Journal of Applied and Natural Science
16(3), 928 - 937 (2024)
ISSN : 0974-9411 (Print), 2231-5209 (Online)
journals.ansfoundation.org

Research Article

Enhancing sensory attributes of dried boneless siganids (*Siganus canaliculatus)* with cryoprotectant marinades: Extension program guide

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Article Info
https://doi.org/10.31018/jans.v16i3.5648
Received: April 13, 2024
Revised: June 21, 2024
Accepted: July 01, 2024

How to Cite
Macabudbud, Jr., S. S. *et al.* (2024). Enhancing sensory attributes of dried boneless siganids (*Siganus canaliculatus)* with cryoprotectant marinades: Extension program guide. *Journal of Applied and Natural Science*, 16(3), 928 - 937. https://doi.org/10.31018/jans.v16i3.5648

Abstract
Drying is one of the important methods of preserving fish throughout the world. The study aimed to explore the sensory attributes of dried boneless siganids treated with cryoprotectant marinades developed across these formulations. This experimental study employed three distinct formulations, varying in the quantities of Carabao milk (CM), Carrageenan powder (CP), Calamansi extract, Salt, and Coconut water treatments. It sought to assess the general acceptability of these mixtures concerning color, flavor, odor, and texture, identify the most preferred formulation (F1, F2, and F3) based on a panel of tasters, and examine potential significant differences among the product attributes. Data analysis involved computing weighted means and conducting One-way analysis of variance (ANOVA). The findings indicated that F1, comprising 50g CM, 2.5g CP, 5g Calamansi extract, 10g salt, and 500g coconut water, was the most favored in terms of color, flavor, odor, and texture, with overall means of 3.94, 3.90, 4.18, and 3.98, respectively. Furthermore, the results revealed an insignificant relationship between the computed F values and the tabulated F value, leading to the rejection of the null hypothesis. The sensory acceptability rating of the most preferred formulation was deemed "acceptable" with a mean of 4.0. Based on these findings, 50g CM and 2.5g CP were adopted as guidelines for the Extension program “Mugna Kaluwasan”.

Keywords: Acceptability test, Cryoprotectant development, Innovative-guide, Sensory analysis

INTRODUCTION

Fresh fish quickly becomes brittle unless a method is employed to preserve it. Drying is a technique for food preservation that operates by removing moisture from the food, thus inhibiting the proliferation of bacteria (Siddhnath *et al.*, 2022). Throughout history, outdoor drying using sunlight and wind has been utilized to preserve dried fish (Onyango, 2021). According to Rifna *et al.* (2022), water is typically eliminated through evaporation, such as air drying, sun drying, smoking, or wind drying, while freeze-drying involves freezing the food first and then removing water through sublimation. Bacteria, yeasts, and molds require water in the food to thrive, and drying effectively prevents their survival in the food (Garg *et al.*, 2022). Recent research has shown that innovative drying techniques, such as microwave- or ultrasound-assisted drying, high electric field drying, heat pump drying and refracting window drying can now be utilized to enhance the efficiency and effectiveness of drying, thereby reducing energy consumption while preserving the quality of the final product (Anukiruthika *et al.*, 2021).

Drying stands as a pivotal method for preserving fish worldwide. Sun drying, a widely adopted low-cost approach, is significant in providing sustenance and income to impoverished coastal communities (PRODUCT, 2023). Fish drying, a longstanding tradition, has been recognized as an effective means of preserving fish that may not be immediately consumed

or sold fresh in the market (Svanberg and Locker, 2020). Dried salted fish represents one of the more prevalent and economical sources of high-quality protein in the Philippines. The consumption of dried fish is increasingly recognized for its role in delivering high-quality proteins; and essential fatty acids including eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), and a distinctive array of vital nutrients such as iodine, zinc, copper, selenium, and calcium (Siddhnath *et al.*, 2022). However, open sun drying is susceptible to microbial contamination, posing a significant concern for food safety, particularly for human consumption. To ensure the safety of food products, it is imperative to implement proper preservation techniques, maintain physico-chemical and microbiological stability, and adhere to appropriate cooking methods (Gallo et al., 2020).

Preserving fish involves maintaining their nutritional value and prolonging their shelf life through techniques such as curing, salting, smoking, and drying (Bindu, 2023). Various approaches exist to uphold fish quality and extend its shelf life. Cryopreservation, for instance, shields cells, tissues, organs, or whole bodies from decay by subjecting them to low temperatures. Given the high perishability of fish, a range of storage strategies is essential to enhance its shelf life, ensuring safety and quality from capture to consumption (Duarte *et al.*, 2020). As a source of nutrition, fish is susceptible to numerous biochemical reactions and is highly vulnerable to different types of microorganisms, which can cause degradation and spoilage over time (Garg *et al.*, 2022). With its high nutrient content, neutral pH, and elevated water activity, fresh fish deteriorates rapidly and immediately after being caught (Pradhan et al., 2020). In many regions worldwide, particularly in African countries lacking access to refrigeration or ice, the physical, chemical, and biological processes leading to the spoilage of freshly caught fish are of significant concern.

Cryoprotectants refer to chemical compounds primarily aimed at safeguarding cells or tissues from damage caused by freezing, particularly during the verification and thawing processes employed in cryopreservation (Wolkers and Oldenhof (2021)). Biological materials such as animal tissues, organs, lymphocytes, cartilage, bone marrow, and proteins can be preserved using appropriate cryoprotectants (Cao *et al.*, 2022). However, optimizing cryoprotectants is challenging, as excessive concentrations may lead to cytotoxicity (Warner *et al.*, 2021). Cryoprotectants are synthetic compounds designed to shield living organisms from damage caused by the freezing of water when exposed to cold temperatures (Fayter, 2020). Cryopreservation involves the preservation of biological materials, such as cells and tissues, by cooling them to low temperatures, typically around -196°C (the temperature of liquid nitrogen), while still maintaining viability upon subsequent warming to temperatures above 0°C (Fahy and Wowk; (2021). It is one of the significant *ex situ* strategies for protection of germplasm and has wide-going applications in aquaculture and fisheries the board (Gazsi *et al.*, 2021). To mitigate cryoinjuries during the cooling and thawing processes, various cryoprotective agents of penetrating and non-penetrating classes are utilized, with commonly used cryoprotective agents including DMSO and glycerol (Chang and Zhao, 2021).

In the province of Cebu, Philippines, Siganids are commonly preserved through various methods such as sun drying, salting whole, or fermenting into bagoong or “guinamos”, a delicacy condiment. Dried salted fish stands as one of the more prevalent yet affordable sources of high-quality protein in the Philippines. Additionally, the production of salted fish represents a predominant livelihood activity in coastal towns throughout the country. Gabriel and Budiao (2015) conducted a study aiming to characterize and compare the quality attributes of sun-dried and mechanically dried salted herrings to ascertain if such products adhere to established national standards and identify key quality parameters requiring attention and enhancement by processors. However, Staphylococcus aureus levels in one sun-dried sample exceeded the established limit by 0.7 log CFU/g, highlighting the need for adherence to good hygiene and manufacturing practices. Therefore, the preservation of dried siganids necessitates the utilization of cryoprotectants to enhance their quality.

Carabao milk as one of cryoprotectant ingredients has been the subject of numerous studies due to its rich content of vitamins, calcium, and high-quality proteins. Research has revealed its potential to reduce the risk of cardiovascular disease, lower bad cholesterol levels, promote strong bones and muscles, and aid in weight loss (medicalnewstoday.com, 2014; Zhang, 2020). Unlike non-dairy products that often contain additives and chemicals, carabao milk is entirely free from such additives. Carabao milk has been utilized to create pastilles and quesong puti in Central Luzon State University in Nueva Ecija. This milk is renowned for its thicker and creamier texture, attributed to its higher fat and protein content compared to cow's or goat's milk. Additionally, it is known to fortify teeth and bones, prevent osteoporosis, and serve as a complete food source, providing carbohydrates, proteins, fats, vitamins, and minerals, which aids in preventing colon cancer (Dairy Council of California, 2013).

The use of carrageenan powder as a cryoprotectant ingredient has been instrumental in enhancing the development of food product quality within the country. As noted by Udo *et al.* (2023), carrageenan, a polysaccharide derived from red algae, has a rich history as a food additive, initially serving as a stabilizer in ice creams and chocolate milk before expanding into a wide array

of products, including pudding, condensed milk, and toothpaste during the 1950s (Hotchkiss et al., 2016; Udo et al., 2023). Carrageenan has garnered significant attention across various applications with its distinct properties and versatile functionalities. Seaweed-derived polysaccharides such as alginate, agar, and carrageenan, known for their gelling abilities, have been extensively utilized for coatings as it shown promise in extending shelf life and preserving the quality parameters of food products throughout their shelf life (Jayakody *et al.*, 2022).

Coconut water is a revitalizing natural beverage, boasting low calorie and fat content while being abundant in minerals, vitamins, and beneficial phytohormones. Tender coconut water's nutritional and therapeutic merits have led to a surge in global consumption and demand for preservation and food processing (Naik *et al.*, 2022). However, preserving tender coconut water poses a significant challenge, as certain processing methods may compromise its nutritional and therapeutic properties. Moreover, coconut water serves as a versatile ingredient for the creation of various innovative value-added products, including tender coconut lassi, honey and coconut spreads derived from concentrated mature water, soufflés, yogurts, sugars, docosahexaenoic acid, probiotics, coconut water kefir, bacterial cellulose, carbon dots, and more (Rethinam and Krishnaku (2022). Furthermore, beyond coconut water itself, derived products such as coconut palm sugar (a value-added product), and various nutraceuticals play a crucial role in averting nutrient deficiencies and offering comprehensive nutrition to combat malnutrition and illness (Mat *et al.*, 2022).

Utilizing carabao milk, carrageenan powder, coconut water, and other organic substances such as calamansi extract and salt as cryoprotectant additives in fish drying for preservation purposes promotes product sustainability. In contrast, commercial processors often resort to applying various harmful insecticides (including nogos, nuvacorn, endrin, malathion, dichloro diphenyl trichloroethane, and basudin) to dried fish to ward off insect infestations and microbial contaminations during drying and storage, posing significant risks to human health (Hoque *et al.,* 2022) which is harmful to human health. However, incorporating these cryoprotectant additives helps maintain the fish's nutritional value, preserve its rich composition, and mitigate the costly and debilitating consequences of fish-borne illnesses (Kolanus, 2020). Furthermore, the utilization of coconut water in fish preservation aids in preventing microorganism invasion when employing mechanical drying methods. Consequently, developing organic cryoprotectant additives is crucial for boosting dried fish production, thereby contributing to poverty alleviation and hunger reduction through livelihood interventions. In line with this objective, the present study evaluates the sensory characteristics of cryoprotectant-based dried boneless siganids, offering an innovative guide for extension programs targeted at underserved fisher folk's communities.

MATERIALS AND METHODS

Research design

The research utilized descriptive-quantitative methods within an experimental framework, employing laboratory techniques and procedures to develop cryoprotectant-based dried boneless siganids using various formulations. Descriptive and inferential statistics were employed to analyze significant differences in respondent acceptance levels across the different cryoprotectant formulations. The product's sensory attributes were evaluated using a modified 5-point rating scale adapted from Likert (1932).

Formulation procedure

The 50g of chilled carabao milk and 10g of rock salt were accurately measured using a digital weighing scale. The 5g of calamansi extract was obtained by extracting juice from the fruit using a fruit extractor to separate the pulp. The 500g of coconut water were extracted from matured coconuts, with the flesh used for other product developments. The water was strained using a stainless steel sifter to remove impurities, then wrapped in plastic and frozen to make ice. The 2.5g of carrageenan powder was purchased from Shemberg Corporation- A processing plant in the nearby city located in Carmen, Cebu, Philippines and accurately weighed using a digital scale. These ingredients were thoroughly combined in a mixing bowl using a whisk and 500g of potable water.

One thousand g of fresh siganids were purchased from the fishing folks association at the town's fishing port. They were deboned by cutting into butterfly shapes with a knife to separate the flesh from the bones. The boneless siganids were then washed with running water, drained, and soaked in a cryoprotectant marinade with iced coconut water for 30 minutes before dehydration. The cryoprotectant-treated siganids were drained using a strainer, and arranged on a drying rack. They were dried at a temperature of 60˚C using a mechanical fish dryer for 2 hours. After removal from the dryer, they were allowed to cool for 30 minutes before packing.

Respondents

The participants of the study were chosen from the Faculty of Hospitality Management (HM) and the Technology and Livelihood Education (TLE) Departments. They were purposively selected from Cebu Technological University (CTU) Daanbantayan Campus, Philip-

pines. There were 50 respondents selected, 15 of whom were faculty members from the Hospitality Management and Technology and Livelihood Education programs and identified as experts through purposive sampling. Additionally, 35 respondents were selected from the staff members representing the consumer population, employing a simple random sampling method.

Methodology

The study employed a research-made questionnaire adapted from the iRubric method for sensory evaluation to identify the acceptability levels of three cryoprotectant formulations. Formulation 1 (F1) comprised 1000g of boneless siganids, 5g of calamansi extract, 10g of rock salt, 500g of potable water, 500g of iced coconut water, 50g of carabao's milk, and 2.5g of carrageenan powder. Formulation 2 (F2) varied slightly in the amounts of carabao's milk and carrageenan powder, containing 1000g of boneless siganids, 5g of calamansi extract, 10g of rock salt, 500g of potable water, 500g of iced coconut water, 75g of carabao's milk, and 5g of carrageenan powder. Similarly, Formulation 3 (F3) differed in carabao's milk and carrageenan powder quantities, comprising 1000g of boneless siganids, 5g of calamansi extract, 10g of rock salt, 500g of potable water, 500g of iced coconut water, 100g of carabao's milk, and 7.5g of carrageenan powder. Various proportions of carabao's milk and carrageenan powder were combined with consistent amounts of calamansi extract, rock salt, potable water, and iced coconut water to form a cryoprotectant marinade. Using a mechanical fish dryer, these mixtures were applied to boneless siganids before dehydration. Subsequently, sensory analysis and acceptability assessments were conducted, evaluating attributes such as color, flavor, odor, and texture. The evaluations were performed using both a five-point Likert Scale and the 9-point Hedonic Scale (Sharif *et al.,* 2017) to gather significant data regarding the preferred formulations of the cryoprotectant-based dried boneless siganids product from the two respondent groups.

Ethical approval

Approval was obtained from the Head of the Research and Development office to conduct the study, and ethical permission was obtained from the Campus Director.

Data procedure

Three formulations (F1 with 1000g of boneless siganids, 5g of calamansi extract, 10g of rock salt, 500g of potable water, 500g of iced coconut water, 50g of carabao's milk, and 2.5g of carrageenan powder, F2 with 1000g of boneless siganids, 5g of calamansi extract, 10g of rock salt, 500g of potable water, 500g of iced coconut water, 75g of carabao's milk, and 5g of carrageenan powder, and F3 with 1000g of boneless siganids, 5g of calamansi extract, 10g of rock salt, 500g of potable water, 500g of iced coconut water, 100g of carabao's milk, and 7.5g of carrageenan powder) were prepared in the food laboratory of Cebu Technological University Daanbantayan Campus, Cebu Philippines. The identified respondents were asked to evaluate the level of acceptability of the cryoprotectant formulations using the research-made questionnaires. The health protocols were used during the study to administer the evaluation process and retrieve questionnaires. The standardized 9-point Hedonic Scale method was used to identify the respondents' acceptability level (Sharif *et al.*, 2017). The evaluation results were collated and tallied using tables for effective analysis and interpretation of the data. A one-way analysis of variance was used to test significant differences in the respondents' level of acceptability regarding the different cryoprotectant-based dried boneless siganids formulations.

Data analysis

The collected data underwent systematic treatment and analysis employing both descriptive statistics and ANOVA analysis. To interpret the results of the descriptive tests regarding cryoprotectant-based dried boneless siganids, the researcher computed the weighted mean of the respondents' scores and categorized them based on predefined criteria ranges. Additionally, the sensory analysis data for the cryoprotectant-based dried boneless siganids, encompassing attributes such as color, odor, flavor, and texture, were analyzed using a 5-point Likert scale method and weighted mean. Furthermore, the sensory acceptability test data, evaluated using the 9-point Hedonic Scale, were also subjected to weighted mean analysis.

To test the null hypothesis and ascertain any significant differences among the three formulations, an Analysis of Variance (ANOVA) was conducted using SPSS. This method ensured reliable computation and interpretation of the results.

RESULTS AND DISCUSSION

Formulations of Cryoprotectant-based dried boneless siganids

An examination of three formulations of cryoprotectant-treated dried boneless siganids, utilizing varying quantities of carabao's milk and carrageenan powder, revealed that Formulation 1 (F1) emerged as the preferred choice among both consumers and food experts, which comprised 50g of carabao milk, 2.5g of carrageenan powder, 5g of calamansi extract, 10g of salt, 500g of potable water, and 500g of coconut water, as detailed in Table 1. Liu *et al.* (2023) suggest that cryoprotectants are effective additives for extending the shelf life and ensuring the acceptability of frozen aquatic

Table 1. Formulation of three recipes using different treatments of carabao's milk and carrageenan powder

Materials	Formulations of Cryoprotectant		
	F1	F2	F3
Carabao's milk	50g	75g	100g
Calamansi extract	5g	5g	5g
Salt	10g	10g	10g
Carrageenan	2.5g	5g	7.5g
Potable water	500g	500g	500g
Iced coconut water	500g	500g	500g

products. According to the review of Walayat *et al.* (2020) and Liu, Z., *et al.* (2023), cryoprotectants prevent protein denaturation due to ice crystal formation and lipid oxidation, thus maintaining product quality during frozen storage.

Marín-Peñalver *et al.* (2021) noted that carrageenans are widely utilized food ingredients known for their stabilizing, gelling, texturizing, and water-binding properties. This underscores the potential of incorporating carrageenan powder to develop cryoprotectant marinades for dried boneless siganids.

Assessment of Sensory Attributes

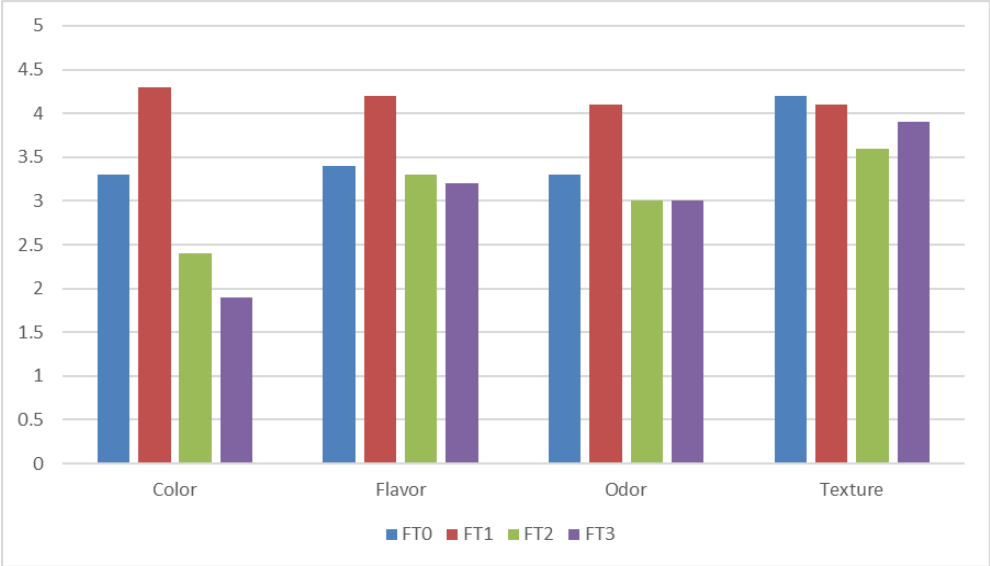
The freshly prepared boneless siganids (*Siganus canaliculatus*), treated with different concentrations of carabao's milk and carrageenan powder mixed with calamansi extract, salt and coconut water as cryoprotectant marinade, underwent sensory evaluation for attributes such as color, flavor, aroma, and texture, as detailed in Fig, 1.

Color

The results indicate that among the three formulations, Formulation 1 garnered favorable acceptance from consumers and food experts, with a weighted mean value of 3.94, described as golden brown. This implies that variations in the quantities of carabao milk, carrageenan powder, and other organic ingredients incorporated into cryoprotectant marinades do not significantly impact the color characteristics of the product.

Flavor

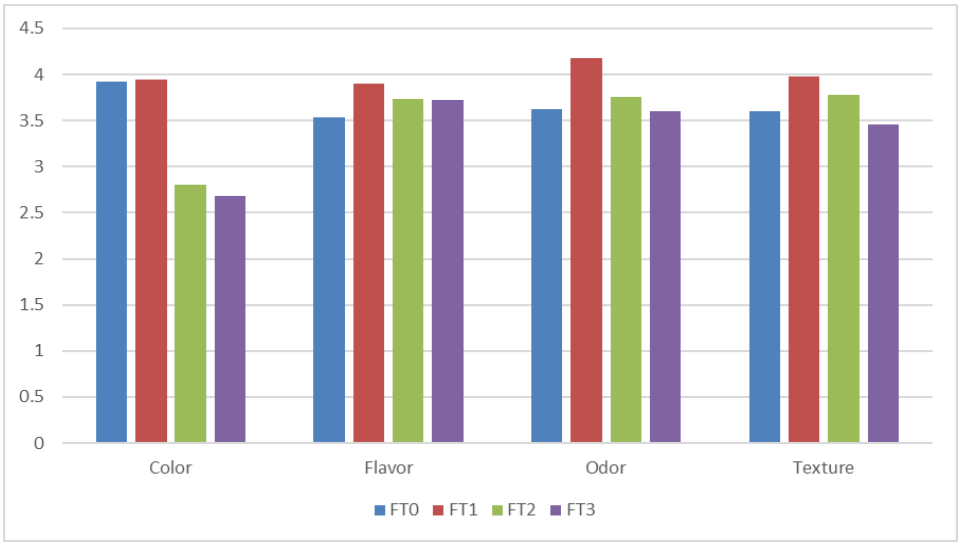
The descriptive rating evaluation conducted among the 50 identified respondents for flavor attributes yielded varying ratings for the three formulations: 3.90 for F1, 3.74 for F2, and 3.73 for F3. All formulations received verbal descriptions indicating a very pleasant odor. However, upon analyzing product attributes, Formulation 1 (F_1) emerged as the most preferred option in terms of flavor. This finding suggests that the inclusion of carabao milk and carrageenan enhances the flavor



Legend:

4.21 – 5.00	--	Liked Very Much (LVM)
3.41 – 4.20	--	Liked (L)
2.61 – 3.40	--	Neither Liked nor Disliked (NLnD)
1.81 – 2.60	--	Disliked (D)
1.00 – 1.80	--	Disliked Very Much (DVM)

Fig.1. *Sensory characteristics of cryoprotectant-based dried boneless siganids product per attribute*



Legend:

4.21 – 5.00	--	Very Much Acceptable (VMA)
3.41 – 4.20	--	Acceptable (A)
2.61 – 3.40	--	Undecided (Und)
1.81 – 2.60	--	Unacceptable (Una)
1.00 – 1.80	--	Very Much Unacceptable (VMU)

Fig. 2. *Sensory Acceptability of cryoprotectant treated dried boneless siganids*

of the dried boneless siganids. Consequently, carabao milk and carrageenan can be integrated into the preparation of boneless siganids before dehydration.

Odor

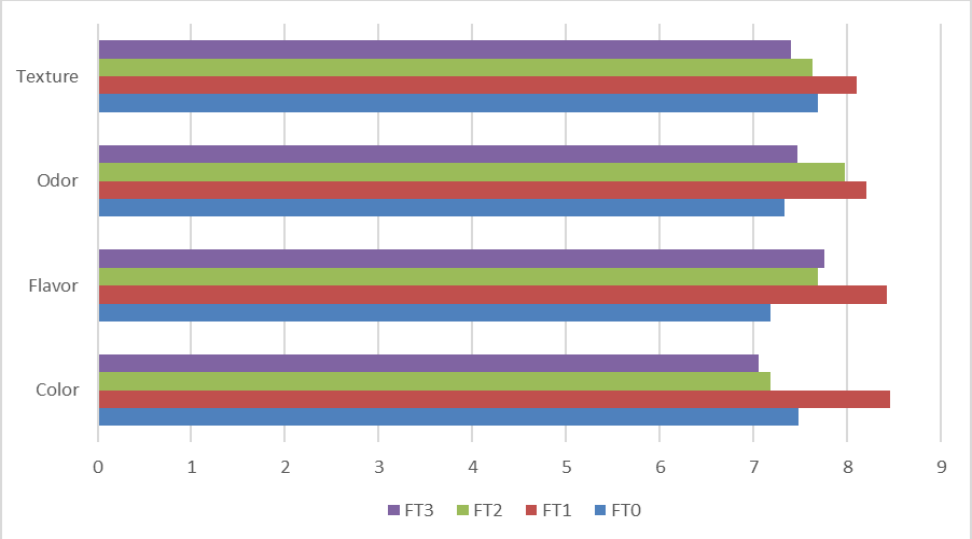
The evaluation revealed positive assessments for all formulations by consumers and food experts regarding the odor attribute. However, upon scrutinizing the product attributes, Formulation 1 (F_1) emerged as the most favored choice regarding odor, achieving an overall weighted mean of 4.18, signifying Liked responses from the participants. Retiaty and Nurjanah (2023) suggested that a solution consisting of 5% lime juice and Ca(OH)2 can effectively eliminate various fishy odor during drying processes. Furthermore, seaweed flour has shown promise as an ingredient for developing nutrient-rich products, particularly due to its iodine content. This finding suggests that integrating carabao milk and carrageenan into dried boneless siganids tends to elevate the level of acceptability, both numerically and nutritionally, concerning the odor of the final product.

Texture

The results signify that among the three formulations evaluated by the identified consumers and food experts, Formulation 1 (F_1) emerges as the preferred option regarding texture, attaining an overall weighted mean of 3.98 described as Very Crispy by the participants. According to Alemu (2023), the textural identity of any food is rarely a simple matter of understanding a singular attribute such as the hardness or cohesiveness of any food is multi-faceted and tied to consumers' sensory expectations. Laureati *et al.* (2020) and Terana (2023) also indicated that texture encompassed many sensory dimensions, from tactile to visual and auditory sensations, thus making it a complex sensory property. The finding implies incorporating caramilk and carrageenan into the boneless siganids before dehydration significantly enhances the product's texture profile.

Sensory acceptability of cryoprotectant-treated dried boneless siganids

Fig. 2 illustrates the perceptions of 50 respondents regarding the suitability of employing a combination of carabao milk and carrageenan powder, along with calamansi extract, rock salt, and coconut water, as cryoprotectant marinades for dried boneless siganids. The results, analyzed using ANOVA, revealed diverse preferences among the respondents. Formulation 1 (F1) emerged as the preferred option across all four sensory attributes: color, flavor, odor, and texture. Further examination showed that Formulation 1 received the highest level of acceptability, with a general weighted mean average of 4.0, categorized as "Acceptable" by both consumers and food experts. Additionally, Sobri *et al.* (2023) demonstrated the potential of sodium alginate as a promising preservation technique, enhancing the physicochemical and sensory properties of vegan surimi. Similarly, Tian *et al.* (2022) investigated the efficacy of trifunctional cryoprotectant compounds in interacting with proteins to prevent protein denaturation. Their research also emphasized the role of mechanical fish dryers in preventing microbial contamination during the drying process, thereby ensuring the safety and hy-



Legend:

8.50-9.0 -*Like Extremely (LE)*
7.50-8.49 -*Like Very Much (LVM)*
6.50-7.49 -*Like Moderately (LM)*
5.50-6.49 -*Like Slightly (LS)*
4.50-5.49 -*Neither Like nor Dislike (NLD)*
3.50-4.49 -*Dislike Lightly (DL)*
2.50-3.49 -*Dislike Moderately (DM)*
1.50-2.49 -*Dislike Very Much (DVM)*

Fig. 3. *Most preferred product formulation per attributes*

giene of dried fish products for consumption.

Most preferred product formulation as per attributes

Fig. 3 displays the outcomes of preference tests regarding the acceptability of incorporating carabao milk and carrageenan powder, alongside calamansi extract, rock salt, and coconut water, as cryoprotectant marinades for dried boneless siganids. The evaluation involved 35 consumers and 15 food experts who utilized a 9-point hedonic scale to rate the final products' color, flavor, odor, and texture attributes across three formulations. The results indicated diverse preferences among respondents, with Formulation 1 (F1) emerging as the most favored across sensory attributes. This formulation consists of 50g of carabao milk, 2.5g of carrageenan powder, 5g of calamansi extract, 10g of salt, 500g of potable water, and 500g of coconut water. It garnered an overall weighted mean of 8.46 for color, 8.42 for flavor, 8.20 for odor, and 8.10 for texture, all denoted as "Liked Very Much" by participants. This underscores the significant impact of carabao milk, carrageenan powder, calamansi extract, salt, and coconut water composition on the sensory quality of dried boneless siganids. As per the findings by Patil *et al.* (2022), sugars like trehalose and sugar alcohols such as glycerol are commonly used cryoprotectants in freeze-drying to maintain enzyme or protein stability in tuna pepsin extract, thereby preserving proteolytic activity. Similarly, Yoha *et al.* (2024) showcased the potential of advanced drying techniques in improving product quality, yield recovery, and nutrient retention in dried food items, thus addressing the limitations of conventional drying methods and enhancing drying efficiency.

Test of significant mean differences among the cryoprotectant formulations

Table 2 illustrates the notable differences in mean scores among the three product attributes perceived by the respondents, as determined through Analysis of Variance (ANOVA). The results revealed an insignificant relationship between the computed F values: 15.34 for color, 9.82 for flavor, 15.74 for odor, and 19.45 for texture. This indicates rejection of the null hypothesis, as the computed F values surpass the tabulated F value of 2.79. Despite these varying preferences, Formulation 1 (F1), comprising 50g of carabao milk, 2.5g of carrageenan powder, 5g of calamansi ex-

Table 2. Showing significant mean difference among the product attributes as perceived by the respondents

Attributes	Fc	Ft (5%)	Decision	Interpretation
Color	15.342	2.79	Reject H0	Significant
Flavor	9.824	2.79	Reject H0	Significant
Odor	15.741	2.79	Reject H0	Significant
Texture	19.453	2.79	Reject H0	Significant

*If Fc > Ft, reject H0

tract, 10g of salt, 500g of potable water, and 500g of coconut water, emerged as the most favored option. This underscores the acceptance of utilizing the preferred marinades, in preserving dried fish particularly siganid fishes using mechanical fish dryer regardless of the significant or insignificant relationships observed among the three formulations. Tian *et al.* (2022) investigated the effectiveness of trifunctional cryoprotectants in inhibiting the formation of malondihaldehyde and aldehydes resulting from lipid oxidation. These compounds were found to interact with proteins, ultimately preventing protein denaturation. Furthermore, Zhang *et al.* (2021) demonstrated the potential of synthetic antioxidants and cryoprotectants, such as butylated hydroxytoluene (BHT) and butylated hydroxyanisole (BHA), in minimizing the degradation of food quality, discoloration, and protein denaturation, particularly under conditions of temperature fluctuation or extended frozen storage. Therefore, the development of natural additives like carabao milk, carrageenan powder, calamansi extract, rock salt, and coconut water as cryoprotectants could effectively prevent protein denaturation in dried fish, preserve nutrient content, and inhibit microbial growth, promoting healthier consumption and income generation.

Conclusion

The present study concluded that Formulation 1, comprising 50g of carabao milk, 2.5g of carrageenan powder, 5g of calamansi extract, 10g of salt, 500g of potable water, and 500g of coconut water, emerged as the most preferred choice for developing cryoprotectant marinades for dried boneless siganids. These results suggest the potential to utilize carabao milk and carrageenan powder, along with calamansi extract, rock salt, and coconut water, as cryoprotectant marinades for dried boneless siganids, thereby enhancing their sensory attributes and transforming them into a value-added food product suitable for human consumption, as indicated by the respondents involved in the study. Furthermore, the research underscores the adaptability of these ingredients for creating various dried fish products in the market, potentially providing economic opportunities, particularly for communities facing financial constraints. The CTU Extension Program is recommended to adopt the Techno-Guide provided in this study to support the establishment of sustainable community livelihood initiatives, dissemination of innovative food processing techniques, and promotion of the integration of natural additives and preservation methods in the production of value-added products like dried boneless siganids. To further develop the expertise of food professionals, hospitality management (HM), and technology and livelihood education (TLE) teachers, they are suggested to embrace the techno-guide for potential entrepreneurial ventures and educational purposes.

Conflict of interest

The authors declare that they have no conflict of interest.

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