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Product Development of Fish Crisp from Sucker Mouth Fish (*Hypostomus plecostomus*)

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Abstract

The study aimed to develop a standard formula and process for baking sliced Sucker Mouth Fish and maintaining its quality at room temperature. The chemical components of the fish were analyzed, revealing moisture level, protein, fat, coarse fiber, and carbohydrate to be 83.20±0.24, 14.63±0.51, 0.48±0.61, 0.61±0.03, 1.40±0.20, and 0.11±0.12, respectively. During the study, testers preferred the second formula for baked sliced fish production and gave it higher average scores in all aspects, so the second formula was used. Testers unanimously preferred the 0:100 ratio when assessing palatability using various ratios (100:0, 25:75, 50:50, 75:25, and 0:100). The physical qualities of the product were also analyzed, including lightness (L), red value (a*), and yellow value (b*), resulting in values of 43.11±0.3, 15.70±0.30, and 18.96±0.48, respectively. The water activity (aw) and crispiness level were measured at 0.41±0.00 and 7.08±1.10, respectively, both within the standardized range. The packaged foil bag with absorbent was kept at room temperature for 2 weeks and analyzed using sensory evaluation, with results showing no significant difference (p>0.05).*

Keywords: *Sucker Mouth Fish, Fish Crisp, Product Development, Hypostomus Plecostomus, baked sliced fish*

1. Introduction

Derivation and significance of the problem.

In recent times, there has been a noticeable increase in the consumption of snacks, particularly among children and young individuals who are not prioritizing regular main meals. While snacks are often associated with pleasure and enjoyment, it is important to note that these food choices often lack sufficient nutritional value. Due to their high flour, sugar, and fat content, along with low protein content, regular consumption of snacks often leads to excessive weight gain in children, increasing their risk of obesity. The rise in childhood obesity rates has been rapid, largely due to societal changes in lifestyle. This phenomenon also appears to highlight the expression of existing genetic abnormalities in younger children. This reflects the importance of current environmental factors that promote unhealthy food intake and hinder children's physical activity (Wanchai, B.E. 2550).

Crispy fish is a product made from fish as the main ingredient. It is a convenient and flavorful food that is widely consumed while traveling or used as an appetizer, leading to an increase in consumption every year. Snacks made from fish rank second in sales after potato chips (Praweena, B.E. 2546). Sucker is a fish imported from abroad. It can adapt to the environment well, is good at finding food, easy to raise, and able to breed quickly. Due to its strange shape and scary appearance, no one dares to consume this kind of fish. Because of these reasons, suckers are found everywhere in the rivers of Thailand (Sittipat, B.E. 2550).

Therefore, there has been an interest in processing sucker mouth fish. This is because the fish is high in protein, readily available, and easily cooked, which reduces production costs. Moreover, it aids in reducing the overall consumption of fish while promoting the consumption of sucker mouth fish. Consequently, sucker mouth fish has been processed into crispy fish snacks, which are nutritious and high in protein. This serves as a guideline for controlling and preventing overnutrition in children, contributing to promoting child health and changing behavior towards healthy food consumption.

The objectives of the study are as follows:

Research Objectives:

1. To analyze the chemical composition of sucker mouth fish.

2. To investigate the basic formula and production process of crispy fish sheets.

3. To determine the appropriate amount of sucker meat for use in producing fish chips from sucker mouth fish.

4. To evaluate the quality changes of crispy fish products made from sucker mouth fish during storage at room temperature.

The scope of the study includes:

The use of Common Sucker (Hypostomus spp.) from Bangkok Fish Market. The study involves blending sucker meat with other ingredients, forming a sheet with dimensions of 3 x 3 centimeters, and subjecting it to baking in a hot air oven at 60 °C for 22 hours. The subsequent step involves frying and removing oil at 70 °C for 20 minutes.

2. Literature Review

Snack and its general significance:

Snacks are defined as food consumed between main meals to alleviate hunger or satisfy food cravings. They are lightweight, easy to carry, and classified as high-energy food due to their carbohydrate content (Rongrat, B.E. 2546). Snack products come in various forms, using different raw materials and production methods. They should be convenient for consumption, small, lightweight, and have a satisfying taste. They can be sweet or savory and are consumed for various occasions, meeting consumer needs and quickly satisfying hunger. (Tasanee, B.E. 2541).

Types of snacks separated by product:

Snacks in the form of potato chips, both stick and sheet types, snacks in the form of fish strips or various flavored fish sheets, molded snacks, including, crispy pastries made from starchy raw materials such as corn starch and other ingredients, formed to have different shapes, nut snacks, prawn crackers, fish crackers and so on, buttered corn snacks, seasoned squid snacks.

Deterioration of snack products:

When stored for a period, there will be a change in quality which can affect the acceptance of the product. There are two deterioration processes that may occur simultaneously: 1) loss of texture due to moisture absorption by food constituents such as biopolymers, which have important features as substances with both an orderly and disorganized structure. 2) The occurrence of a rancid odor caused by oxidation, which is catalyzed by oxygen and light, is an important cause of food quality loss.

Changes in temperature and humidity levels can impact the properties of food, particularly its texture. The glass transition temperature (Tg) is crucial, as it determines the material's mechanical properties. Below Tg, the food becomes brittle, while above Tg, it becomes more flexible and rubberier. Additionally, moisture content and water activity (aw) significantly influence the textural properties of snacks. Water can act as a plasticizer or non-plasticizer, affecting the starch/protein matrix structure and altering the product's texture. Sensory evaluation has shown that crispness decreases with increasing aw value, and products are generally not accepted when the aw value is between 0.35-0.5. Additionally, rancidity, catalyzed by oxygen and light, contributes to the deterioration of food quality, particularly through lipid oxidation, involving a free radical mechanism.

Step 1: Free fatty acids, react with catalysts like heat, light, and metal radicals.

Step 2: Fatty acid free radicals react with oxygen, forming peroxide free radicals. These radicals can also react with other fatty acids, producing new hydroperoxides and free radicals. The hydroperoxides may decompose, generating more free radicals. This process, known as autoxidation, can result in the development of compounds causing an unusual odor or other damage to food quality.

Step 3: Free radicals further react with each other, forming stable molecules.

Preservation of snack products:

Nowadays, various types of gases are used in the packaging process of food products to maintain their quality and nutritional value for extended periods. This method involves placing the product under a specific gas atmosphere, such as carbon dioxide or nitrogen gas, to displace the air inside the container.

It is widely used for products sensitive to oxidation and helps to preserve high-fat foods, fruit juices, and other perishable items by reducing the presence of oxygen. The most employed gas in the food industry for gas flushing systems is nitrogen gas. This is because it is colorless, odorless, tasteless, and non-toxic, making it safe for use in all food products. Nitrogen gas is also preferred as a replacement for oxygen gas as it prevents the oxidation of fats and oils and browning reactions. It is an environmentally safe, non-explosive gas that exhibits high solubility in both water and fat. Nitrogen gas is also used to remove air from snack food containers, allowing manufacturers to extend the shelf life of their products. Other factors to consider in food preservation include storage conditions such as temperature control, light exposure, humidity levels, quantity, and microbial status. The appropriate type and concentration of gas for each food product, as well as the equipment used in packaging, also play crucial roles in ensuring product quality and longevity (Khongwut, B.E. 2550).

Suckermouth armored catfish:

The Suckermouth armored catfish, scientifically known as *Pterygoplichthy pardalis,* is a species native to the South American river basin. It has a body shape that typically ranges from 15 centimeters to 30 centimeters in length. This catfish is characterized by its relatively large head, small eyes, and most notably, a prominent largemouth located on the underside of its body. This unique feature enables the catfish to cling to or absorb various materials present in the water. It possesses a hard and rough body, with a tall and wide dorsal fin. Its body is covered in 23-24 bony plates on each side, resembling a suit of armor. The coloration of this species typically consists of brown or black spots scattered across its body. In its natural habitat, it resides near the water surface and feeds on a variety of small organisms and aquatic animals, including fossils. In B.E. 2520, the suckerfish was imported to Thailand as an ornamental fish, primarily used to clean up food scraps or algae present inside tanks. Occasionally, when food resources are scarce, suckermouth fish may display aggressive behavior and suck the mucus of other fish until their demise. Due to their remarkable adaptability to diverse environments, they can survive even in toxic conditions or water with below-normal oxygen levels, surpassing the tolerances of most fish species. Consequently, they have become an invasive species, causing environmental issues. To address this concern, the Fisheries Department has declared suckermouth fish as a prohibited species for breeding and sale. Instead, efforts are being made to promote their consumption as a food source The Suckermouth armored catfish, also known as Pterygoplichthy pardalis, is a species native to South American river basins. It has a unique feature of a large mouth located on the underside of its body, allowing it to cling to or absorb various materials present in water. This fish possesses a hard, rough body, with a tall and wide dorsal fin and 23-24 bony plates on each side that resemble armor. It typically feeds on small organisms and aquatic animals and is known for its remarkable adaptability to diverse environments, enabling it to survive in toxic conditions or water with below-normal oxygen levels. Due to their adaptability, they have become an invasive species, causing environmental issues. The Fisheries Department has declared suckermouth fish as a prohibited species for breeding and sale and is promoting their consumption as a food source instead (Trisin, B.E. 2556).

Figure 1. Sucker mouth fish appearance

Source: Freshwater Aquaculture Research and Development Center (PSU.)

Production Process of Crispy Fish Chips:

1) Temperature control.

The use of cooling in food preservation can be categorized into two levels: refrigeration and freezing. Refrigeration involves keeping food at a low temperature above the freezing point, while freezing maintains food at a temperature below the freezing point. Both methods are used to extend the shelf life and maintain the quality of products by inhibiting microorganism growth and preserving the color, aroma, taste, and nutritional value of food. However, specific temperature requirements and durations may vary depending on the type of food being preserved. It is also important to note that the presence of super-cooled water can lead to the formation of ice crystals when latent heat of crystallization is extracted:

Factors such as initial microorganism levels, temperature, and humidity play a crucial role in determining the shelf life and quality of meat when stored in cold storage facilities. Higher initial levels of microorganisms can lead to a shorter shelf life and maintaining a consistent temperature of 3°C or lower is crucial for preserving the quality of meat and meat products. Cold storage facilities should also maintain relative humidity levels between 88-92%, as lower humidity can result in weight loss and shrinkage of meat, while high humidity can promote the growth of bacteria and fungi, leading to spoilage. Proper control of these factors, along with good hygiene practices, is necessary to ensure optimal preservation of meat.

2. Cutting and Mixing process.

Size reduction and blending are two important processes in meat processing. Size reduction involves reducing the size of meat fractions using tools like meat grinders, silent cutters, and emulsion mills to create sub-parts of varying sizes. This process improves the uniformity of the product, makes it more tender, and prepares it for blending. Blending is the process of uniformly distributing all components, including trace elements like nitrites and spices, and is achieved through finely chopping or emulsifying the meat. Emulsification involves mincing meat and changing the structure of muscle fibers to extract myosin, which acts as an emulsifying agent. The myosin protein helps combine essential ingredients like water and fat that are normally incompatible. Fat is chopped into fine droplets and encased in water-soluble proteins, dispersed throughout the continuous phase, creating the emulsification condition in meat products (Comprehensive Food Information Network Center, PSU.)

3. Baking.

Baking involves the removal of water from a material, resulting in a lower proportion of liquid and a solid product. Baking can be applied to wet solids, slurry, or clear liquids to obtain a powdered product. During baking, heat transfer occurs through convection and radiation, causing changes like browning, denaturation of proteins, and the formation of a hard crust. Preventing and reducing contaminants is crucial when baking meat products, and using high-quality ingredients, cleanliness, and low heat to destroy microorganisms before drying are important. Enzymes play a significant role in baking, and their reaction decreases proportionally when the water content decreases to less than 5.6-8.5% (Pimpen and Nithiya, B.E. 2556, Wilai, B.E. 2545).

4. Drying process.

The drying process is a method of food preservation that involves reducing the moisture content of food by evaporating water through drying, frying, or sublimation. It extends shelf life, ensures food safety, reduces volume, and creates new products for consumers. The factors that affect the drying process include the nature, size, shape, volume, and surface area of the food, as well as temperature, humidity, wind speed, pressure, and physical changes. Shrinkage, the occurrence of cracks, and chemical changes like lipid oxidation and enzymatic reactions can also occur during the drying process, causing a decrease in quality (Source: Sakmon, PSU.)

5. Frying.

Frying gives snack foods, a crispy texture and unique flavor, and reduces moisture due to the high temperature of frying.

- Deep-fat frying is a popular food and snack processing method that uses high-temperature oil or fat. The quality of the oil used for frying impacts the quality of the processed product.
- When oil is heated to 160-180 degrees Celsius during frying, chemical reactions occur that lead to oil deterioration. These chemical reactions include oxidation, which forms non-oxidative peroxide radicals that decompose into aldehyde or ketone compounds.
- When fats or oils are heated, they are hydrolyzed, breaking down into free fatty acids, which increase the acidity and produce a foul odor.

- Frying food at 200-300 degrees Celsius causes unsaturated fatty acids in triglycerides to combine, forming polymers. These polymers lead to increased foaming of the oil and the formation of a sticky substance.
- The quality of fried snacks is influenced by various factors, particularly the frying process. When the pressure is equal to the resistance, the food undergoes even and uniform swelling, resulting in the perfect crispiness and texture.
- The quality of the oil used in frying has a significant impact on the quality of the final fried product. Oil that has been heated for a prolonged period or reused multiple times tends to deteriorate, which can negatively affect the shelf life and overall quality of the product.
- Frying temperature and time significantly influence oil absorption in the final product. Additionally, the size of the food pieces being fried also affects oil absorption, and the type of oil used can also affect the color of the final product.
- The study conducted by Krokida et al., (2001) found that frying at higher temperatures (190 °C) resulted in lower lightness and increased red and yellow color values, but the brightness values remained constant.
- The initial humidity or moisture content of the raw materials used in snack foods can affect the density of the final product. Additionally, the amount of water required in the mixture may decrease when incorporating other ingredients with high moisture content.
- The initial moisture content of the raw materials affects the oil absorption of the final product, and the amount of oil retained, and the amount of water released are correlated with the frying temperature.
- The size of the food plays a significant role in the oil absorption and color of the final product (Wilasini, B.E. 2554). Smaller pieces of food tend to be highly oily, while larger pieces have lower oil absorption. This is supported by experiments conducted by Moreira et al. (1997) and Krokida et al. (2000). In addition, the thickness of potato slices used in frying impacts the oil absorption and color of the final product. Potatoes with a thickness of 5 mm had higher oil absorption and lower brightness but higher red (a) and yellow (b) values compared to potatoes with a thickness of 10 and 15 mm, as observed in a study by Krokida et al. (2001)

Water activity and shelf-life control of food products:

Water Activity value is an important factor in controlling and preventing spoilage of food products. It is used to assess which microorganisms are or are not the cause of food spoilage, and to control and prevent food spoilage caused by microorganisms. Moisture content is a factor related to food spoilage, and methods to preserve food aim to reduce the moisture content by adding sugar or salt to food. However, many people tend to confuse water activity with humidity, and vice versa. The relationship between moisture content and water activity can be determined by measuring these values for each product at a certain temperature only. The relationship graph between moisture content and water activity can be easily created by placing the food in containers with known relative humidity values. The relationship is non-linear, and the Moisture Sorption Isotherms curves of different products will have different characteristics.

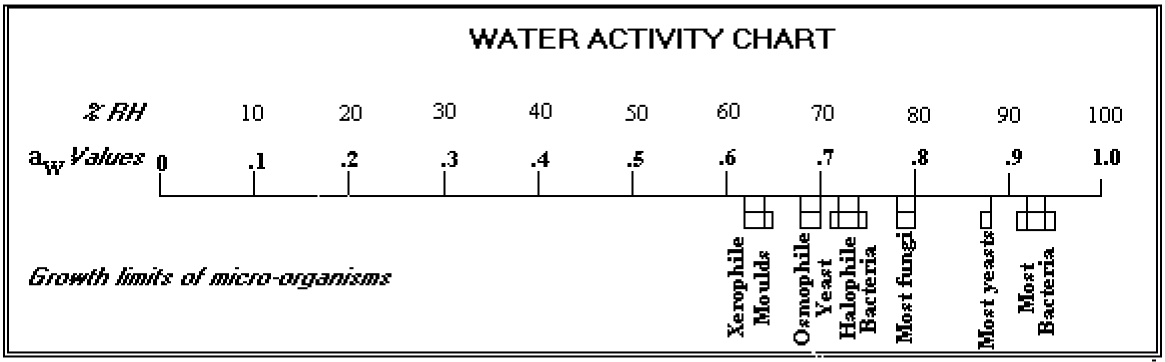

Figure 2. Relationship of moisture content and Water Activity.

Source: Technology Innovation Center, B.E. 2546.

Water Activity value and food requirements and standards:

Based on the relationship between Water Activity and the growth of microorganisms that cause food spoilage, especially those that produce toxins which may harm consumers, many countries have laws that enforce and control the quality of food produced or sold within their jurisdictions. For instance, in the United States, the Food and Drug Administration (FDA) utilizes the Water Activity value as a food safety index. Food is classified into four categories based on pH and Water Activity values.

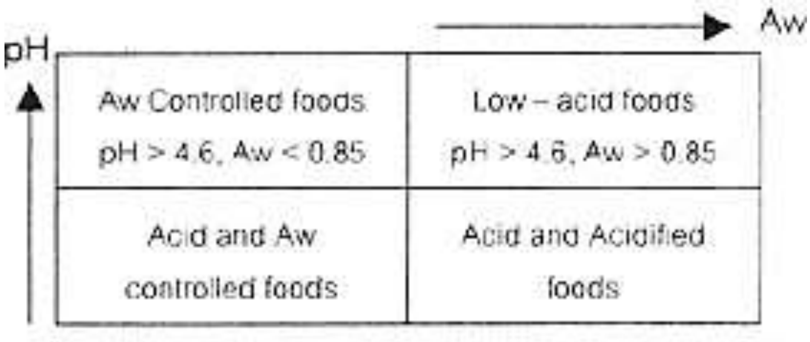

Figure 3. Relationship between pH and Water Activity.

Source: Technology Innovation Center, B.E. 2546.

Water Activity and shelf life of food products:

During processing, transportation, and storage, food products undergo various changes that can affect their quality and shelf life. Therefore, food manufacturers conduct studies to identify the causes of spoilage for each product. Food spoilage occurs due to the growth of microorganisms such as bacteria, yeasts, and molds, which depend on the specific types and components present in each food product. Water Activity control methods are widely employed in the food industry.

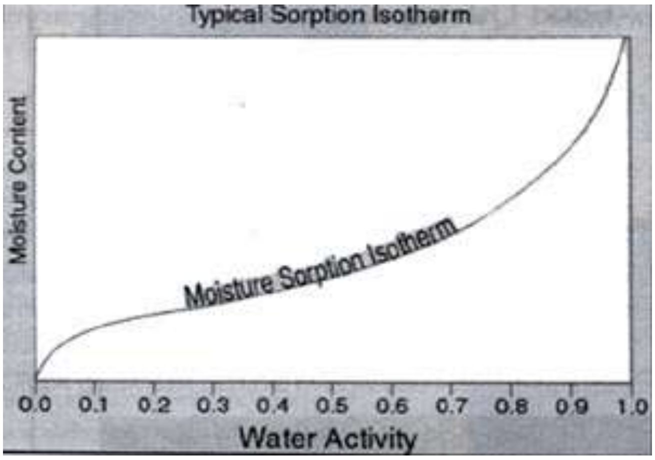

Figure 4. Shows the limiting water activity level of microorganisms. Source: Technology Innovation Center, B.E. 2546

In general, foods with high Water Activity include raw foods such as meat, vegetables, and fruits, as well as processed foods like soft cheese and smoked meat products. Proper storage at refrigerated temperatures is crucial for these products. However, for certain food groups, controlling the Water Activity level allows for storage at room temperature. This includes items like fruit cakes, puddings, chocolates, and caramel. The Water Activity of food products should be controlled to prevent fungal growth, with a recommended value of 0.75. However, some yeasts and molds can still grow at lower Water Activity values. In special cases, a value lower than 0.6 may be necessary for long shelf life (Food Science Australia Fact Sheet). Storage conditions, such as temperature and humidity, also impact shelf life. Hurdle Technology, which combines various preservation methods, can be used in addition to controlling Water Activity. For example, it can include high-temperature applications, pH control, the addition of preservatives, and other ingredients (Postharvest Technology Innovation Center, B.E. 2546).

3. Materials And Methods

Study on the chemical composition of sucker mouth fish: The smashed smoked fillet samples were analyzed for their chemical composition, including moisture content, protein content, fat content, coarse fiber content, ash content, and carbohydrate content. The analysis of the chemical composition involved several methods.

Moisture Content Analysis: The samples were dried to a constant weight in a hot air oven (AOAC, 2000). The protein content was determined using the Kjeldahl Method, and it was calculated based on the nitrogen content in the samples. The fat content was determined using the ether extraction method (AOAC, 2000). Coarse fiber content analysis was performed using acid and base hydrolysis (AOAC, 2000). The ash content was determined by calcining the sample at 500-600 °C (AOAC, 2000). Carbohydrate content determination involved calculating the difference in dry sample weight and the sum of the percentages of moisture, protein, fat, coarse fiber, and ash.

This study is to examine the fundamental formula and production process for making crispy fish sheets:

1) This study is to investigate the basic formula and production process of crispy fish sheets. Additionally, the objective is to select a suitable basic formula as a prototype to produce crispy fish sheets. To accomplish this, 3 different basic formulas were studied, and the details are provided in Table 1.

Table 1. Mixing ratios of 3 formulas is used in the production of crispy fish sheets.

Ingredients	**Ingredient weight (grams)**		
	Formula 1	**Formula 2**	**Formula 3**
Minced fish	500	500	500
Ground salt	2	2	15
Caraway seeds	1	1	-
Pepper	1	1	-
Coriander seeds	1	1	-
Soy sauce	25	30	-
Dark soy sauce	2.5	2	-
Sugar	50	65	50
Tapioca flour	40	-	40
Cayenne	-	-	2.5

Source: Formula 1. Praweena (B.E. 2545), Formula 2. Aquaculture Industry Development Division (B.E. 2552), Formula 3. Vanisara (B.E. 2531)

Production process of Crispy fish sheets.

wash the tilapia with water. and then frozen at -18 °C.

↓

Remove the tilapia from the freezer, Set aside until the internal temperature of the fish is -2 to 2 °C.

↓

Remove the tilapia from the bones and skin and cut into small pieces. Then washed in 4% saline solution at a temperature of 0-4 °C.

↓

Chill the tilapia fillets until the internal temperature is -2 to 2 °C (control the temperature before mashing the fish for processing).

↓

Blend the tilapia meat thoroughly with Max for 2 minutes.

↓

Bring fish and all ingredients in a food processor for 3 minutes using speed 1.

↓

Weigh 80 grams of the mixed ingredients and place them into an 8x12 centimeter plastic bag. Flatten the mixture until it forms a thin sheet and ensure that the bag is filled completely. (forming)

↓

Cut off the sides and bottom of the bag, put it in a hot air oven at a temperature of 60 °C

↓

Bake in hot air for 1 hour and 30 minutes, then cut the fish strips into small 4x4 cm strips, peel the plastic wrap from the fish and flip it over. Continue to bake for 20 hours and 30 minutes.

↓

Take the fish sheets that have been analyzed for physical quality, which is. a_w, moisture content and color value.

↓

Fry the fish sheets in oil at 180 °C for 10 seconds.

↓

Dry the oil with a hot air oven at 70 °C for 20 minutes.

Diagram 1. Production process of fish sheets, 3 formulas.

Source: Adapted from Aquaculture Industry Development Division (B.E. 2552)

Quality Analysis

2.1) Measure the amount of free water (Water Activity) by grinding the crispy fish product into fine pieces and placing them in a sample container. Use an aw meter, such as the AQUA LAB brand, model CX3TE, to measure the water activity.

2.2) Measure the color value of the finely ground crispy fish products by placing them in a sample container and using a colorimeter or spectrophotometer. Use a KONIKA MINOLTA brand, model CM-3500d, with program version CM-S100 W1.70.0001, to measure the color values. The measured values should include color L* (luminance, ranging from 0 to 100, where 0 represents a bright black object and 100 represents a white object), a* (with positive values indicating red and negative values indicating green), and b* (with positive values indicating yellow and negative values indicating blue).

2.3) Measure the moisture content of the fish products by placing finely ground baked crisps (approximately 3 grams) into a sample container. Use an Infrared Moisture Determination Balance, such as the IR Kett model FD-620, to measure the moisture content.

2.4) Evaluate texture characteristics By using crispy baked fish sheet products to measure the crispness value. By analyzing sensory quality by planning a randomized complete block design (RCBD), 100 untrained test subjects were used, who were professors and students of Rajamangala University of Technology Phra Nakhon. Sensory test by evaluating sensory quality in terms of texture (crispness) with a liking score of 9 levels (9-Point Hedonic Scale). The results were analyzed to find variance (Analysis of Variance - ANOVA).

The mean difference was analyzed by Duncan's New Multipe's Range test (DMRT).

2.5) The sensory quality of 3 basic formulas of crispy fish products was analyzed using a Randomized Complete Block Design (RCBD) with students from Rajamangala University of Technology Phra Nakhon. The sensory test evaluated the quality based on appearance, color, odor, taste, texture, and overall preference using a 9-point liking scale (9-Point Hedonic Scale). The results were subjected to analysis of variance (ANOVA) to determine variance, and mean differences were assessed using Duncan's New Multiple Range Test (DMRT) for selection. The best formula identified will be utilized for further development.

To study the appropriate amount of sucker meat used in the production of crispy fish products from sucker mouth fish:

3.1) Utilize the best formula identified in section that investigates the optimal quantity of sucker mouth fish meat required for producing crispy fish sheet products, which significantly impacts sensory quality. Plan a completely randomized experiment in blocks using a Randomized Complete Block Design (RCBD). Study the quantity ratio of tilapia to sucker mouth fish at five levels: 100:0, 75:25, 50:50, 25:75, and 0:100 as presented in Table 2.

Table 2. Proper ratios of tilapia to sucker meat are used in the production of crispy fish snacks for 5 formulas.

Ingredients	Ingredient weight (grams)				
	Formula 1	**Formula 2**	**Formula 3**	**Formula *4***	**Formula *5***
Tilapia fillet	500	375	250	125	-
Sucker mouth fish fillet	-	125	250	375	500
Ground salt	2	2	2	2	2
Caraway seeds	2	2	2	2	2
Ground pepper	1	1	1	1	1
Coriander seeds	1	1	1	1	1
Soy sauce	30	30	30	30	30
Dark soy sauce	2	2	2	2	2
Sugar	65	65	65	65	65

Source: Adapted from Aquaculture Industry Development Division (B.E. 2552)

Quality analysis

1) Measure the amount of free water (Water Activity) using fish products. Crispy baked sheets made from sucker mouth fish that are ground into a fine paste. put in sample container Using an a_w measuring device, brand AQUA LAB, model CX3TE.

2) To measure the color value of crispy fish products made from minced smoked fish, place them in a sample container and use a colorimeter (spectrophotometer) such as the Konika Minolta CM-3500d model with program version CM-S100 W1.70.0001. The measured values should include the L* value, which represents luminance and ranges from 0 to 100. A value of 0 indicates a bright black color, while 100 indicates white brightness. Additionally, measure the a* value, where a positive (+) value indicates a red object, and a negative (-) value indicates a green object. Finally, measure the b* value, where a positive (+) value indicates a yellow object, and a negative (-) value indicates a blue object.

3) Measure the moisture content by placing approximately 3 grams of minced smoked fish chips into the sample container. Use an Infrared Moisture Determination Balance such as the IR Kett model FD-620 to measure the moisture content.

4) Measure the crispiness value of crispy fish products made from sucker mouth fish to evaluate the texture. Conduct a sensory quality analysis using a randomized complete block design (RCBD) with 100 untrained testers, who are teachers and students from Rajamangala University of Technology Phra Nakhon. The sensory test should assess the texture (crispness) using a 9-point preference score (9-Point Hedonic Scale). Analyze the results using variance analysis (ANOVA) and perform mean comparison using Duncan's New Multiple Range test (DMRT) to determine any significant differences between means.

5) Analyze the sensory properties of five formulas of crispy fish sheets made from sucker mouth fish using a Randomized Complete Block Design (RCBD). Conduct the sensory analysis with 50 untrained testers, who are teachers and students from Rajamangala University of Technology Phra Nakhon. Evaluate the sensory quality based on appearance, color, odor, taste, texture, and overall liking using a 9-point liking rating (9-Point Hedonic Scale). Analyze the results using variance analysis (ANOVA) and compare means using Duncan's New Multiple Range test (DMRT) to determine the best formula.

To study the quality changes of crispy fish products from sucker mouth fish:

The dried fish snacks made from sucker mouth fish, which received the highest rating from the panelists as shown in previous section, were used to study rancidity. The fish snacks were packed in zip-lock aluminum foil bags measuring 6×9 inches and containing 30 g of desiccant, weighing 2 g. The bags were then stored at room temperature. Weekly random checks were conducted for a period of 2 weeks or until the Water Activity value in the snacks exceeded 0.6, at which point the study on rancidity was stopped. Various quality checks were performed during this period as follows:

1) Measure the Water Activity (^{aw}) of crispy baked sheets made from ground sucker mouth fish paste by using an Aqua Lab brand aw meter, model CX3TE. Place the sample in a sample container and measure the free water content.

2) Measure the color value of crispy fish products made from minced smoked fish using a colorimeter (spectrophotometer). Use a Konika Minolta brand CM-3500d model, program version CM-S100 W1.70.0001. The measured value should be the L* color value, which ranges from 0 to 100. A value of 0 indicates a bright black color, while 100 indicates brightness. A positive (+) value indicates a red object, while a negative (-) value indicates a green object. The b* value indicates the object's yellowness, where a positive (+) value indicates a yellow object, and a negative (-) value indicates a blue object.

3) Determine the moisture content by placing approximately 3 g of minced smoked fish chips into a sample container. Use an Infrared Moisture Determination Balance from IR Kett, model FD-620, to measure the moisture content accurately.

4) Measure the crispiness value of crispy fish products made from sucker mouth fish to assess the texture. Conduct a sensory quality analysis using a randomized complete block design (RCBD) with 100 untrained testers, who are teachers and students from Rajamangala University of Technology Phra Nakhon. The sensory test should evaluate the texture (crispness) using a 9-point preference score (9-Point Hedonic Scale). Analyze the results using variance analysis (ANOVA) and perform mean comparison using Duncan's New Multiple Range test (DMRT) to determine any significant differences between means.

5) Analyze the sensory properties of five different formulas of crispy fish sheets made from sucker mouth fish to evaluate their sensory quality. Use a randomized complete block design (RCBD) with 50 untrained testers, who are teachers and students from Rajamangala University of Technology Phra Nakhon. Conduct a sensory test to assess the appearance, color, odor (rancidity), taste, texture (crispiness), and overall liking of the fish sheets. Use a 9-point liking rating scale (9-Point Hedonic Scale). Analyze the results using variance analysis (ANOVA) and determine the mean differences using Duncan's New Multiple Range test (DMRT) to select the most suitable storage period.

Experiment Places

1) Workshop at Food Science and Technology Laboratory 521, 522, 621 and 622, Faculty of Home Economics Technology. Rajamangala University of Technology Phra Nakhon.

2) Sensory quality test at the Faculty of Home Economics Technology Rajamangala University of Technology Phra Nakhon.

Time period for conducting the experiment.

This trial ran from 1 October B.E. 2561 – 23 March B.E. 2562.

3. Results and Discussion

TABLE 1. Results of the study on the chemical composition of sucker mouth fish.

Study the chemical composition of sucker mouth fish. The smashed smoked fillet samples were analyzed for chemical composition, which are moisture content, protein content, fat content, coarse fiber content, ash content and carbohydrate content.

Table 3. Chemical composition of sucker mouth fish.

Composition Chemical	Amount (Percentage)
Moisture	83.20±0.24
Protein	14.63±0.51

Fat	0.48±0.16
Coarse Fibers	0.16±0.03
Ash	1.40±0.20
Carbohydrates	0.11±0.02

According to Table 3, the chemical composition of sucker mouth fish is as follows: moisture content 83.20±0.24%, protein 14.63±0.51%, fat 0.48±0.16%, coarse fibers 0.16±0.03%, ash 1.40±0.20%, and carbohydrates 0.11±0.02%. On the other hand, tilapia has the following chemical composition: moisture content 81.6±0.23%, protein 15.5±0.14%, fat 1.2±0.10%, coarse fibers 0.1±0.11%, ash 1.5±0.21%, and carbohydrates 0.1±0.09% (Buntarika, 2016). Based on these values, it can be observed that sucker mouth fish and tilapia have similar chemical compositions, with slight variations in protein, fat, and ash content. Sucker mouth fish is notably high in protein and provides a readily available and cost-effective source of protein. Due to this characteristic, it is attractive to consumers and can serve as an alternative protein source to tilapia or other fish options (Sittipat, B.E. 2550).

2. The results of the study of the basic formula and the production process of crispy fish sheets.

2.1) Results of the study of the basic formula and production process for crispy fish chips.

From studying the basic formula and production process suitable for producing fish products, crispy baked sheets, with 3 different production formulas, the appearance was studied with sensory testing to study the basic formula and process that is correct.

Table 4. Product characteristics of crispy fish sheets with 3 different formulas.

Product characteristics	**Basic Recipe Crispy Baked Fish Sheet**		
	1	**2**	**3**
			
	Darker brown Crispy texture Sticky, not puff	Darker brow Crispy texture Puffy	Darker brown Hard texture Not Puff

Source:

Formula 1 Praweena (B.E. 2545)

Formula 2 Aquaculture Industry Development Division (B.E. 2552)

Formula 3 Vanisara (B.E. 2531)

2.2 Results of analysis of physical and sensory properties

Table 5. Results of analysis of product properties of crispy fish sheets, with different basic formulas, totaling 3 formulas.

Quality	**Basic Recipe Crispy Baked Fish Sheet**		
	1	**2**	**3**
a_w ns	0.41±0.03	0.41±0.00	0.45±0.00

Moisture	2.92±0.36[b]	3.70±0.48[a]	2.06±0.25[c]
Color Value			
Brightness (L*)	40.37±0.21[b]	41.43±0.15[a]	34.75±1.49[ab]
Red (a*)	14.15±0.30[b]	14.88±0.13[a]	12.96±0.65[ab]
Yellow (b*)[ns]	15.80±0.27	17.24±0.23	11.80±1.09
Texture (Crispness)	6.68±0.93[b]	8.16±1.02[a]	6.26±1.03[c]

Note: Different horizontal characters mean values that are statistically different ($p \leq 0.05$). The letter "[ns]" indicates that the means are not significantly different ($p > 0.05$).

Analyzing Tables 4 and 5, it can be observed that when examining the appearance of crispy fish sheet products produced using 3 different raw materials (Formulas 1, 2, and 3), Formulas 1 and 3 have similar appearances. Specifically, when fried, the fish sheets from Formulas 1 and 3 turn out to be non-puffy, hard, not crispy, and exhibit a reddish-brown color. The presence of white flour mixed in gives them an unappetizing look. On the other hand, Formula 2 displays a more appealing reddish-brown color and has a puffy and crispy texture compared to both other formulas. From the analysis of the appearance of the crispy fish products with differing raw materials, it was evident that Formula 2 had a superior appearance. Its puffy and crispy texture, along with the appetizing color, contributed to its visual appeal. The sheet-like structure of the fish meat in Formula 2, characterized by short fibers and minimal connective tissue, can be easily destroyed during the production process (Nanavdo, B.E. 2558). Moreover, the heat treatment applied during the drying process followed by frying causes the fish sheets to expand and puff up. In contrast, Formulas 1 and 3 contain tapioca starch as an ingredient. Tapioca starch is suitable for producing dense and tough food items. However, when used for frying, it does not yield crispiness (Manao, B.E. 2560). Both Formulas 1 and 3 do not undergo a steaming process to cook the starch, leading to the starch molecules remaining densely packed with an intact crystal structure (Prince of Songkla University, PSU). Consequently, the fish sheets in these formulas lack the characteristic puffiness.

Table 6. Appearance scores for Crispy Baked Fish Sheet products, with different basic formulas, totaling 3 formulas.

Product characteristics	**Basic Recipe Crispy Baked Fish Sheet**		
	1	**2**	**3**
Appearance	694±0.84[b]	7.88±0.96[a]	6.50±1.23[c]
Color	6.90±0.93[b]	7.82±1.04[a]	6.94±1.42[b]
Aroma	6.92±1.14[b]	8.00±0.86[a]	6.56±1.30[c]
Favor	6.80±1.03[b]	8.00±0.86[a]	6.44±1.63[c]
Taste	6.78±1.00[b]	8.22±0.68[a]	6.26±1.01[c]
Texture (Crispness)	6.76±1.12[b]	8.18±0.75[a]	6.30±1.25[c]
Overall liking	6.80±1.07[b]	8.34±0.74[a]	6.34±0.87[c]

Note: Different horizontal characters mean values that are statistically different ($p \leq 0.05$).

Based on the evaluation of sensory quality presented in Table 6, it was observed that, the testers rated Formula 2 higher compared to Formulas 1 and 3 in all aspects. The testers' preferences for appearance, color, aroma, flavor, taste, texture (crispness), and overall liking were found to be significantly different ($p \leq 0.05$). Consequently, Formula 2 was selected for further study and development. The variation among the three basic formulas lies in their ingredients used during production. The panelists expressed a greater preference for the second formula, as it achieved higher average scores for appearance, color, aroma, flavor, taste, texture (crispness), and overall liking. These scores significantly differed from those of Formulas 1 and 3 ($p \leq 0.05$). Formulas 1 and 3 were found to have a dense and non-crisp texture due to the inclusion of tapioca starch. Tapioca starch is more suitable for sticky foods and does not promote a crispy texture when used for frying (Manao, B.E. 2560). Additionally, Formula 3 exhibited a fishy odor in the fish meat as it lacked spices that help eliminate this smell. Hence, Formula 2 was deemed suitable for further research and development.

3. The results of the study on determining the optimal amount of sucker mouth fish meat used in the production of crispy fish baking sheets.

3.1 Analysis results of physical and sensory properties.

Table 7. The product properties of crispy fish made from sucker mouth fish were analyzed, considering 5 different levels of sucker mouth fish.

Quality	Amount of Tilapia : Amount of Sucker mouth fish				
	100 : 0	25 : 75	50 : 50	75 : 25	0 : 100
a_w ns	0.43±0.07b	0.38±0.03b	0.50±0.01a	0.39±0.00b	0.41±0.00b
Moisture	4.48±0.18a	4.02±0.23b	3.59±0.12c	3.38±0.24c	3.38±0.29c
Color Value					
Brightness (L*)	43.89±0.45bc	44.66±0.48ab	45.35±0.66a	38.83±0.38d	43.11±0.30c
Red (a*)	15.29±0.67ab	16.04±0.10a	15.59±0.65ab	15.00±0.20b	15.70±0.30ab
Yellow (b*) ns	19.69±0.73c	23.63±0.26a	21.18±0.22b	16.87±0.40d	18.96±0.48c
Texture(Crispness) ns	6.78±1.05	7.20±1.05	7.14±1.37	7.04±1.48	7.08±1.10

Note :

Different horizontal letters mean values that are statistically different ($p \leq 0.05$). The letters ns mean that the means are not significantly different ($p > 0.05$

Table 8. Product preference scores for crispy baked fish sheets made from sucker mouth fish, with different amounts of sucker mouth fish, at 5 levels.

Product Characteristics	Amount of Tilapia : Amount of Sucker mouth fish				
	100 : 0	**25 : 75**	**50 : 50**	**75 : 25**	**0 : 100**
Appearance	7.14±1.12ab	6.86±1.26bc	7.24±1.02a	6.80±1.31c	7.36±1.06a
Color	7.18±1.34a	6.72±1.32b	7.24±1.04a	6.76±1.45b	7.30±1.18a
Aroma	6.98±1.35a	6.68±1.38ab	6.82±1.30ab	6.50±1.40b	6.62±1.41ab
Favor ns	6.36±2.00	6.40±1.68	6.76±1.61	6.58±1.47	6.68±1.58
Taste	6.08±2.24b	6.34±1.81ab	6.80±1.59a	6.40±1.87ab	6.60±1.64ab
Texture (Crispness)	6.70±1.62ab	6.96±1.56a	7.20±1.38a	6.32±1.86b	7.08±1.35a
Overall liking	6.40±1.82b	6.50±1.61b	7.06±1.43a	6.48±1.66b	7.06±1.22a

Note :

Different horizontal letters mean values that are statistically different ($p \leq 0.05$). The letters [ns] mean that the means are not significantly different ($p > 0.05$).

From Tables 7 and 8, the evaluation of the physical and sensory quality of 5 formulas of crispy fish sheets made from sucker mouth fish revealed certain findings. In Table 4.5, the physical values including the percentage of tilapia to sucker mouth fish at levels of 100:0, 25:75, 50:50, 75:25, and 0:100 showed no significant differences in texture values ($p > 0.05$). However, the [aw] values, moisture values, and color values were found to be statistically significantly different ($p \leq 0.05$). Table 4.6 presented results for sensory characteristics such as appearance, color, aroma, taste, texture (crispness), and overall liking. The percentage of tilapia to sucker mouth fish at levels of 100:0, 25:75, 50:50, 75:25, and 0:100 displayed significant differences ($p \leq 0.05$), except for aroma and flavor, which were not significantly different ($p > 0.05$). The highest average sensory quality score was observed for the 50:50 ratio, followed by the 0:100 ratio. The percentages of tilapia to sucker mouth fish that yielded the best sensory quality scores were 50:50 and 0:100. Considering the overall results and the lack of significant differences ($p > 0.05$) in average sensory qualities, the researchers opted for selecting crispy fish sheets made from sucker mouth fish with a ratio of 0:100 in favor of studying and further development, as it allowed for greater exploration and understanding of the properties of sucker mouth fish.

Effect of change in quality of fish snacks from Sucker mouth fish during storage at room temperature. Packed in aluminum foil bags with desiccant, the quality of the products stored for 2 weeks was analyzed, the results are shown in Table 9.

Table 9. Product quality of crispy fish sheets from sucker mouth fish during storage at room temperature for 2 weeks.

Physical Quality	Storage Period (Week)		
	0	1	2
a_w [ns]	0.32±0.00	0.30±0.00	0.30±0.00
Moisture [ns]	2.06±0.11	2.02±0.37	2.00±0.21
Color Value			
Brightness (L*) [ns]	40.17±0.93	38.99±0.44	38.85±0.58
Red (a*)	13.90±0.17[c]	15.59±0.12[a]	14.84±0.47[b]
Yellow (b*)[ns]	17.40±0.83[b]	19.67±0.19[a]	18.05±0.47[b]
Texture (Crispness)	8.20±0.76[a]	8.17±0.81[a]	8.03±1.01[ab]

Note: Different horizontal letters mean values that are significantly different ($p \leq 0.05$). The letter [ns] means that there is no statistically significant difference ($p > 0.05$).

From Table 9, a study on the rancid smell of crispy fish sheets made from sucker mouth fish revealed that the change in raw value decreased and remained constant over a period of 1-2 weeks. This can be attributed to the effective packaging of the sheets in aluminum foil bags. The use of these bags prevents any moisture penetration from the external environment. Additionally, the inclusion of a desiccant in the packaging helps to maintain low humidity and oxygen levels. As a result, the moisture content in the crispy fish sheets from sucker mouth fish reaches a state of equilibrium, leading to a low aw value. This allows for long-term storage of the product while preserving its quality.

Changes in moisture content of crispy fish from sucker mouth fish.

Based on the study, it was found that the moisture content of the crispy fish sheets made from sucker mouth fish decreased. This decrease in moisture content is attributed to the desiccant effect, which lowers the moisture content inside the container. Consequently, the atmosphere within the container is adjusted to facilitate the slow dehydration of the crispy fish sheets made from smoked fish (Natta, B.E. 2547).

Changing the color value. It was found that the L*, a* and b* values were quite constant. Because aluminum foil bags are effective in blocking light, which can trigger the browning reaction, the browning reaction without the presence of enzymes occurs at a slower rate. This reaction is most efficient within the range of a_w 0.65-0.85 (Phairot, 1996). The a_w value of crispy fish crisps obtained from sucker mouth fish is lower than 0.65, indicating that the browning reaction without enzymes occurs slowly. As a result, the color values change gradually over time. In terms of texture measurement, it was observed that the Crispness value did not show significant variations. This is attributed to the fact that the crispy fish crisps are packed in aluminum foil bags, which prevent moisture penetration from the external environment. Additionally, packing the product with a desiccant helps to maintain its crispiness.

From the study on the rancid smell of crispy fish products from sucker mouth fish at 0, 1, and 2 weeks, it was observed that this aspect significantly affected the sensory quality of crispy smoked fish snacks in terms of appearance, color, odor, taste, texture (crispness), and overall preference. To quantify the level of rancidity in the product throughout its shelf life, a sensory test was conducted.

Table 10. Liking scores of crispy fish sheets from sucker mouth fish at weeks 0, 1, and 2.

Product Features	**Storage Period (Week)**		
	0	**1**	**2**
Appearance ^{ns}	7.85±1.00	7.55±0.69	7.45±0.75
Color	7.95±0.69^{a}	7.55±0.61^{ab}	7.20±0.95^{ab}
Aroma ^{ns}	7.75±0.68	7.69±0.54	7.61±0.44
Favor	8.20±0.67^{a}	8.04±0.61^{a}	7.81±0.50^{ab}
Taste ^{ns}	8.10±0.65	8.03±0.58	7.91±0.54
Texture (Crispness)	8.25±0.64^{a}	7.99±0.63^{a}	7.78±0.50^{b}
Overall preference ^{ns}	8.30±0.73	8.11±0.68	8.09±0.65

Note: Different horizontal letters mean values that are significantly different (p≤0.05). The letter ^{ns} means that there is no statistically significant difference (p>0.05).

From Table 10, the evaluation of the sensory quality of crispy fish sheets from sucker mouth fish revealed that there were no significant differences (p>0.05) in terms of appearance, smell, taste, and overall taste at weeks 0, 1, and 2 of the shelf life. The study also indicated that the aspect of rancidity did not impact the panelists' evaluation of the products at the 0-, 1-, and 2-week shelf life. However, there were statistically significant differences (p≤0.05) in factors such as color, smell, taste, and texture (crispness) due to shelf life at 0, 1, and 2 weeks. These changes occurred slowly. Nevertheless, the packaging of the crispy fish sheets in aluminum foil bags with desiccant maintained their crispiness by preventing moisture penetration from the outside.

The findings of this study have significant implications for the food industry and public health. Firstly, the development of a standard formula and process for baking sliced Sucker Mouth Fish and maintaining its quality at room temperature provides a new and innovative way to utilize this fish species that is readily available, high in protein, and easily cooked, which reduces production costs. Moreover, the crispy fish snack made from Sucker Mouth Fish is nutritious and high in protein, making it a potential healthier alternative to other snack options that are often high in sugar, fat, and low in protein.

The study also highlights the importance of sensory evaluation in product development, as testers unanimously preferred the 0:100 ratio when assessing palatability using various ratios (100:0, 25:75, 50:50, 75:25, and 0:100). This information can guide future product development and help ensure that products are more appealing to consumers.

Additionally, the physical qualities of the product were analyzed, including lightness (L*), red value (a*), and yellow value (b*), resulting in values of 43.11±0.3, 15.70±0.30, and 18.96±0.48, respectively. These values are important in ensuring the quality of the product and can guide future production processes.

Finally, the study's findings on the water activity (aw) and crispiness level, both of which were measured at 0.41±0.00 and 7.08±1.10, respectively, are important in terms of product safety and shelf life. The fact that the packaged foil bag with absorbent was kept at room temperature for 2 weeks and analyzed using sensory evaluation, with results showing no significant difference (p>0.05), suggests that the product has a reasonable shelf life and is safe for consumption. The findings of this study have important implications for the food industry and public health, providing a new and innovative way to utilize Sucker Mouth Fish and highlighting the importance of sensory evaluation in product development.

4. Conclusion

Analysis of the chemical composition of sucker mouth fish revealed a moisture content of 83.20±0.24%, protein content of 14.63±0.51%, fat content of 0.48±0.16%, coarse fiber content of 0.16±0.03%, ash content of 1.40±0.20%, and carbohydrate content of 0.11±0.02%. After the production process of crispy fish sheets, it was found that the formula using only fish meat and no flour received the highest liking score from the panelists. Testers rated this formula highest in all aspects, including appearance, color, smell, flavor, taste, texture (crispness), and overall preference. Research on the appropriate amount of sucker mouth fish used in the production of crispy fish products showed that sheets made solely from sucker mouth fish with a 0:100 ratio of tilapia to sucker mouth fish received the best sensory preference score. The percentage quantity of tilapia to sucker mouth fish at levels 50:50 and 0:100 did not show a significant difference ($p>0.05$) in terms of sensory quality. The study of rancid smell in crispy fish sheets made from sucker mouth fish showed that the product can be stored for a long time, as the rancidity of the products at the 0-, 1-, and 2-week shelf life had no effect on the testers. During the storage period from week 0 to week 2, the moisture content decreased, the value of free water (aw) decreased, and the color value slowly changed. The texture value was slightly reduced, but the product remained crispy.

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