

Optimization of Sea Urchin Roe Ice Popsicles Formulation Using Milkfish (*Chanos chanos*) Bone Gelatin as a Natural Stabilizer

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Abstract

The study aimed to optimize sea urchin (1.5%, 2.5%, and 3.5%) and milkfish bone gelatin (0.3%, 0.5%, and 0.7%) ice popsicles using a central composite design. Gelatin was extracted via hydrolysis, followed by soaking in a 1:3 (w/v) salt-vinegar solution as a pretreatment step. Evaluations included sensory acceptability (appearance, taste, texture, aroma, and overall acceptability) using a 9-point hedonic scale and physicochemical parameters (% overrun, TSS, melting rate, pH). The optimized formulation was further analyzed using descriptive tests, nutritional composition, and consumer preference testing. Response surface regression analysis revealed that ice popsicles scored from “like slightly” to “like very much” across attributes, with significant differences ($p < 0.05$) in all sensory and physicochemical parameters. The optimal formulation contained 3.5% sea urchin and 0.7% milkfish bone gelatin, with an overrun of 99.89%, TSS of 22.67%, pH of 7.33, and melting rate of 34.08%. Proximate analysis showed 7.85% moisture, 0.55% ash, 2.05% crude fat, 0.90% crude protein, and 24.65% carbohydrates, with the gelatin containing 13.27% crude protein. This formulation was preferred by 77% of panelists over a commercial product during consumer preference testing, indicating market potential. Descriptive analysis noted a color similar to “French vanilla,” a sweetness comparable to a 1:1 sugar-water blend, minimal fishy odor, and a texture comparable to commercial ice pops, highlighting the potential of milkfish bone gelatin to enhance the sensory and market acceptance of sea urchin ice popsicles. The study concludes that a formulation of 3.5% sea urchin roe and 0.7% milkfish bone gelatin is optimal for producing a high-quality, consumer-accepted ice popsicle, demonstrating the potential of marine by-products as valuable, sustainable food ingredients.

Keywords: Stabilizer, sea-urchin roe, milkfish bone, popsicles

Introduction

Food product innovation is crucial in addressing consumer demands for healthier, sustainable, and convenient options, driving advancements in ingredients, formulations, and processing techniques within the food industry (Saravanan et al., 2020). Milkfish (*Chanos chanos*), primarily cultivated in Southeast Asia, has been a dietary staple for centuries (Fernando et al., 2017). Milkfish, commonly known as bangus, is a fast-growing, herbivorous tropical fish widely cultivated in aquaculture and distinguished by its silvery body, forked tail, and numerous fine intermuscular bones. The Philippine Statistics Authority (PSA) recorded an 8.3% increase in milkfish production, totaling 184,926.7 metric tons in June 2021. Post-harvest processing often discards significant portions of fish, particularly the bones. Recent studies have shown that these bones are a viable source of gelatin extraction (Suarni et al., 2015).

Gelatin derived from milkfish bones exhibits properties similar to those of mammalian-derived gelatin and has potential applications in various food products (Purnama et al., 2016). With a viscosity of 5.39 cP, milkfish bone gelatin complies with the standard viscosity range of 0-7 cP when dissolved in water (Hutapea et al., 2020).

Ice popsicles are frozen desserts typically made from water, fruit juice, or dairy products, and are often flavored and sweetened. Advantages include their refreshing texture, ease of consumption, and flavor versatility, while disadvantages may include high sugar content and the potential for ice crystallization, which can affect texture. Quality standards focus on microbial safety, ingredient composition, texture, and sensory appeal, similar to those for ice cream but with stricter control of Swastawati et al., 2022). Ice popsicles differ from ice cream primarily in their lower fat content and overrun, and they do not require aging or churning.

Adding sea urchin roe to ice popsicles can serve multiple purposes beyond simply enhancing nutrition. Sea urchin roe is rich in protein, amino acids, and minerals, which can improve the nutritional profile of the popsicle. Additionally, the bioactive compounds and natural polysaccharides in sea urchin roe may improve texture, water-binding capacity, and mouthfeel, acting as a natural stabilizer (Ayudiarti et al., 2020; Kurniasari et al., 2023). Therefore, sea urchin roe contributes to both nutritional value and sensory quality, enhancing the flavor, creaminess, and overall acceptability of frozen desserts. In the study by Ayudiarti et al. (2020), the addition of 0.1% tuna gelatin resulted in a lower overrun of 30.63%, indicating a lesser expansion from the liquid to gas state. Thus, the study aims to optimize the combination of gelatin and sea urchin roe concentrations for ice popsicle development, enhancing their structure, texture, and taste. Specifically, it seeks to calculate the percent yield and crude protein of milkfish bone gelatin, and to determine the effects of different levels of milkfish bone gelatin and sea urchin roe on the sensory acceptability of ice popsicles, including their sensory attributes. Additionally, the study evaluates the physicochemical properties of sea urchin ice popsicles, determines the optimal levels of sea urchin roe and milkfish bone gelatin for production, and assesses the sensory profile and nutritional composition of the optimal formulation.

Materials and Methods

Source of Materials

The milkfish bones were obtained from local fisherfolk of Liatemco, Lianga, Surigao del Sur, who are involved in milkfish deboning. Sea urchin roe, approximately 2 years old, was obtained from a local source in Lianga, Surigao del Sur. Evaporated milk (Jersey, Philippines), condensed milk (Doreen, Malaysia), all-purpose cream (Angel, Philippines), white sugar, and distilled water were purchased from a local store in Lianga, Surigao del Sur. Acetic acid (Datu Puti, Philippines) and sodium chloride (rock salt, Philippines) were obtained from a local store in Lianga, Surigao del Sur.

Preparation of sea urchin roe

Sea urchin roe that had already been removed from its shell was purchased from the local gleaners of Lianga, Surigao del Sur. It was acquired the night before processing in Lianga, Surigao del Sur, to ensure its freshness. The roe was immersed in sufficient milk to remove the fishy odor, and then cooled (Sevier, 2017). Afterward, the milk was drained, and the roe was blended using a 400 W heavy-duty blender (Hanabishi, Philippines) until a smooth texture was obtained. The blended roe was then weighed using a 0.001g analytical balance (ATX84R, Shimadzu, Philippines) according to the distribution per treatment.

Preparation of milkfish bone gelatin

The extraction of gelatin from milkfish bones was conducted following the procedure outlined by Rahimah et al. (2020). First, the fishbone was boiled in distilled water at 80 °C for 30 minutes on a gas range over low heat, to facilitate the separation of the bones from the remaining fish meat. After boiling, the fish bones were soaked in a 1:3 (salt: vinegar) solution at room temperature for 24 hours. The fishbones were then removed from the solution and washed three times with distilled water to eliminate the unpleasant odor. The extraction process was initiated by heating the fishbone in distilled water at a 1:3 (fish bone:water) ratio at 80 °C for 30 minutes. The resulting extract was filtered using a filter cloth to separate the residue from the filtrate. A 35-mL portion of the filtrate was placed in a Pyrex glass dish and dried in a kitchen oven (Fabriano gas range f5s40g2-bl, Philippines) at 180°C for 20 minutes to facilitate water removal. The resulting dried sheets of filtrate constituted the gelatin; which was scraped using a stainless-steel blade (Dorco, Philippines) and incorporated into the ice popsicles at varying levels. The crude protein content of milkfish bone gelatin was analyzed at the Central Laboratory Facility of Davao del Norte State College.

Experimental design

There were 10 treatments with three replicates for each experimental combination in the study, using a central composite design. There were three levels of sea urchin roe (1.5%, 2.5%, and 3.5%) and gelatin concentration (0.3%, 0.5%, and 0.7%) (Swastawati et. al., 2022). The treatment combinations are shown in Table 1.

Preparation of ice popsicles

Condensed milk (50 mL), evaporated milk (100 mL), all-purpose cream (100 mL), and white sugar (250g) were combined. Based on the treatment combinations, different levels of sea urchin roe (1.5%, 2.5%, 3.5%) and milkfish bone gelatin concentrations (0.3%, 0.5%, 0.7%) were added. The ingredients were mixed using a hand mixer (HE-133, Scarlett, Philippines) until a rich and homogeneous texture was achieved. The mixture was then placed in ice pop molds and allowed to settle for 20 minutes before being frozen at -18 °C for 12 hours in a single-door freezer (SJ-DL80AS-SS, Sharp, Philippines).

Yield of the gelatin

Gelatin yield was determined by calculating the ratio of the dry weight of gelatin to the fresh weight of milkfish bones. The powdered gelatin was weighed after drying, and its yield was calculated using the formula provided by Rahimah et al. (2020).

$$\text{Yield (\%)} = \frac{\text{weight of gelatin after oven drying}}{\text{weight of the milkfish bone}} \times 100\%$$

Table 1. Treatment Combinations of the Study

Treatments	Sea Urchin Roe (%)	Gelatin Concentration (%)
1	1.5	0.3
2	1.5	0.5
3	1.5	0.7
4	2.5	0.3
5	2.5	0.5
6	2.5	0.7
7	3.5	0.3
8	3.5	0.5
9	3.5	0.7
10	2.5	0.5

Overrun value of ice popsicles (Expansion of the Popsicle's Volume)

The overrun value was calculated as the difference between the weight of the ice popsicles and the weight of the dough in the same volume (Goff & Hartel, 2013). The following formula was used to compute it:

$$\text{overrun (\%)} = \frac{\text{weight of the dough} - \text{weight of the popsicles}}{\text{weight of the popsicles}} \times 100\%$$

Melting rate (AOAC, 2000)

The melting rate was determined to each replicate, with five ice popsicles placed on a plate after freezing. The popsicles were allowed to melt completely at 26 °C, and the melting time was recorded. Full melting was defined as the point at which the ice popsicle became sufficiently liquid to flow, and the unit of measurement for melting was expressed as minutes per 5 g.

Total soluble solids of ice popsicles (TSS) (AOAC, 2019)

Total soluble solids (TSS) were measured using a 0-32% Brix refractometer (ATC, China). The measurement was done by placing 1-2 drops of ice popsicle mixture onto the prism of the refractometer, and the reading was recorded and expressed as degrees Brix (°Brix).

pH

The pH of the ice popsicles was measured using a smart sensor pH meter (E4763, China). The pH electrode was immersed in 20 mL of melted ice popsicle sample, and the pH value was recorded upon stabilization of the reading.

Cost of production

The total cost of producing ice popsicles containing sea urchin roe and milkfish bone gelatin was calculated by summing the costs of all ingredients based on the quantity used for each treatment. This analysis provided an estimate into the financial investment required to produce the ice popsicles with unique ingredients compared with conventional ice popsicles (USDA, 2021).

Sensory acceptability

Acceptability testing was one of the response variables used to determine the optimal formulation of the ice popsicles. The different formulations were evaluated by 60 volunteer panelists (Malgor et al., 2020) who were inclined to eat seafood and ice cream. These panelists were provided with an orientation on the nature of the product and the evaluation procedure to minimize potential risks. Ice popsicles from different treatments were molded using an ice cube shaper with popsicle sticks labeled with three-digit codes, with approximate dimensions of 7/8 × 7/8 × 7/8 inches. Each treatment was removed from the refrigerator and placed in separate cups, then placed in an icebox filled with crushed ice to maintain the quality of the ice pops at approximately 4°C, and served to the panel only when they were ready. Each panelist was given six samples from different treatments to evaluate, along with water as the palate cleanser. Upon receiving the samples, the panelists immediately conducted the evaluation, taking into account the product's sensitivity to gradual melting and serving it in a sequential monadic manner. An Incomplete Block Design (IBD) with a seating plan of t=10, k=6, r=9, b=15, e=0.74, as described by Cochran and Cox (1975) was used. The seating plan was repeated four times to obtain 36 evaluations per treatment per replicate. A total of three batch productions were conducted to

obtain 108 evaluations per treatment. The panelists were asked to evaluate the product's acceptability in terms of appearance/color, taste, texture, aroma, and overall acceptability using the 9-point hedonic scale (Peryam et al., 1957; de Souza et al., 2021).

Optimization

The optimization of the ice popsicle formulation was conducted using a systematic approach. First, acceptability and physicochemical properties (overrun, melting rate, TSS, and pH) were analyzed using STATISTICA software. Response Surface Regression Analysis (RSReg) was employed to assess the effects of independent variables and their interactions using a mixture design. Graphical representations were generated to visualize the effects of these variables on the responses. The optimum formulation was identified by superimposing the graphs of sensory and physicochemical properties, with an acceptable cutoff values set to determine the optimal product region.

To validate the model, a verification test was conducted by rerunning the optimal formulation and evaluating it with 50 panelists (Meilgaard *et al.*, 2016; AMSA, 2016). A t-test was used to compare the predicted and actual values of the optimal product to confirm the accuracy of the model.

Trained panelists conducted product profiling to describe the sensory characteristics of the optimal ice pop sample. The panelists evaluated appearance, taste, texture, and odor. This profiling served as the basis for the subsequent Quantitative Descriptive Analysis (QDA). QDA is widely used to generate a detailed and objective description of product characteristics by trained panelists (Lawless and Heymann, 2010).

For the QDA, 10 trained panelists who had previously passed a basic taste threshold screening, evaluated the optimum formulation using a 15-inch unstructured line scale. The scale consisted of a straight horizontal line, typically labeled with opposing descriptors at each end (e.g., "low sweetness" to "high sweetness"). Panelists indicated the perceived intensity of each attribute by placing a mark along the line. The distance (in inches) from the origin is then measured and converted to numerical data, enabling the quantification of sensory perceptions.

The panelists assessed attributes such as color, sweetness, texture, and fishy odor. The collected measurements were subjected to statistical analysis to generate detailed sensory profiles, allowing comparison among samples and identification of key attributes influencing product acceptability.

Finally, a consumer preference test was conducted with 100 participants across age groups (children, teens, college students, and adults). The participants were provided with both the optimal formulation and a commercial ice popsicle for comparison, using a paired-preference test. The results helped confirm the consumer acceptability of the optimized product (Öcel and Durak, 2023; Isaskar et al., 2021).

Proximate analysis

The study assessed the nutritional composition of the optimum sea urchin ice popsicle formulation. Samples were sent to Davao del Norte State College for analysis. Proximate analysis was conducted to determine the following parameters:

Moisture content

The moisture content of the ice popsicle was determined using the oven-drying method. A known weight of the sample was placed in a pre-weighed dish and dried in a hot-air oven at 105 °C until a constant weight was obtained. The loss in weight represented the amount of water present in the sample (AOAC, 2000).

Ash content

Ash content was determined by incinerating the sample in a muffle furnace at 550 °C until all organic matter was completely burned off, leaving only inorganic mineral residues. The remaining ash was then cooled in a desiccator and weighed to calculate the total mineral content.

Crude fat

Crude fat content was determined using Soxhlet extraction (AOAC, 2000). The dried sample was placed in a thimble and extracted with petroleum ether for about 6 hours. The solvent was then evaporated, and the remaining residue was weighed to determine the crude fat content.

Crude protein

Crude protein content was determined using the Kjeldahl method. The sample was first digested with concentrated sulfuric acid in the presence of a catalyst to convert nitrogen into ammonium sulfate. The digest was then neutralized with sodium hydroxide, distilled, and titrated with a standard acid solution to measure the nitrogen content. The nitrogen value was multiplied by the factor 6.25 to obtain the crude protein percentage.

Carbohydrates

Carbohydrates were calculated by difference, subtracting the sum of moisture, ash, protein, and fat contents from 100.

Results

Gelatin Yield

Studies have reported varying gelatin yields from milkfish bones depending on the extraction conditions and the type of acid used during pretreatment. Dewi et al. (2019) obtained a gelatin yield of 9.74% using citric acid, whereas Meiliana et al. (2024) reported a lower yield when acetic acid was used. In contrast, hydrochloric acid pretreatment produced the highest reported yield of 26.7%, demonstrating the strong influence of the extracting agent on collagen solubilization and gelatin recovery. In the present study, the gelatin yield from milkfish bones was 2.97%, which is comparable to the average yield of 3.83% reported by Salahuddin et al. (2019).

The lower yield observed in this study compared with that reported by Meiliana et al. (2024) and other reports may be attributed to several methodological and material-related factors. Gelatin yield is influenced not only by the type and concentration of acid used but also by pretreatment duration, extraction temperature, extraction time, and the ratio of solvent to raw material. Variations in the age, size, mineral content, collagen composition, and freshness of the milkfish bones may likewise affect the amount of collagen that can be converted into gelatin. Furthermore, milder extraction conditions are often employed to preserve gelatin quality, although they may reduce extraction efficiency and yield. These differences in extraction protocols and raw material characteristics likely contributed to the lower gelatin yield obtained in the present study.

Sensory Properties

Table 2 shows the mean acceptability ratings for each treatment. Table 3 presents the parameter estimates for the different sensory attributes of the product. Indicating the relationships between the responses and the predictor variables.

Table 2. Mean Acceptability Score of the Sensory Attributes of Milkfish Bone Gelatin as Stabilizer to Ice Popsicles Made from Sea Urchin

Trt	% of Sea Urchin	% Fishbone Gelatin	Appearance	Taste	Texture	Aroma	Overall Acceptability
1	1.5	0.3	7.26±0.10	7.2±0.11	6.76±0.10	7.23±0.11	7.11±0.10
2	1.5	0.5	8.01±0.10	7.75±0.11	7.29±0.10	7.56±0.11	7.76±0.10
3	1.5	0.7	8.38±0.10	8.08±0.11	8.22±0.10	7.68±0.11	8.05±0.10
4	2.5	0.3	7.93±0.10	7.64±0.11	6.4±0.10	6.99±0.11	7.76±0.10
5	2.5	0.5	8.03±0.10	7.85±0.11	7.56±0.10	7.57±0.11	7.98±0.10
6	2.5	0.7	8.09±0.10	8.04±0.11	8.38±0.10	7.82±0.11	8.20±0.10
7	3.5	0.3	7.5±0.10	7.7±0.11	7.43±0.10	7.81±0.11	7.77±0.10
8	3.5	0.5	7.72±0.10	7.77±0.11	7.69±0.10	7.83±0.11	7.79±0.10
9	3.5	0.7	7.85±0.10	8.15±0.11	8.18±0.10	7.99±0.11	8.14±0.10
10	2.5	0.5	7.9±0.10	7.85±0.11	7.41±0.10	7.44±0.11	7.88±0.10

Table 3. Summary of Parameter Estimates for the Response of Sensory Acceptability of all the Sensory Attributes of Ice Popsicles

Parameter	Appearance	Taste	Texture	Aroma	General Acceptability
% sea urchin	1.35012*	0.721318 ^{ns}	-0.122853 ^{ns}	-0.80245*	1.445251*
% sea urchin^2	-0.19310*	-0.070421 ^{ns}	0.147642*	0.23179*	-0.192887*
% fishbone	5.00679*	2.588072 ^{ns}	4.462897*	3.41058 ^{ns}	2.831948 ^{ns}
% fishbone^2	-1.23943 ^{ns}	0.207067 ^{ns}	1.260483 ^{ns}	-1.38126 ^{ns}	0.386151 ^{ns}
% sea urchin*% fishbone	-0.96065*	-0.543981*	-0.891204*	-0.32407 ^{ns}	-0.703138*

Footnote: *: significant; ns: not significant

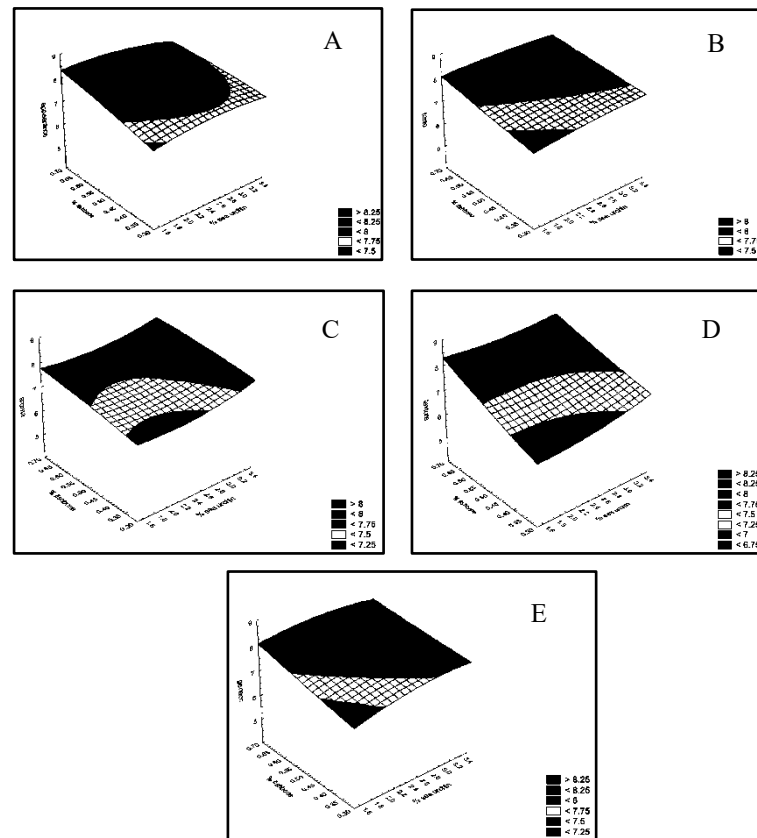


Figure 1. Response surface plot for the sensory attributes (A) Appearance; (B) Taste; (C) Texture; (D) Odor; (E) General Acceptability of the ice popsicles with different levels of sea urchin roe and fishbone gelatin

Figure 1 presents the response surface plots showing the combined effects of sea urchin roe and fishbone gelatin levels on the sensory attributes of ice popsicles, including appearance, taste, texture, odor, and overall acceptability. In general, the plots illustrate how variations in these two ingredients influence sensory responses, indicating the presence of optimal formulation regions where acceptability is maximized.

Appearance (color)

Color acceptability scores for the optimized ice popsicles ranged from 7.26 to 8.38, indicating a preference ranging from "like moderately" to "like very much" on the 9-point hedonic scale. A French vanilla color was attributed to the sea urchin ice popsicles based on the QDA test. This finding is consistent with the findings of Swastawati et al. (2022), who reported that a 0.7% gelatin concentration was favored. Figure 1A shows that higher levels of fish bone gelatin significantly improved color acceptability. Additionally, although increasing sea urchin roe concentration enhanced color appeal, its positive effect diminished beyond 2.5%. Parameter estimates (Table 3) indicate a significant positive linear effect and a negative quadratic effect, suggesting that higher sea urchin roe levels contributed to better color ratings.

Taste

The taste profiles of the various treatments ranged from "moderately sweet" to "very sweet," with corresponding acceptability scores ranging from 7.2 to 8.15, reflecting ratings ranging from "like moderately" to "like very much" on the 9-point hedonic scale. Parameter estimates presented in Table 3 demonstrate that there was no significant difference for either the linear or quadratic terms, but a significant difference for the cross-product term for sea urchin roe and milkfish bone gelatin. This indicates that the combination of sea urchin roe and milkfish bone powder significantly affects the taste acceptability of the ice popsicles, as visually represented in Figure 1B. The figure shows that with lower levels of sea urchin roe and milkfish bone gelatin, taste acceptability also tended to be lower. A study by Ayudiarti et al (2020) on the addition of gelatin to ice cream, however, found no significant effect on taste. Panelists reported that the inclusion of tuna-derived gelatin was undetectable, likely masked by the sweetness of sugar and the savory taste of milk. A study of Portuguese consumers revealed that while many were willing to taste sea urchin roe in restaurants, only about half would consider purchasing it in supermarkets, indicating mixed acceptance depending on the setting (Lourenço et al., 2021).

Texture

The average ratings for texture acceptability of the product ranged from 6.40 to 8.38 on the 9-point hedonic scale, indicating varying levels of preference from "like slightly" to "like very much" (Table 2). This trend is depicted in the response surface plot in Figure 1C. Similar to taste, acceptability was lower when low levels of both sea urchin roe and fish bone gelatin are used, whereas higher gelatin levels resulted in high acceptability regardless of the sea urchin roe level. This may be attributed to high gelatin levels result in a softer ice cream-like texture (Swastawati et al. 2022).

Aroma

The average aroma acceptability score for the ice popsicles was 7.59, indicating a moderate preference on the 9-point hedonic scale (Table 2). Treatment 9 received the highest score of 7.99. The parameter estimates in Table 3 showed that sea urchin roe significantly influenced aroma acceptability, with a negative linear correlation, while milkfish bone had no significant effect. Figure 1D illustrates that higher levels of sea urchin roe increased aroma acceptability. Kurniasari et al. (2023) found that the addition of fish bone gelatin did not significantly affect ice cream aroma. Lee et al. (2022) reported that the aroma of sea urchin in food products received mixed consumer responses, with some individuals appreciating its distinct marine scent, while others found it less acceptable.

General acceptability

Panelists rated the ice popsicles between "like moderately" and "like very much," with mean scores ranging from 7.11 to 8.14 on a 9-point hedonic scale. Sea urchin roe significantly influenced acceptability in both the linear and quadratic terms, likely due to its contribution to flavor, umami compounds, and overall sensory appeal, which may enhance consumer preference in food products (Sara Spinelli et al., 2024). In contrast, milkfish bone gelatin had no significant effect on overall acceptability, possibly because gelatin primarily functions as a textural stabilizer rather than a flavor contributor. At low concentrations, its impact on sensory perception is often minimal and may not be readily detected by consumers (H. Douglas Goff and Richard W. Hartel, 2013; H. T. Lawless and Heymann, 2010).

The response surface plot further shows that higher levels of sea urchin roe and gelatin are associated with greater acceptability, indicating that sea urchin roe plays a dominant role in enhancing the product's appeal. In contrast, gelatin contributes indirectly by improving texture stability.

Physico-chemical Properties

Table 4 shows the physicochemical properties of ice popsicles from different levels of sea urchin roe and milkfish bone gelatin. In contrast, Table 5 shows the parameter estimates of the relationships between the response and predictor variables.

Table 5 and Figure 2 illustrate the effects of sea urchin roe and milkfish bone gelatin on the physicochemical properties of the ice popsicles, including overrun, total soluble solids (TSS), melting rate, and pH. In general, the results indicate that variations in the levels of these ingredients influence the product's physical and chemical characteristics, with some parameters showing significant linear and quadratic effects. The response surface plots further illustrate the interaction between sea urchin roe and gelatin, highlighting optimal regions where desirable physicochemical properties are achieved.

Overrun

Overrun is the percentage increase in the volume of a frozen product resulting from the incorporation of air during freezing. In popsicles, higher overrun generally results in a lighter and less dense texture and less dense, while low overrun results in a harder, icier product with reduced smoothness and palatability. Treatment 9 recorded the highest overrun at 99.89%, associated with the highest levels of sea urchin roe and milkfish bone gelatin. This indicates that these ingredients effectively increase the weight of ice popsicles. In contrast, Treatment 1, with the lowest concentrations, showed the lowest overrun at 88.8%. Both sea urchin roe and gelatin levels significantly affected overrun, as indicated by the parameter estimates. Higher levels of these ingredients resulted in higher overrun values, consistent with findings that 0.7% gelatin optimally improves product quality. Figure 2A shows a better overrun with high levels of both sea urchin roe and fishbone gelatin. Similarly, Swastawati et al. (2022), a gelatin concentration of 0.7% is optimal for enhancing the quality of ice cream overrun. This outcome surpasses the overrun rates achieved by ice cream formulations incorporating konjac stabilizer (66.70%) and carrageenan (46.99%) sans emulsifier, as reported by Soad et al. (2014).

Total soluble solids

The total soluble solids (TSS) in ice popsicles ranged from 21.33 to 24.33, with relatively similar values. The parameter estimates in Table 5 indicate that milkfish bone gelatin has no significant effect on TSS, either linearly or quadratically, which agrees with the findings of Gómez-Estaca et al. (2007), who reported that gelatin mainly affects texture rather than soluble solids in gels. However,

sea urchin roe exhibited a significant quadratic effect. Moreover, the cross-product analysis reveals a significant interaction effect, indicating a significant association between sea urchin roe and milkfish bone gelatin concerning the soluble solids content of ice popsicles. The response surface plot in Figure 2B shows that as

both fishbone gelatin and sea urchin roe levels increase, soluble solids increase, supporting the interaction effects observed in combined ingredient systems (Rao and Rizvi, 2010). Conversely, reducing the levels of sea urchin roe and fishbone gelatin results in a decrease in soluble solids.

Table 4. Summary of Average Mean of the Physicochemical Properties of Ice Popsicles

Trt	% Sea Urchin	% Milkfish bone gelatin	Overrun (%)	TSS (% Brix)	Melting Rate (%)	pH
1	1.5	0.3	88.8	24.33	26.69	7.45
2	1.5	0.5	91.17	21.33	27.35	7.45
3	1.5	0.7	91.17	22	31.08	7.42
4	2.5	0.3	89.18	24	27.7	7.4
5	2.5	0.5	91.93	23.33	28.81	7.38
6	2.5	0.7	98.94	21.33	30.72	7.35
7	3.5	0.3	84.99	23.67	31.09	7.36
8	3.5	0.5	90.08	22.33	31.69	7.33
9	3.5	0.7	99.89	22.67	34.08	7.33
10	2.5	0.5	92.6	23.33	30.35	7.34

Table 5. Summary of Parameter Estimates Results for the Physicochemical Properties

	%overrun	TSS	Melting Rate	pH
% sea urchin	4.4595*	-0.13063 ^{ns}	0.09678 ^{ns}	-0.167857*
% sea urchin ²	-2.3314*	0.72524*	-0.39239*	0.023571*
% fishbone	-44.3303*	5.90794 ^{ns}	-2.30328 ^{ns}	-0.217063 ^{ns}
% fishbone ²	27.6726*	10.46429 ^{ns}	-6.41351 ^{ns}	0.130952 ^{ns}
% sea urchin*% fishbone	15.6708*	-2.80000*	1.53996*	0.000000 ^{ns}

*significant $p \leq 0.05$; ns not significant

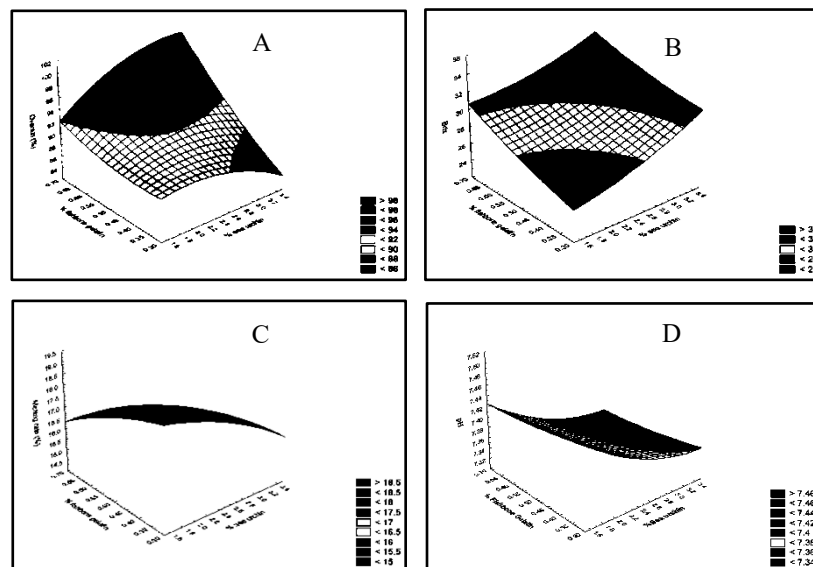


Figure 2. Response surface plot for the physicochemical parameters (A) overrun; (B) Total Soluble Solids; (C) Melting rate; (D) pH of the ice popsicles with different levels of sea urchin roe and fishbone gelatin

Melting rate

The melting rate of the ice popsicles was evaluated at 26 °C, with values ranging from 26.69% to 34.08%. Although gelatin is generally known to improve melting resistance by enhancing water-binding capacity and stabilizing the frozen matrix, as reported by Ayudyarti et al. (2020), the present study found that fishbone gelatin at levels between 0.30 and 0.70 did not exert a significant linear or quadratic effect on melting rate. This suggests that within the tested concentration range, gelatin alone was insufficient to markedly modify the structural stability of the product. However, its interaction with sea urchin roe levels significantly influenced melting behavior, indicating a combined functional effect within the formulation. As per the parameter estimates detailed in Table 5, a statistically significant negative quadratic effect of sea urchin roe is observed. This is visually represented in Figure 2C, indicating that increasing sea urchin levels beyond a certain point may result in a decreased melting rate. Conversely, there is no significant effect found in milkfish bone gelatin, whether linearly or quadratically.

pH

The pH of the ice popsicles ranged from 7.33 to 7.45, with higher sea urchin roe levels slightly decreasing pH, whereas milkfish bone gelatin showed no significant effect. This small pH reduction may enhance protein interactions, improve air entrapment and contribute to the highest overrun (99.89%) observed in treatments with elevated levels of sea urchin roe and gelatin. Similarly, increases in total soluble solids with higher ingredient levels likely supported better viscosity and foam stability. Although milkfish bone gelatin alone did not significantly affect the melting rate, its interaction with sea urchin reduced the melting rate at higher concentrations, suggesting that pH-mediated protein interactions and increased solids collectively stabilize the frozen matrix. Figure 2D shows that a higher level of sea urchin roe and milkfish bone gelatin leads to a decreased pH level.

Production cost

The cost of preparing 500 g of ice popsicles ranged from Php76.26 to Php106.26. These costs fall within a moderate range, attributable to the use of by-products derived from milkfish without the inclusion of commercial stabilizers or binders such as cornstarch and eggs. Commercial stabilizers and binders are generally more expensive than fish-derived gelatin because they are industrially processed, require additional manufacturing steps, and are sourced from higher-cost raw materials (Rao & Rizvi, 2010). Eggs, similarly, contribute to higher costs due to market price fluctuations and their nutritional

value. Cornstarch increases costs because it undergoes extensive processing and purification to achieve the desired thickening and textural properties.

Notably, the cost increases with higher amounts of sea urchin roe and milkfish bone gelatin. This increase is due to the greater need for fishbone gelatin, which requires labor-intensive processing and electricity for extraction. Optimizing gelatin extraction from fish bones can involve treatments such as enzymatic hydrolysis or acid/base soaking, but poorly scaled-up processes can reduce production efficiency. In contrast, sea urchin roe is a naturally rich ingredient and is generally less costly per unit than industrial stabilizers. Therefore, using marine by-products such as milkfish bones and sea urchin roe can reduce reliance on commercial additives while still achieving desirable texture and soluble solids in ice popsicles.

Blue Food, a seafood supplier, reports that sourcing fish by-products locally can lower costs compared to purchasing processed stabilizers, supporting the feasibility of this approach for small-scale ice pop production.

Determination of optimum region

The shaded area in Figure 3 highlights the optimum formulation of 3.5% sea urchin roe and 0.7% milkfish bone gelatin. This shaded portion extends to the edge of the graph, suggesting that increasing the amounts of sea urchin and milkfish bone gelatin could still be accepted and enhance the food appeal. To determine the optimum formulation, an acceptability score of >7.5 was set, corresponding to an overrun of 99.66% and a melting rate of 14.76%. Moreover, higher total soluble solids (Brix> 30) were help ensure the desired quality and consumer acceptability.

Verification

The optimum formulation (3.5% sea urchin roe and 0.7% milkfish bone gelatin) was validated by reproducing the formulation and conducting sensory evaluations. The actual values were significantly higher than predicted (Table 6), indicating higher acceptability than expected based on the model (Halagarda & Suwafa, 2018). Table 7 presents the number of panelists who preferred the commercial formulation over the optimum formulation.

Consumer preference test

The optimized ice popsicle was preferred over a commercial brand across all age groups, as shown in the Chi-square test (Table 7). Significant differences in preference were observed across age groups 6-12, 13-19, and 36-45, with participants favoring the optimized formulation for its smooth texture and balanced flavor.

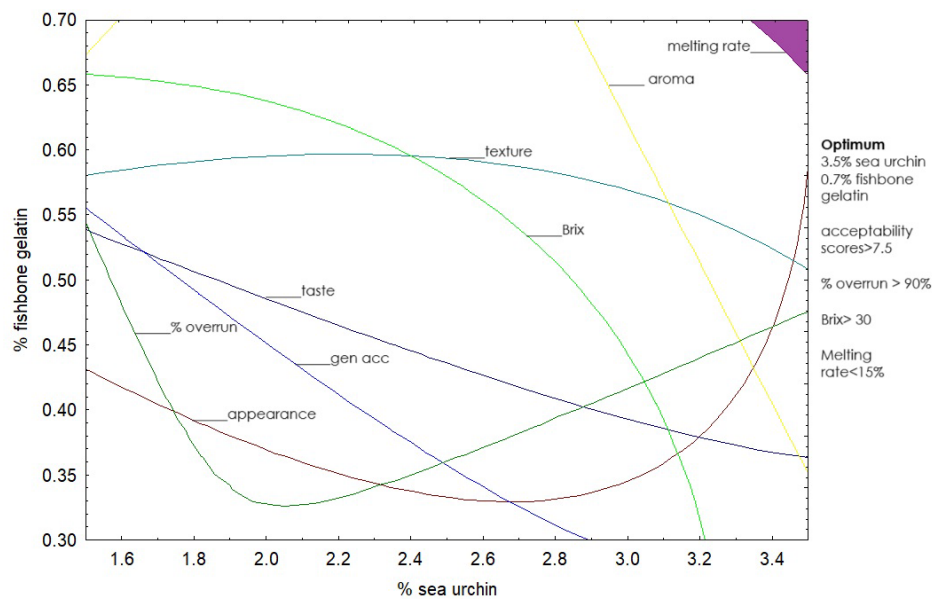


Figure 3. Superimposed plot for the acceptability of ice popsicles with different levels of sea urchin and fish bone gelatin with an acceptability value of >7.75, %overrun of >90%, brix of >30, and melting rate of <15%

Table 6. Summary of the T-test Between the Actual and Predicted Value

Attributes	Predicted	Actual values	t-value
Appearance	7.756	8.360000.605124*	12.225
Taste	8.055	8.293333.608074*	4.809
Texture	8.300	8.300000±0.527753ns	0.002
Aroma	8.037	8.173333.642423*	2.594
General acceptability	8.054	8.373333±0.550127*	7.110

Table 7. Summary of Chi-square Test on Consumer Preference Between the Optimum Ice Popsicle Formulation Versus a Commercial Brand

Age	Commercial	Optimum Formulation	Chi-value
6 to 12	8	17	3.24*
13 to 19	9	16	1.96 ^{ns}
20 to 35	6	19	6.76*
36 to 45	0	25	25*
TOTAL	23	77	29.16*

The results highlight strong consumer interest and market potential. Desire for this product. These findings underscore the favorable market potential of the optimized ice popsicle formulation, driven by its sensory attributes and consumer appeal, thereby warranting further exploration and potential commercialization.

Quantitative Descriptive Analysis

The spider diagram revealed key sensory attributes of the optimized ice popsicle. Minimal fishy odor (score

3.06), a "French vanilla" color (score 8.5), sweetness comparable to that of a 1:1 sugar–water solution (score 11.8), and a texture comparable to Aice brand ice popsicles (commercial) (score 11.01) were observed, emphasizing its appealing sensory profile.

Proximate analysis

The optimized formulation of the ice popsicles revealed the following nutrient composition: 71.85% moisture, 0.55% ash, 2.05% crude fat, 0.90% crude

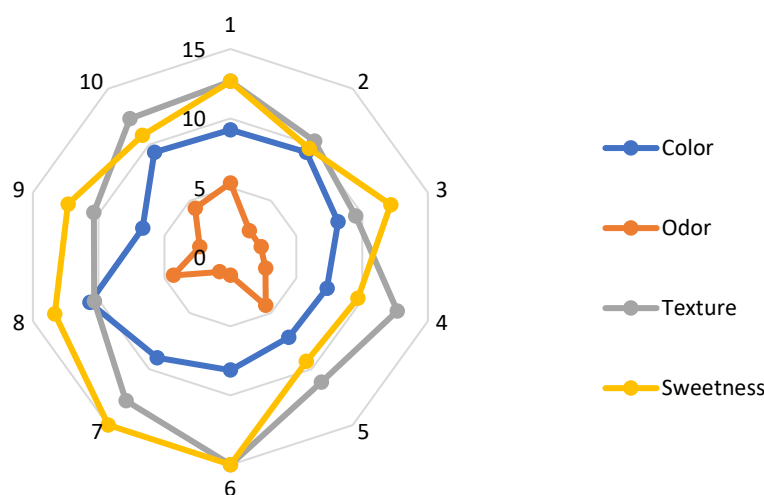


Figure 4. Spider graphic representative of the quantitative descriptive analysis of optimized ice popsicles

protein, and 24.65% carbohydrates, based on a 3 g sample. This composition is consistent with the findings of by Gindi et al. (2022), who reported that the addition of *Bacteria angulata* peel to ice cream resulted in lower protein and moisture contents, but higher fat, ash, and carbohydrate content. The use of sea urchins and milkfish bone gelatin as stabilizers in the ice popsicles demonstrates a competitive nutrient profile. While the gelatin extracted from milkfish bones has a crude protein content of 13.27%, the relatively low protein content in the ice popsicles may be due to the relatively small proportion of gelatin incorporated into the formulation. Haetam et al. (2006) emphasized that proper soaking time and concentration are crucial to prevent collagen loss, which can reduce yield.

Conclusions

Milkfish bones yielded 2.97% gelatin and 13.27% crude protein, highlighting their potential as stabilizers in ice popsicles. Sea urchin roe and milkfish bone gelatin significantly affected sensory acceptability, with 9-point hedonic scores ranging from 6.4 to 8.38 across appearance, taste, texture, aroma, and overall liking. These ingredients also influenced physicochemical properties: overrun (88.88–99.89%), pH (7.33–7.45), total soluble solids (21.33–24.33%), and melting rate (26.69–34.08%). Treatment 9 (3.5% sea urchin roe, 0.7% gelatin) was optimal, achieving the highest sensory scores (99.89% overrun, 22.67% TSS, 34.08% melting rate, and pH 7.33), and was preferred by 77% of consumers. Descriptive profiling indicated "French Vanilla" color, sweetness equivalent to a 1:1 sugar–water mixture, texture similar to commercial ice pops, and aroma like a 1:5 sea urchin solution. Proximate composition was 71.85% moisture, 0.55% ash, 2.05% fat, 0.90% protein, and 24.65% carbohydrates.

In summary, this study demonstrates the feasibility of using milkfish bone waste as a source of gelatin and sea urchin roe as a functional ingredient in the development of an acceptable, acceptable ice popsicle product. The findings highlight the potential to transform underutilized fish-processing by-products and marine resources into a value-added food product with desirable sensory and physicochemical qualities. This approach supports sustainable resource use, promotes waste valorization in the fisheries sector, and offers an innovative product that aligns with growing consumer demand for sustainable, functional foods.

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References

- American Meat Science Association. (2016). *Research guidelines for cookery, sensory evaluation, and instrumental tenderness measurements of meat (2nd ed., version 1.0)*. Champaign, IL: Author. Retrieved from <https://meatscience.org/docs/default-source/publications-resources/research-guide/amsa-research-guidelines-for-cookery-and-evaluation-1-02.pdf>
- AOAC. (2020). *Official methods of analysis of AOAC International (21st ed.)*. Gaithersburg, MD: AOAC International.
- Ayudarti, D. L., Suryanti, & Oktavia, D. A. (2020). The effect of different types and gelatin concentrations on ice cream quality. *E3S Web of Conferences*, 147, 03026. Retrieved from https://www.e3s-conferences.org/articles/e3sconf/pdf/2020/07/e3sconf_ismfr20_03026.pdf

- Balian, G., & Bowes, J. H. (1977). The structure and properties of collagen. In A. G. Ward & A. Courts (Eds.), *The science and technology of gelatin* (pp. 1–27). London, UK: Academic Press.
- Cochran, W. G., & Cox, G. M. (1957). Experimental designs (2nd ed.). New York, NY: John Wiley & Sons.
- de Souza, V. R., Pereira, P. A. P., Pinheiro, A. C. M., Bolini, H. M. A., & Nunes, C. A. (2021). Analysis of various sensory evaluation methods. *Food Research International*, 150, 110761. <https://doi.org/10.1016/j.foodres.2021.110761>
- Ellen MacArthur Foundation. (2013). *Towards the circular economy*. Retrieved from <https://www.aquafil.com/assets/uploads/ellen-macarthur-foundation.pdf>
- Fernando, H. N., et al. (2017). Milkfish aquaculture in Southeast Asia: Progress and prospects. *Aquaculture Research*, 48(2), 312–324. Retrieved from <https://repository.seafdec.org/ph/handle/10862/155>
- FlavorSum. (n.d.). *Sensory analysis guidelines for food and beverage*. Retrieved from <https://flavorsum.com/sensory-analysis-guidelines-food-and-beverage/>
- Gindi, S., Ling, I., An, W., Chua, S., & Lun, P. (2022). Proximate analysis of ice cream incorporated with *Baccaurea angulata* peel. *Borneo Journal of Science and Technology*, 4(1), 6–8. <https://doi.org/10.3570/bjost.2022.4.1-02>
- Goff, H. D., & Hartel, R. W. (2013). *Ice cream* (7th ed.). New York, NY: Springer.
- Gómez-Estaca, J., Montero, P., Fernández-Martín, F., & Gómez-Guillén, M. C. (2007). Physico-chemical and film-forming properties of bovine-hide and tuna-skin gelatin: A comparative study. *Journal of Food Engineering*, 80(3), 697–705. <https://doi.org/10.1016/j.jfoodeng.2006.06.018>
- Haetami, J. K., & Maulina, I. (2006). Gelatin production of fish bones for capsule shells. *Fishery*.
- Halagarda, M., & Suwała, G. (n.d.). Sensory optimisation in new food product development: A case study of Polish apple juice. *Italian Journal of Food Science*.
- Hutapea, T. P. H., Mulyadi, R., Madurani, K. A., Suprpto, M., & Kumiawan, F. (2020). *Chemistry and physicochemical characterization of milkfish (Chanos chanos) gelatin*. <https://doi.org/10.1051/e3>
- Isaskar, P., Patil, S., & Kulkarni, S. (2021). Consumer preference testing of novel ice cream formulations using paired-comparison method. *International Journal of Dairy Technology*, 74(3), 458–467. <https://doi.org/10.1111/1471-0307.12752>
- Kurniasari, R., Sabrina, S., Salma, A. N., & Syahbanu, F. (2023). Effect of fish gelatin on the characteristics of horn plantain banana (*Musa paradisiaca* fa. *corniculata*)-based ice cream. *International Journal of Food Studies*, 12(1).
- Lawless, H. T., & Heymann, H. (1998). *Sensory evaluation of food: Principles and practices*. New York, NY: Chapman & Hall.
- Lawless, H. T., & Heymann, H. (2010). *Sensory evaluation of food: Principles and practices* (2nd ed.). New York, NY: Springer.
- Lee, S. Y., Kim, H. J., & Park, J. H. (2022). Consumer perception and sensory characteristics of sea urchin-based products. *Food Quality and Preference*, 98, 104512.
- Lourenço, S., Mendes, S., Raposo, A., Santos, P. M., Gomes, A. S., Ganhão, R., Costa, J. M., Gil, M. I., & Pombo, A. (2021). Motivation and preferences of Portuguese consumers towards sea urchin roe. *International Journal of Gastronomy and Food Science*, 24, 100312. <https://doi.org/10.1016/j.ijgfs.2021.100312>
- Malgor, M., Scilingo, A., & Sabbione, A. C. (2020). Amaranth lemon sorbet: Elaboration of a potential functional food. *Plant Foods for Human Nutrition*, 75(3), 1–9. <https://doi.org/10.1007/s11130-020-00838-0>
- Marshall, R. T., & Arbuckle, W. S. (2000). *Ice cream* (5th ed.). New York, NY: Chapman & Hall.
- Meilgaard, M., Civille, G. V., & Carr, B. T. (2016). *Sensory evaluation techniques* (5th ed.). Boca Raton, FL: CRC Press. <https://doi.org/10.1201/b19493>
- Öcel, A., & Durak, M. (2023). Sensory evaluation and consumer acceptance of frozen desserts: A comparative study. *Journal of Food Science and Technology*, 60(2), 789–798. <https://doi.org/10.1007/s13197-022-05678-3>
- Peryam, D. R., & Pilgrim, F. J. (1957). Hedonic scale method of measuring food preferences. *Food Technology*, 11(9), 9–14.
- Purnama, K., et al. (2016). Potential milkfish industry waste: Extraction and characterization of gelatin from its bone. *Food Hydrocolloids*, 61, 212–218. Retrieved from <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7142178/>
- Rahimah, S., Fadhillah, A., Lembong, E., Sukril, N., & Cahyanto, T. (2020). *Characteristics of Spanish mackerel (Scomberomorus commerson) bone gelatin for ice cream stabilizer*. Retrieved from <http://journal.uinsgd.ac.id/index.php/ijhar/article/view/7820>
- Rao, M. A., & Rizvi, S. S. H. (2010). *Engineering properties of foods* (4th ed.). Boca Raton, FL: CRC Press.
- Saravanan, D., Gajendran, S., & Parimelazhagan, T. (2020). Food product innovation: A review. *Journal of Food Science and Technology*, 57(3), 832–841. <https://doi.org/10.1007/s13197-019-04147-4>
- Sevier, B. (2017). What's in your mission statement? *Phi Delta Kappan*, 99(1), 47–48.
- Shalahuddin, F. A., Almekahdinah, S. S., & Nandiyanto, A. B. D. (2019). Preliminary economic study on the production of ZnO nanoparticles using a sol-gel synthesis method. *Jurnal Kimia Terapan Indonesia*.
- Smith, S. E. (1947). The sorption of water vapor by high polymers. *Journal of the American Chemical Society*, 69(3), 646–651. <https://doi.org/10.1021/ja01195a053>
- Spinelli, S., Masi, C., Dinnella, C., Zoboli, G. P., & Monteleone, E. (2024). Umami perception and its influence on food preference: A review. *Food Quality and Preference*, 110, 104897.
- Soad, H. T., Mehriz, A. M., & Hanafy, M. A. (2014). Quality characteristics of ice milk prepared with combined stabilizers and emulsifiers blends. *International Food Research Journal*, 21(4), 1609–1613.
- Stone, H., Sidel, J. L., Oliver, S., Woolsey, A., & Singleton, R. C. (1974). Sensory evaluation by quantitative descriptive analysis. *Food Technology*, 28(11), 24–34.
- Suarni, S., Hermanto, S., & Alamsyah, M. (2015). Characteristics of gelatin from milkfish bone based on different sizes. *International Journal of Food Science & Technology*, 50(11), 2408–2414.
- Swastawati, F., Ardie, B. R., Romadhon, Fahmi, A. S., & Purnamayati, L. (2022). *The potential of milkfish (Chanos chanos) gelatin as stabilizer in ice cream production*. Retrieved from <https://iopscience.iop.org/article/10.1088/1755-1315/1033/1/012062/pdf>
- U.S. Department of Agriculture, Food and Nutrition Service. (2021). *Thrifty Food Plan, 2021*. Retrieved from <https://www.fns.usda.gov/tnp/thrifty-food-plan-2021>