic coconut encapsules.

Literature Review

1. Aromatic coconut

Fig. 1. Aromatic coconut; Scientific name: *Cocos nucifera Linn,* Common name: Palmae, Species: Palmae; Source: Pornla (2019).

Aromatic coconut has gained popularity as a cash crop for both fresh consumption and export to international markets. It is also widely used as a raw material in the beverage industry, further driving the demand for aromatic coconuts (Molina, 2023). Thai aromatic coconuts are a mutation of a short, green coconut variety known as Mu Khiao, and they are predominantly grown in the central region of Thailand, particularly in Nakhon Chai Si District of Nakhon Pathom Province, as well as in Samut Sakhon, Chachoengsao, Ratchaburi, and Samut Songkhram. To ensure a profitable return, it is crucial to establish a coconut plantation with careful consideration of various factors, including the selection of the right environment, coconut varieties, nursery practices, shoot selection, planting techniques, and ongoing care (Antonio-Gómez 2023). For example, the chosen coconut planting site should have loamy soil, consistent rainfall, suitable temperatures, and adequate sunlight. It is also important to plant mature-sized fruits in designated plots to ensure successful sprouting. During the rainy season, the shoots are moved and planted in appropriate planting holes. Various chemical fertilizer formulas are applied based on the age of the coconut trees, determined through soil analysis. Additionally, organic fertilizers such as manure, compost, and green manure are used. Maintaining weed and pest control, as well as managing plant diseases, are crucial aspects of coconut plantation care. When the coconut trees are young, intercropping with short-lived plants like pineapples, nuts, and pumpkins is recommended. Once the coconut trees reach 12-15 years of age, shade-loving perennial crops such as coffee and pepper can be planted alongside them. Feeding bees, cows, and buffaloes with the coconuts can also help increase coconut yield by adding more organic matter to the plantation (Multisona *et al.* 2023). Aromatic coconuts are available in various formats, including chilled coconut water, peeled and trimmed whole coconuts, roasted coconut, and Nata de coco. The latter is a jelly-like substance that results from bacterial fermentation and resembles a lump or sticky membrane. It is also known as orange juice jelly or heavenly juice jelly. These aromatic coconut products are in high demand both domestically and internationally, particularly in Japan (English *et al.* 2023), where the market is rapidly expanding due to the perceived health benefits associated with coconut consumption. In summary, aromatic coconuts have become a popular cash crop due to their versatile uses and increasing demand. Establishing a successful coconut plantation involves careful selection of the environment, varieties, nursery practices, shoots, and ongoing care. A wide range of aromatic coconut products, such as chilled coconut water, peeled and trimmed whole coconuts, roasted coconut, and Nata de coco, are highly sought after both domestically and internationally, with the Japanese market showing rapid growth due to the perception of coconuts as a healthy food choice, increasing demand can make coconut farming have a good future and generate sustainable income. Coconut is a perennial plant with feather-like compound leaves. The highlight of coconut farming is its commercially grown variety, coconut water, which has a sweet aroma and taste (Allegra *et al.* 2017). Early fruiting coconuts and low-growing trees are commonly grown for the sale of young fruit. The blooming of both male and female flowers is close, making them self-pollinate. This characteristic of aromatic coconuts reduces the likelihood of mutation compared to crossing with original tall coconut trees (Bourtoom 2008).

2. Botanical characteristics

Leaves: The leaves have a feathery appearance and spread to cover the trunk from the base of the large leaf stalk. They are arranged in a small, pleated fan shape with pointed leaf bases and tips and smooth edges.

Fruit: The fruit is spherical or oval-shaped with a smooth surface. When young, it has a green rind and soft fibres. Inside, there is a hard shell, followed by soft white meat. The meat has a sweet, oily taste and is filled with clear water. It has a sweet and fragrant flavour.

Trunk: The coconut tree is a perennial plant with a single, erect stem. The trunk is round and has a hard and tough shell with jagged embossed buttons. There are remnants of fallen branches, and the bark is grey. The flowers are axillary inflorescences in both sexes. The base of the inflorescence is female, while the end is male and has a small spherical shape. The male inflorescence has a soft yellow colour and contains a significant amount of nectar. The roots have a tap root system that penetrates deep into the soil. The roots are round, with small roots and hairy roots surrounding them, and they are brown.

3. Cultivation of aromatic coconuts

The shoots should have a height of at least 50 cm. After preparing the soil, dig a hole that is 50 × 50 × 50 cm deep and keep 7 m between each tree. If it is a garden groove, plant the trees in two rows with a zigzag pattern. If it is a flat area, plant the trees in rows that are 7 m apart. Sprinkle approximately 2 tablespoons of furadan at the bottom of the hole to prevent insects from damaging the young roots. Plant the tree and firmly press the soil around it, covering only half of the coconut tree. Ensure that all shoots are facing the same direction, as this will result in a visually appealing appearance when the coconut tree matures. It is recommended to plant the trees between April and September, as this is the rainy season.

4. Nutritional value of coconut

Information from the Department of Health indicates that 1 young coconut juice weighing 259 g provides 60 calories. The main components are approximately 243 g water, 19 g sugar, 3 mg vitamin C, 27 mg sodium, 855 mg potassium, 30 mg calcium, and other minerals, including various vitamin elements.

5. Benefits of coconut

- Consumption of coconut oil in larger quantities can help prevent heart disease by increasing HDL (good cholesterol) levels, which in turn reduces the workload on the liver. However, it is important to note that reducing intake of coconut oil may increase the liver's workload, necessitating the consumption of additional cholesterol. It is worth mentioning that coconut oil is naturally low in cholesterol.
- The properties of coconut oil make it effective in treating influenza, killing viruses, and eliminating germs. This supports the idea of using coconut oil alongside or as an alternative to Tamiflu or other medications. Consuming 2 tablespoons of coconut oil per day can help combat viral infections within the body.
- Coconut water can aid in stimulating waste excretion, promoting overall bodily balance. The tall trunk of a coconut tree facilitates the filtration of nutrients absorbed from the soil, ensuring that the fruit, particularly the water on top, remains pure. Coconut water is a nutritious beverage rich in easily absorbable glucose. Moreover, coconuts are highly alkaline fruits, which can be beneficial for treating diseases caused by excessive body acidity. Thai traditional healers consider coconuts as tonics that strengthen tendons and treat bone disorders. Chinese practitioners believe that coconuts possess neutral properties and can eliminate parasites. In cases of simultaneous vomiting and diarrhoea, drinking coconut water can aid in glucose absorption by the body. However, it should only be used for a short period.
- Prevention of heart disease: Studies have shown that consuming coconut oil does not lead to weight gain and does not increase levels of bad cholesterol (LDL). Instead, it increases levels of good cholesterol (HDL), which in turn helps to reduce harmful cholesterol levels. As a result, coconut oil can have a direct impact in preventing heart disease and vascular diseases.
- Rehydration: After exercising and losing water, coconut water can be consumed as a substitute for sports drinks. It is rich in calcium, potassium, magnesium, various vitamins, and minerals. Additionally, it is a natural source of mineral salts. Coconut water effectively alleviates fatigue and exhaustion caused by exercise. When compared to commercially sold mineral drinks, coconut water contains lower levels of two elements: sodium, which aids in replenishing electrolytes lost through sweat, and carbohydrates, which provide energy for the body.

6. Precautions for consuming aromatic coconuts

1) Patients with conditions such as kidney disease, high blood pressure, and heart disease, who need to limit their potassium intake, should be cautious when consuming coconut oil. Excessive intake of coconut oil can potentially impact the function of the heart muscle.
2) Menopausal women should be mindful of consuming coconut water, as it contains phytoestrogens. High consumption of phytoestrogens can increase the risk of endometrial hyperplasia.
3) It is important to buy aromatic coconuts from reliable and clean sources. This is because some coconuts may undergo bleaching processes to enhance their taste and appearance. These bleaching agents can be harmful to the body and should be avoided.

7. Food additives

Food additives mean substances that are not normally used as food or considered an important component of food. Regardless of whether the material has nutritional value or not. It is used as an adulterant in food for the technological benefit of production, packaging, storage, or transportation. This affects the quality, standard, or nature of food and includes objects that are not used as food additives but are also used together with food for the benefits (Camargo Prado 2015). Using food additives has the following main purposes: to maintain food stability, for example, using an emulsifier to turn the food into an emulsion, maintaining a stable texture, preventing water and oil from separating (stabilizing agent), and increasing viscosity (thickening agent) to give the food a stable and homogeneous texture. Anticaking agents help prevent foods like salt from sticking together and make them easier to use. To maintain the overall quality of food products, preservatives are used to prevent food deterioration caused by yeast, mould, bacteria, and rancidity. They also help prevent oxidation in foods containing oils and fats, as well as preserve the colour of fresh fruits and vegetables. Additionally, additives are used to control the acidity and alkalinity of food by adding acids, which can help reduce the temperature and time required for food sterilization. Acids are also used in baking powder to release carbon dioxide and give baked goods the desired characteristics. Furthermore, food additives are employed to add colour and flavour based on consumer preferences and needs (Espitia *et al.* 2016).

8. Sodium alginate

Sodium alginate is a polysaccharide that is found in the cell wall of brown algae. It has a viscous and glue-like property when bound to water and is a crucial component of orange-toned biofilms produced by *Pseudomonas aeruginosa* species. Sodium alginate is available in various forms including fibres, pellets, and powder, and can be extracted from brown seaweed and stored. Due to its natural origin, alginate is considered safe and finds wide applications in the food, textile, and pharmaceutical industries. It is commonly used as a gelling agent. Different species of brown algae have varying chemical structures, leading to diverse physical characteristics of alginate. These differences include gelling content and colour, enabling its versatile use in various food production applications. Sodium alginate, also referred to as algin, is indeed extracted from brown seaweed, particularly from the *Phaeophyceae* class. Different species of brown seaweed have varying alginate content. *Macrocystis pyrifera* typically contains around 14-19% algin, while *Laminaria cloustoni* and *Laminaria digitata* have approximately 15-40%. The actual alginate content can be influenced by factors such as the type of seasonal algae and the specific source from which the seaweed is harvested. These algae are commonly found worldwide. The top producing countries of alginate are the USA, UK, France, Spain, Norway, Canada, and Japan. Sodium alginate is an unbranched binary copolymer consisting of 1,4-b-D-manuronic acid (M) and L-guluronic acid (G). The molecule contains homopolymeric regions of G and M, known as G-blocks and M-blocks, respectively, and some of the molecules are MG-blocks. The proportions of the copolymer and these structures determine the properties of alginate. For example, if the polymer contains a high amount of G, the property is that it forms a hard gel at a specific concentration of cationic polyvalent metal. On the other hand, if the polymer has a high M content, it tends to form a soft gel. Additionally, it has a broader range of conditions for gel formation compared to commercially produced alginate. The viscosity of the resulting alginate solution depends on several factors, including its concentration, temperature, molecular weight, and the presence of positively charged metals. It is important to note that not all alginates have gelling properties, and only some will form a gel when reacted with Ca^{2+}. The gel structure of alginate can be described as resembling an egg box, with Ca^{2+} ions attached to the polymer strands. One advantageous characteristic of alginate is that it forms an irreversible gel in cold water in the presence of Ca^{2+}. This low-temperature gelling property distinguishes alginate from hydrocolloids derived from red algae.

Alginate has been utilized in various food products since the 1920s, initially finding its application in canned foods. It is commonly employed as a viscosity-increasing agent and stabilizer for emulsions. Additionally, it serves as a gelling agent and syneresis inhibitor in food products (Sirirachana 2020).

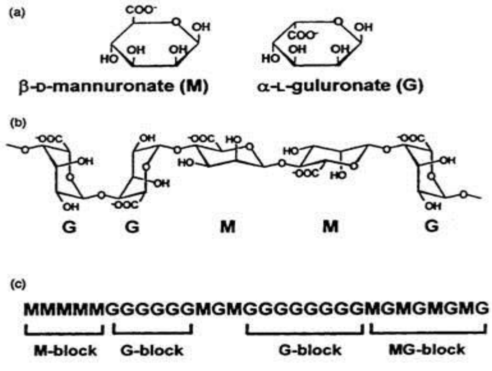


Fig. 2. Structure of various types of alginates; Source: Sirirojana (2020).

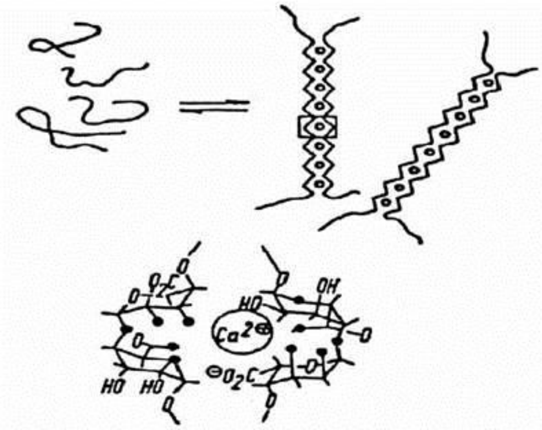


Fig. 3. Mechanism of gelation of calcium alginate (Egg-box model); Source :Sirirachana.(2020)

9. Beverages

Sodium alginate is a polysaccharide that can be dissolved in water, making it an excellent food additive. It is particularly useful in beverage production, where it acts as a thickener and emulsifier. For example, it helps to prevent separation and sedimentation in fruit juice production. Sodium alginate also prevents clumping together (agglutination) and flocculation of proteins in fermented milk drinks like Leben, as well as the formation of wax and flocculation of proteins in beverage production.

10. Jelly

Sodium alginate serves as a stabilizer in jelly production, similar to other substances like carrageenan, agar, or jelly powder. It is frequently used as an ingredient in the creation of water drop mochi or Mizu Shingen Mochi Recipe, which is currently gaining popularity.

11. Calcium chloride

Calcium chloride is an inorganic compound that consists of chlorine and calcium ions. It typically appears as white crystals, granules, or flakes, and it can also be in the form of white or grey-white solids. Calcium chloride is odourless and has a slightly bitter taste. It remains stable under normal temperature and pressure conditions. Calcium chloride finds applications in various industries such as general industry, food industry, agricultural industry, and pharmaceutical industry. It is considered stable under typical conditions of use and when stored tightly. If the container of calcium chloride is left open, the substance will tend to absorb moisture from the air due to its hygroscopic nature. Calcium chloride can also function as a desiccant. When it is dissolved in water, it readily forms hydrochloric acid (HCl) according to the equation: $CaCl_2 + H_2O = CaO + 2HCl$. Regarding its solubility, anhydrous calcium chloride salt dissolves in approximately 59 g per 100 mL water at a temperature of 0 ℃. Noteworthy, when calcium chloride undergoes the process of melting, it releases heat. In the case of calcium chloride salt with 2 water molecules, $CaCl_2{\cdot}2H2O$ (dihydrate), it exhibits good solubility in water, approximately 97 g per 100 mL water at 0 ℃. Calcium chloride is commonly utilized in various industries. It is employed in the removal of moisture or water from solvents, acting as a dehumidifying agent in the production of alcohol, esters, ethers, and acrylic resins. It is also used as a desiccant when working with dry gases such as nitrogen, oxygen, hydrogen, hydrogen chloride, and sulphur dioxide. In the construction sector, calcium chloride can be employed in concrete to accelerate the hardening process and enhance compressive strength. Moreover, calcium chloride finds utility in other industries like textiles, petroleum, oil, paper, ink, and as a means to treat industrial wastewater. It is also available in a food-grade variation for use in the food industry. Calcium chloride solution is used to extend the shelf life of agricultural products, such as vegetables and fruits, by spraying before and after harvesting or by dipping them directly into the solution. It adds crispness to fruits and increases the tenderness of various meats, such as beef and chicken. It also helps prevent microbial growth in food. In some foods, calcium chloride is used to add flavour and extract protein from meat. It is used with fruits before canning and in the milk production process.

Fig. 4. Calcium chloride; Source: Chemical products for industry (PSU).

12. Encapsulation methods

Encapsulation refers to the process of coating, bonding, or completely wrapping a substance or mixture of substances with other materials. The substances being encapsulated are typically liquids, but in some cases, they can be solid particles or gases. These substances are referred to by various names, such as the core material or internal phase. The material used for coating is known as the wall material, carrier, membrane, shell, or coating. An example of encapsulation is seen in probiotic foods, where cell encapsulation is carried out. This process involves coating microbial cells with hydrocolloids to maintain their viability. Flavour encapsulation, on the other hand, refers to encapsulating flavouring substances.

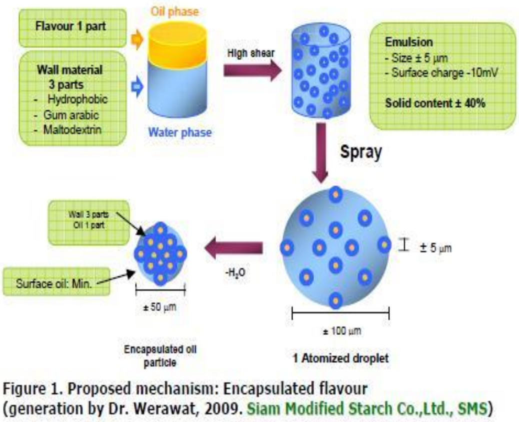


Fig. 5. Encapsulation process; Source: Dziezak (1988), Jackson & Lee (1991), Shahidi & Han (1993).

Encapsulating flavourings can protect flavourings that may interact with ingredients in food products, reduce the occurrence of foreign odours caused by the reaction of the flavouring agents, and protect the flavouring agents from light and/or oxidation. It can also extend the shelf life of flavouring agents or control the release of flavouring agents in food products (soft food) ingredients (Giri *et al.* 2018). can be encapsulated using various techniques, including acids, fats, enzymes, microorganisms, sugar substitutes, vitamins, minerals, colorants, and salts. Flavour encapsulation typically involves a two-step process. The first step is the emulsion of the core substances, which are then coated using polysaccharides or proteins. The second step involves drying or cooling the emulsion. The choice of flavour compounds in encapsulation techniques can affect the distribution and stability of these compounds in food products during storage (Dziezak 1988; Jackson & Lee 1991; Shahidi & Han 1993).

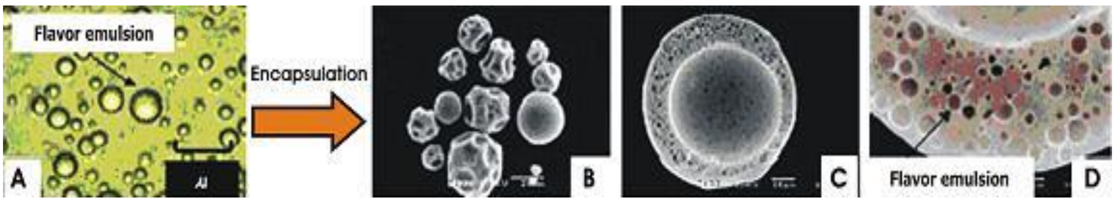


Fig. 6. Flavour encapsulation; Source: Dziezak 1988; Jackson & Lee 1991; Shahidi & Han 1993).

Flavour encapsulation can be achieved through various methods. The commonly employed industrial techniques are spray drying and extrusion. In addition, other methods such as spray chilling, spray cooling, coacervation, fluidized bed coating, liposome entrapment, inclusion complexation, and freeze-drying techniques can also be utilized (Beristain *et al.* 1996; Goubet *et al.* 1998).

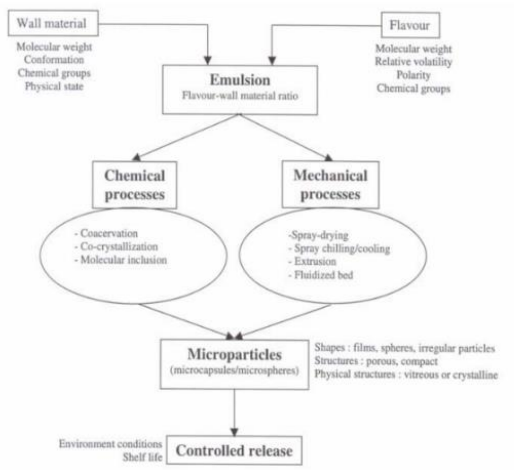


Fig. 7. Techniques used to encapsulate flavouring agents. Source: Beristain *et al.* (1996) and Goubet *et al.* (1998).

13. Related research

Encapsulation technology involves the process of enclosing liquids or particles within a capsule that is coated with a thin polymer layer, forming microcapsules. These microcapsules typically range in size from 1 to 1,000 microns. The thin polymer layer serves to protect or release the important substances contained within. This is achieved by coating the particles with a thin film or by emulsifying and drying the active substance within the microcapsule, which is referred to as the core. The thin layer that encapsulates the important substances is referred to as the wall. A good wall should possess certain characteristics, including the ability to spread into a thin film, flexibility, and strength. It should also have the ability to emulsify and adhere well to the core without reacting. Additionally, the wall should have low viscosity in its solid state and should not easily become damp. It should be highly stable to protect the core from external factors and allow for controlled release according to the intended purpose. It is evident that the wall plays a crucial role in the microencapsulation technique. It is crucial to select the appropriate material for the wall based on the specific substance and conditions it will encounter. In certain cases, a dual-layer wall may be necessary, with an inner layer for core protection and an outer layer for retaining odours, colours, and other properties. Various materials can be used for the wall, and many inexpensive options are available. Common choices include substances from the starch group, such as maltodextrin (maltodextrin) and Giri *et al.* (2018), survival of probiotics including *Lactobacilus plantarum CIF17 A5*, *L. plantarum* TISTR 875 and *L. acidophilus* TISTR 1034 encapsulated in sodium alginate and used to test survival in an acidic pH 2.0 condition for 3 h. It was found that, *L. acidophilus* TISTR 1034 in 2% sodium alginate using an 18 g syringe was the optimum condition used for cell encapsulation with a survival rate of 45.6% in acidic conditions and from comparison of the acid tolerance of probiotic isolates from humans, rats and encapsulated fermented food were found to. *L. plantarum* CIF17A5, which was isolated from humans, had a high survival rate of 71.11%, while *L. plantarum* TISTR 875 and *Lactobacilus acidophilus* TISTR 1034, which were isolated from fermented food and rats, gave survival of 25.8 and 31.88% respectively, From the experiment, it can be seen that encapsulating probiotic cells increased probiotic survival more than free cells containing acid. An experiment on encapsulating *L. plantarum* CIF17 A5 with the addition of 10 plant extracts and dietary fibres and testing for acid resistance found that, encapsulated *L. plantarum* CIF17 A5 combined with the addition of 2% weight per volume of soybean fibre provided, the highest survival was 84.39% ($p > 0.05$) at pH 2.0 for 3 h, while the control set, which consisted of free cells and cells that were encapsulated without adding plant extracts or fibres, had survival rates of 61.92 and 68.78%, respectively. It was found that, the concentration of soybean fibres was suitable for use in cell encapsulation is 3% weight per volume. It increased the survival of *L. plantarum* CIF17 A5 from 68.78 to 85.30%. It was also found that cell encapsulation combined with the addition of soybean fibre and coating the gel beads with chitosan increased the survival of the probiotic by 86.58%, while uncoated and alginate solution-coated gel beads provided 84.14 and 82.36% encapsulation survival, respectively.

MATERIALS AND METHODS

Study of the appropriate amount of sodium alginate for making aromatic coconut encapsulation

The appropriate amount of sodium alginate for encapsulating coconut water

Which affects the sensory quality by modifying the formula from making encapsulations. Encapsulated from Lipton Iced Tea by studying the ratio of sodium alginate to encapsulated aromatic coconut in 3 formulas: 2, 2.5 and 3 g, shown in Table 1.

Table 1. Appropriate ratio of sodium alginate to encapsulation for making 3 formulas of aromatic coconut encapsulation.

Ingredients	Formula)g(		
	Formula 1	**Formula2**	**Formula3**
Aromatic coconut water	100	100	100
Clean water	500	500	500
Calcium chloride	3	3	3
Sodium alginate	4%	5%	6%

Source : Adapted from, Encapsulation Lab, food processing class(2559)

Quality analysis (Gel texture)

1) A spectrophotometer were utilized, specifically the KONIA MINOLTA model CM-3500d, to measure the colour values of the prepared aromatic coconut encapsules. Then we placed the encapsules in a beaker and measured the colour using the spectrophotometer. The results were displayed in the form of brightness values: L* (ranging from 0 to 100, where 0 represented a bright black object and 100 represents a bright white object), a* (positive values indicated red objects, while negative values indicated green objects), and b* (positive values indicate yellow objects, while negative values indicate blue objects).
2) Acid-base (pH) level was determined by finely grinding the encapsulated pellets for 3 seconds, transferring them to a beaker, and measuring the pH using a Sartorius brand pH meter, specifically the FB-10 model.
3) Total dissolved solids (TSS%) were measured using a refractometer, specifically a Hand Refractometer with a range of 0-30°Brix. Then the encapsulated pellets were rotated and the total amount of dissolved solids were measured by shining a light through and read the value.
4) The viscosity of the encapsulated pellets was measured using a Bostwick Consistometer, a rail-type instrument. Specifically, we used the Bostwick brand model 24925-000, which has a capacity of 75 mL and a scale ranging from 0 to 23.5 cm with a resolution of 0.5 cm.

The process for making aromatic coconut encapsulation:

↓

Weigh 3 g calcium chloride ($CaCl_2$) per 500 g clean water, mix in clean water, stir until dissolved and set aside.

↓

Weigh 200 g aromatic coconut water and prepare it into a 500-mL beaker. Quantity: 3 sample sets.

↓

Take the finely ground sodium alginate powder and add it to the prepared weighed aromatic coconut water. According to the following ratio, 2, 2.5 and 3 respectively.

↓

Stir the two ingredients until slightly dissolved with a glass stirrer, then blend with a blender. High speed (homogenizer) for 3 minutes.

↓

Take a 5 mL syringe, cut off the head with a diameter of 0.5 cm, then suck up the sodium alginate mixed with aromatic coconut water.

↓

Make drops into round tablets. Diameter 0.35 cm, volume 0.2 mL into clean water mixed with calcium chloride.

↓

Then take a stainless-steel strainer, size 8 × 22 cm, and scoop out the encapsulated pellets to drain the water. Set aside in a container.

Diagram 1. Process for producing 3 formulas of aromatic coconut encapsules; Source: Adapted from the Encapsulation practice chapter, Food Processing Course (B.E. 2559).

Examining physical characteristics and chemistry of the encapsulated aromatic coconut

Physical quality analysis (Encapsule).

1) To measure the colour value, we placed the encapsulated coconuts in a beaker and used a spectrophotometer, specifically the KONIA MINOLTA model CM-3500d. This machine provided results in the form of brightness values: L* (ranging from 0 to 100, where 0 represents a bright black object and 100 represents a bright white object), a* (positive values indicate a red object, while negative values a green object), and b* (positive values indicate yellow objects, while negative values blue objects).

2) The sensory quality analysis included the evaluation of three basic encapsulation formulas. To conduct the analysis, a Randomized Complete Block Design (RCBD) was planned, involving 50 untrained testers who were teachers and students from Rajamangala University of Technology Phra Nakhon. The sensory testing assessed the quality based on appearance, colour, odour, taste, texture, and overall liking. A 9-point Hedonic Scale was used for rating the liking levels.

The results were analysed for variance using Analysis of Variance (ANOVA), followed by a comparison of means using Duncan's New Multiple Range Test (DMRT). This analysis was performed to identify the best formula among the tested options.

Chemical quality analysis

3.1. To measure the acid-base (pH) level, we finely ground the encapsulated pellets for 3 seconds, transferred them to a beaker, and measured the pH using a Sartorius brand pH meter, specifically the FB-10 model.

3.2. The total dissolved solids (TSS%) were measured using a refractometer, specifically a Hand Refractometer with a range of 0-30°Brix. We rotated the encapsulated pellets and then measured the total amount of dissolved solids by shining a light through and reading the value.

Microbial quality analysis (Encapsule)

The total amounts of microorganisms were analysed using Plate Count Agar (PCA) media and rotating the culture plate left and right (pour plate technique).

The amount of yeast and mould present in the sample were analysed.

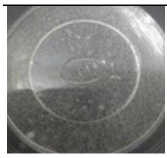
Studying consumer acceptance of encapsulated aromatic coconut water

In a study on consumer acceptance of encapsulated coconut water, 100 untrained consumers from various age groups, including teenagers and middle-aged individuals were selected to evaluate their satisfaction with coconut encapsules. Each consumer was served 3 samples per 1 cup, and the evaluation focused on aspects such as aroma, taste, texture (breakdown), and overall liking. Subsequently, the data collected were analysed to determine the percentage of consumer acceptance.

RESULTS AND DISCUSSION

1. Results of the study on the ratio and encapsulation method of 3 formulations of aromatic coconut water containing different sodium alginate in each formulation, the results are shown in Table 2.

Table 2. Appearance of aromatic coconut water after adding different amounts of sodium alginate, 3 formulas.

Formula	Color	Sensory	Texture
 **Formula 1**	Clearly white	Had a coconut scent	The texture is gelatinous and liquidity
 **Formula 2**	Milky white	Had a coconut scent	The texture is slightly gelatinous
 **Formula 3**	Milky white	Had a coconut scent	The texture is gelatinous and coagulate.

1.1 Quality analysis results

Table 3. Results of analysis of the quality of aromatic coconut water after adding different amounts of sodium alginate, 3 formulas.

Quality	Results of analysis		
	Formula 1	**Formula 2**	**Formula 3**
Physical			
Color Value Brightness)L(*	91.78 ± 0.01^{c}	92.09 ± 0.01^{a}	92.00 ± 0.02^{b}
Red) a(*	0.24 ± 0.02^{a}	0.20 ± 0.02^{b}	0.21 ± 0.01^{ab}
Yellow)b(*	2.47 ± 0.01^{a}	2.40 ± 0.02^{b}	2.43 ± 0.01^{ab}
Viscosity value	5.17 ± 0.29^{a}	4.17 ± 0.29^{b}	3.57 ± 0.58^{c}
Chemical			
Acid-alkaline amount. **)pH(**^{ns}	5.20 ± 0.02	5.19 ± 0.64	5.23 ± 0.02
Total amount of dissolved solids.)°Brix(^{ns}	6.43 ± 0.06	6.37 ± 0.06	6.27 ± 0.06

Note: Letters a, b, and c that are assigned different values in the same horizontal line show a statistically significant difference ($p \leq 0.05$), ^{ns} shows a value that is not significantly different ($p > 0.05$).

According to Tables 2 and 3, the results of analysing the quality of aromatic coconut water after adding different amounts of sodium alginate in 3 formulas displayed that the physical quality of aromatic coconut water, after the addition of sodium alginate, had a colour brightness value (L*) of 92.09 ± 0.00, 92.00 ± 0.02, and 91.78 ± 0.01, respectively. Formula 2 exhibited the highest brightness value, which was significantly different from Formula 1 and Formula 3. The red value (a*) for Formula 1 was the highest, while Formula 3 did not differ significantly from Formula 1 and Formula 2. The yellow values (b*) were 2.47 ± 0.01, 2.43 ± 0.01, and 2.40 ± 0.02 for the three formulas, with Formula 3 not differing significantly from Formula 1 and Formula 2. The colour values of all 3 formulas were therefore significantly different ($p < 0.05$). The viscosities of aromatic coconut water after adding sodium alginate were 5.17 ± 0.29, 4.17 ± 0.29, and 3.57 ± 0.58, with Formula 3 exhibiting the highest viscosity while Formula 1 the lowest. All three formulas were significantly different ($p < 0.05$) in terms of viscosity. The pH content were 5.23 ± 0.02, 5.20 ± 0.02, and 5.19 ± 0.64 for the three formulas, showing no significant difference ($p > 0.05$) in the acid-base (pH) content. The dissolved solids (ºBrix) were 6.43 ± 0.06, 6.37 ± 0.06, and 6.27 ± 0.06 for the three formulas, with no significant difference ($p > 0.05$) among the three formulas.

Table 4. Encapsulated appearance with three different formulas.

Formula	Colour	Sensory	Texture
 **Formula1**	Milky white	Had a coconut scent	The texture is watery inside the tablets
 **Formula2**	Milky white	Had a coconut scent .	The texture is slightly sticky and there is a little water inside the tablets
 **Formula 3**	Milky white	Had a coconut scent	The texture is sticky and gelatinous soft

2. Results of physical characteristics and chemistry of aromatic coconut encapsulates
2.1. Results of physical and chemical quality analysis

Table 5. Properties of aromatic coconut encapsulates with 3 different formulas.

Quality	Result of analysis		
	Formula 1	**Formula 2**	**Formula 3**
Physical Color value			
Brightness) L(*	45.18 ± 0.03^{a}	40.47 ± 0.01^{c}	42.53 ± 0.00^{b}
Red) a(*	-0.50 ± 0.01^{a}	-0.66 ± 0.01^{b}	-0.91 ± 0.01^{c}
Yellow)b(*	-3.12 ± 0.01^{b}	-3.25 ± 0.00^{c}	-2.94 ± 0.01^{a}
Chemical			
Acid-alkaline amount)pH(^{ns}	5.20 ± 0.00	5.23 ± 0.01	5.24 ± 0.01
Total amount of dissolved solid.)^{o}Brix(^{ns}	6.43 ± 0.00	6.36 ± 0.01	6.27 ± 0.00

Note: The letters a, b and c assigned differently in the same horizontal line show a statistically significant difference ($p \leq 0.05$).^{ns} showed values not significantly different ($p > 0.05$).

From Tables 4 and 5, The analysis of the physical properties of aromatic coconut encapsules, utilizing three different formulas, yielded the following results:

The colour and brightness (L*) values were found to be 45.18 ± 0.03, 42.53 ± 0.00, and 40.47 ± 0.01 for the three formulas, respectively. Formula 1 exhibited the highest brightness value, which was significantly different from Formula 2 and Formula 3 ($p < 0.05$).

The red values (a*) were -0.50 ± 0.01, -0.66 ± 0.01, and -0.91 ± 0.01, while the yellow values (b*) were -2.94 ± 0.01, -3.12 ± 0.01, and -3.25 ± 0.00 for the three formulas, respectively. All three formulas exhibited significantly different colour values ($p < 0.05$).

The acid-base contents (pH) were found to be 5.24 ± 0.01, 5.23 ± 0.01, and 5.20 ± 0.00 for the three formulas, respectively. There was no significant difference in pH content among the three formulas ($p > 0.05$), indicating that their acidity and alkalinity levels were similar. The amounts of dissolved solids (°Brix) were measured to be 6.43 ± 0.00, 6.36 ± 0.01, and 6.27 ± 0.00 for the three formulas, respectively. The values of dissolved solids did not show a significant difference among the three formulas ($p > 0.05$).

2.2 .Sensory test results

Table 6. Sensory test results of aromatic coconut water encapsulate with 3 different formulas.

Appearance	Sensory Test Result		
	Formula 1	Formula 2	Formula 3
Appearance ^{ns}	7.70 ± 0.76	7.62 ± 0.75	7.48 ± 0.91
Color	7 .78 ± 0.76^{ab}	7.66 ± 0.63^{b}	8.00 ± 0.00^{a}
Sensory ^{ns}	7.74 ± 0.80	7.52 ± 0.81	7.46 ± 0.97
Flavor	7.64 ± 1.00^{a}	7.38 ± 0.94^{ab}	7.12 ± 1.04^{b}
Texture)dis-integrate(	7.62 ± 0.83^{a}	7.34 ± 0.87^{ab}	7.04 ± 0.95^{b}
Overall liking	7.72 ± 0.85^{a}	7.34 ± 0.80^{b}	7.12 ± 0.87^{b}

Note: Letters a and b assigned different values in the same horizontal line show a statistically significant difference ($p < 0.05$);^{ns} shows a value not significantly different ($p > 0.05$).

Table 6 presents the results of a study on the appropriate amount of sodium alginate to make encapsules of aromatic coconut water. Three levels were tested: 2, 2.5, and 3 g per 200 g of aromatic coconut water. Testers rated their preferences for appearance, sensory, flavour, texture (breakdown), and overall liking. For appearance and sensory, all three ratios of sodium alginate were not significantly different ($p > 0.05$), since the same type and strain of aromatic coconut water from the same fruit were used. Testers preferred the 3-g amount for appearance, while the 2.5-g formula was least preferred. The 2-g and 2.5-g formulas were not significantly different ($p > 0.05$). Regarding flavour, testers liked the 2-g amount the most, while the 3-g the least. However, the 2 formulas were not significantly different ($p > 0.05$). In terms of texture (breakdown), testers preferred the 2-g and 3-g amounts of sodium alginate the most, while the 2.5 g amount was least preferred. The 2.5-g formula was not significantly different ($p > 0.05$) from formulas 1 and 3. For overall liking, testers gave the highest score to the 2-g amount of sodium alginate. As a result, Formula 1, which had a sodium alginate amount of 2 g, was selected for further testing of consumer acceptance. Table 7 presents the results of a microbial quality test conducted on the aromatic coconut encapsules. This test involved 100 people and aimed to assess the presence of microorganisms in the product.

Table 7. Microbiological properties of aromatic coconut encapsules.

Properties	Properties of aromatic coconut encapsule
Microbiological	
- All microorganism (CFU g^{-1})	<10
- Yeast-Mold (CFU g^{-1})	<10
- Coliform (MPN mL^{-1})	<3

According to Table 7, a microbial quality analysis was conducted on aromatic coconut encapsulated products. Based on the standards (MPN) specified in Coconut jelly product 341/2004, the total amount of microorganisms, yeast and mould, and *Escherichia coli* by the MPN method should not exceed 3 per 1 g of sample. In addition, the aromatic coconut encapsulated product should have a total microbial amount that does not exceed 1 × 104 colonies/g, a yeast and mould quantity not exceeding 100 colonies/g, and an *E. coli* concentration that is required to be less than 2.2 per 100 mL of sample.

2.3. Results of the consumer acceptance of aromatic coconut water encapsulates

The study aimed to explore consumer acceptance of the encapsulated coconut water. A total of 100 individuals within the age range of 15-40, representing the teenage to working-age group, were participated in the study. They were asked to complete a questionnaire that consisted of Part 1, which focused on gathering general information about the consumers. This section of the questionnaire included questions about gender, age group, religion, education level, and income. The collected data are presented in Table 8.

Part 1. Information of the respondents

Table 8. Information of the respondents.

Information	Percentage
.1 Genders	
-Male	31
-Female	69
.2 Age	
- Under 18years	13
24-18-years	76
- Not over 40 years	11
.3 Religion	
-Buddhist	88
-Islam	2
-Christian	10
-Other	0
.4Education	
-Primary Vocational Certificate or High School	28
-Vocational Certificate or Bachelor's Degree	69
-Higher than bachelor degree	3
.5 Occupation	
-Student/undergraduate student	96
- Civil servants/state enterprises	1
-Business Owners	0
-Private companies employee	2
-Other, please certify	1
.6 Monthly Income	
-Less then 5,000Baht	16
10,000 – 5,001-Baht	17
15,000 – 10,001-Baht	43
30,000 – 15,001-Baht	20
-More than 30,000 Baht	4

According to the data presented in Table 8, most of the consumers surveyed were female, accounting for 69%. In terms of age group, the highest percentage was found in the 18-24 years category, accounting for 76%. Furthermore, the study indicated that 88% of the consumers surveyed identified as Buddhist. In addition, 69% of the participants had a bachelor's degree level of education. The occupation category with the highest percentage was students, accounting for 96%. Finally, 43% of the consumers reported an income range of 10,001-15,000 baht.

Part 2. Behavioural data and the attitude of the respondents.

According to the data presented in Table 9, it is evident that most consumers (85%) surveyed have consumed pearl pop pellets. The frequency of consuming pearl pop pellets was reported to be 1-2 times per month, which accounts for 47% of the respondents. In addition, most consumers (94%) purchased pearl pop products from department stores. Notably, a significant proportion of consumers (98%) expressed interest in a pop pearl pellet product made from aromatic coconut water using sodium alginate and calcium chloride.

Table 9. Behavioural data and the attitude of the respondents.

Data	Percentage
.7 Have you ever eaten bubble pop products in drinks?	
- Ever	85
- Never	15
.8 How often do you eat bubble pop and how much?	
2-1-times per week	47
- 4-3times per week	8
-More than 4 times per week	10
-Other, please certify.	5
.9 Where do you usually buy bubble pop products at bubble tea shops?	
) More than 1 answer can be given(	
- Shops in department stores	94
- Shops in commercial building	0
- Supermarket	3
- Convenience store/general market	3
.10 If there was a product of pop pearls made from aromatic coconut water using sodium alginate and calcium chloride, would you be interested?	
- Interested	98
-Not Interested	2

Part 3: Data on respondents' acceptance of the product.

Table 10. Data on respondents' acceptance of the product.

Data	Percentage
.11 Please put a ✓ in the box regarding your level of satisfaction in each aspect of the Aromatic Coconut Water Encapsulated Sample.	
.11Packaging size-shape	
- Highest	15
- High	50
- Moderate	34
- low	1
- lowest	2
.12Flavour	
- Highest	9
- High	49
- Moderate	38
- low	4
- lowest	0
.13Taste	
- Highest	34
- High	35
- Moderate	28
- low	3
- lowest	0
.14Texture (disintegrate)	
- Highest	4
- High	42
- Moderate	49
- low	3
- lowest	2

According to the findings presented in Table 10, the study on consumer acceptance of Encap Namhom Coconut Water revealed that consumers were highly satisfied with various characteristics of the product including size, shape, packaging, flavour, taste, and overall preferences. The satisfaction level for these aspects was reported to be very high. However, when it came to the texture characteristics, consumers expressed a moderate level of satisfaction. Notably, 76% of the consumers accepted the use of sodium alginate and sodium chloride in the encapsulated coconut water. Furthermore, the study indicated that if the product were available for sale, most consumers (58%) would choose to purchase it. When asked about their opinion on the price of the product, which is packed in a 1-ounce plastic box with a net weight of 29 g per box, 51% of consumers suggested that the price should be 10 baht. Compared to other encapsulation techniques such as spray drying or extrusion, liposome entrapment offered several benefits. It was a gentle process that did not expose the core material to high temperatures, helping to preserve the flavour profile and nutritional value of the encapsulated substance. In addition, liposome entrapment allowed for the use of a wider range of wall materials, including natural compounds like phospholipids, which are biocompatible and can improve the bioavailability of nutrients. The resulting encapsules were also typically smaller in size and had a more uniform distribution of the core material, leading to a more consistent sensory experience for consumers. In the case of aromatic coconut water, liposome entrapment could help maintain the unique aroma and flavour of the coconut, while also providing a convenient and innovative delivery system for consumers. The expected benefits of this study are numerous and significant. By determining the appropriate amount of sodium alginate needed to effectively encapsulate aromatic coconut, this study could help in the development of new forms of aromatic coconut water that offer enhanced value through scientific processes. This could open new avenues for the use of aromatic coconut in the food and beverage industry, as well as in the development of new products that take advantage of its properties. Furthermore, by examining the physical, chemical, and sensory properties of the encapsulated capsules containing aromatic coconut, the study could provide valuable insights into the behaviour and characteristics of the encapsulated coconut aroma. This information could be used to optimize the encapsulation process, improve the quality of the product, and ensure consistency in production. It could also offer a better understanding of how encapsulation affects the nutritional profile, composition, and chemical attributes of the encapsulated coconut aroma. Finally, by evaluating consumer acceptance of the aromatic coconut capsules, this study could provide valuable feedback on the product's taste, aroma, texture, and overall satisfaction. This could help in refining the product to better meet consumer preferences and needs and could ultimately lead to increased marketability and sales. The study has the potential to make a significant contribution to the field of food science and technology, as well as to the industry and consumers who benefit from these innovations.

CONCLUSION

1. Examining the appropriate amount of sodium alginate for the encapsulation of aromatic coconut water.

Using sodium alginate in the amount of 2 g per 200 g coconut water, 500 g clean water, and 3 g calcium chloride made encapsulated coconuts to have an appropriate viscosity. It can be dissolved into water inside the encapsulated or coated tablets.

Physical quality of aromatic coconut water encapsules. The colour brightness (L*) was 91.78 ± 0.01, the red (a*) 0.24 ± 0.02 and the yellow (b*) 2.47 ± 0.01. The pH value was 5.20 ± 0.02 pH value within the same level, the total dissolved solids (°Brix) 6.43 ± 0.06, while the optimum viscosity 3.57±0.58.

2. Results of physical characteristics and chemistry on encapsulated aromatic coconut

There was a physical quality value of colour; brightness (L*) was 45.18 ± 0.03, red value (a*) -0.50 ± 0.01 and yellow value (b*) -3.12 ± 0.01. The amount of acid-base (pH) was 5.20 ± 0.00 and the amount of dissolved solids (°Brix) 6.43 ± 0.00. Microbial content of aromatic coconut water encapsulated products did not exceed the value specified by the standard (CMU. 341/2547)

3. Results of consumer acceptance of encapsulated coconut water.

Consumers were very satisfied with the product. Thet accepted using sodium alginate and sodium chloride in encapsulating coconut water accounting for 76%. If there are products available for sale consumers, they will choose to buy accounted for 58%.

Suggestions

Encapsulated aromatic coconut products can be processed to increase product variety.

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