

Vacuum-packed pastil made from freshwater fishes

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ABSTRACT

This study developed and evaluated vacuum-packed pastil made from selected freshwater fish species—tilapia (F1), catfish (F2), mudfish (F3), and pangasius (F4)—with chicken (F0) serving as the control. The products were assessed for proximate composition, metabolizable energy, sensory acceptability, shelf life at room temperature, and economic viability in terms of return on expenses. Proximate analysis determined moisture, ash, lipid, protein, fiber, and carbohydrate contents, while metabolizable energy was computed using standard Atwater factors. Data were analyzed using one-way Analysis of Variance (ANOVA) and Tukey's Honestly Significant Difference (HSD) test at a 0.05 level of significance. Results showed significant differences among formulations in moisture, ash, lipid, protein, carbohydrate, and energy, except for fiber, which remained consistently low. Catfish (F2) exhibited the highest ash, lipid, and metabolizable energy values, indicating superior mineral and caloric content. Mudfish (F3) had the highest protein level, while chicken (F0) recorded the highest carbohydrate content. Sensory evaluation revealed that catfish pastil (F2) achieved the highest overall acceptability, rated as "Like Very Much," while chicken scored highest in appearance and aroma due to familiarity. Fish-based formulations performed better in taste, texture, and overall preference. Shelf-life assessment indicated that vacuum-packed pastil stored at room temperature remained acceptable for only one day. Economic analysis showed that tilapia pastil (F1) yielded the highest return on expenses, making it the most viable option for commercialization. Overall, freshwater fish-based pastil products demonstrated strong potential as nutritionally valuable, sensory acceptable, and economically feasible ready-to-eat foods, with specific formulations offering targeted benefits in protein, energy, and profitability.

Keywords: Fish pastil, freshwater fish, proximate composition, sensory evaluation, shelf life, metabolizable energy, economic viability.

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INTRODUCTION

The Philippines is an archipelagic country located in Southeast Asia that continuously faces challenges related to food availability, quality, and nutrition, thereby ensuring access to safe, portable, and nutritious meals remains a significant concern for communities. As emphasized by the Food and Agriculture Organization (FAO, 2015), food must ensure both convenience and nutritional adequacy to prevent malnutrition. Unfortunately, despite the availability of commonly consumed processed foods in the market, they are truly convenient; nonetheless, they lack essential nutrients vital for a balanced diet.

Pastil, locally known as kagikit, is a traditional Maguindanaoan dish composed of steamed rice topped with shredded pork, chicken, or fish and wrapped in banana leaves. It is known for its portability and cultural significance among the Moro people of Maguindanao. However, pastil in its traditional form is perishable, limiting its potential use beyond immediate consumption. While traditional pastil is prepared using oil, the integration of freshwater fish such as tilapia, mudfish, catfish, and pangasius contributes with protein and other needed nutrients that enhance the nutritional profile of the product (FAO, 2015; FAO, 2020). To maximize its market potential, modern preservation techniques must be applied. Preservation technologies can improve the stability and quality of perishable meals such as pastil allowing it to be improve as a ready-to-eat product.

In the Philippine aquaculture industry, Tilapia (*Oreochromis niloticus*), Mudfish (*Channa striata*), catfish (*Clarias gariepinus*), and pangasius (*Pangasianodon hypophthalmus*) are freshwater fishes valued not only for their economic importance but also for their rich nutritional profiles. The Philippine Statistics Authority (PSA, 2022) reported that Tilapia (*Oreochromis niloticus*) remains one of the country's top aquaculture products, particularly abundant in Isabela province, where Magat Dam sustains freshwater fish farming. Tilapia is valued for its affordability, adaptability to different environments, and a major source for high-quality protein content (Mohanty et al., 2019 & FAO, 2020). Mudfish (*Channa striata*) on the other hand, also contributes to the nutrient benefits to human consumption due to its high protein and albumin content as well as favorable amino acid composition (Prastari et al., 2017; Baehaki et al., 2018). *Clarias gariepinus*, commonly known as catfish, is valued as a nutrient-dense freshwater species that provides substantial amounts of protein, amino acids, and minerals, including iron and zinc (Craig & Helfrich, 2017; FAO, 2022). In addition, due to the lean flesh and favorable fatty acid profile of pangasius (*Pangasianodon hypophthalmus*), it has gained a rising importance and contributes to the dietary protein intake among several population groups (Bogard et al., 2015; Sokamte et al., 2020; Haque et al., 2021). Collectively, FAO (2020) stated that these freshwater species can provide nutrient-dense raw materials rich in protein and lipids, which aid in developing value-added fish-based food products.

Preservation methods such as vacuum-packing have been proven effective in maintaining food safety. Similarly, Masniyom (2011) and Nosedá et al. (2012) affirmed that vacuum packaging minimizes oxygen exposure, thereby slowing down microbial growth and prolonging the freshness of fish and other perishable goods. The application of such preservation techniques to traditional foods like pastil provides an opportunity to enhance the stability and marketability of the product while preserving the nutritional contribution and cultural identity.

The proposed development of vacuum-packed pastil made from freshwater fishes aligns with national goals on food security and value-added and ready-to-eat product. It directly supports several Sustainable Development Goals (SDGs) such as Zero Hunger (SDG 2), No Poverty (SDG 1), Gender Equality (SGD 5), Decent Work and Economic Growth (SDG 8), Responsible Consumption and Production (SDG 12), and Partnerships to achieve the goal (SDG 17). The study promotes local aquaculture, empowers fisherfolk, and introduces an

accessible food option that strengthens community resilience during emergencies. Furthermore, it encourages the utilization of locally available raw materials, contributing to both environmental sustainability and community-based food systems.

Despite the availability of studies on vacuum-packed fish products (Relekar et al., 2020), there remains a lack of research exploring vacuum-packed fish pastil as a value-added, ready-to-eat food product using different freshwater fish species. This study addresses that research gap by developing and evaluating vacuum-packed tilapia pastil in terms of its acceptability, nutritional value, and economic feasibility. It aims to create an innovative food product that meets the criteria for ready-to-eat meals—nutritious, safe, cost-effective, and culturally acceptable.

The innovation also supports sustainable livelihood by providing new opportunities for local fish producers and small-scale food processors. By improving the shelf life of fish-based products through vacuum packaging, the research contributes to reducing food waste, increasing product value, and ensuring food availability.

Statement of the problem

Generally, this study aimed to develop a processing technology for vacuum-packed pastil made from freshwater fishes.

Specifically, it sought to address the following questions:

1. What is the proximate composition of vacuum-packed pastil made from freshwater fishes?
2. What is the level of acceptability among the four formulations of vacuum-packed pastil made from freshwater fishes in terms of color/appearance, odor/aroma, taste/texture, and general acceptability?
3. What subjective sensory changes are observed in vacuum-packed pastil stored at room temperature over a given storage period in terms of color/appearance, odor/aroma, taste/texture, and texture?
4. What is the Return on Expenses computed for the different formulations of vacuum-packed pastil made from freshwater fishes?

METHODOLOGY

This study employed a developmental research design aimed at producing a processing technology for vacuum-packed pastil made from freshwater fishes. The product was developed through a series of controlled procedural steps, from ingredient selection and preparation to formulation, sensory evaluation, nutrient analysis, storage studies, and cost and return analysis. The entire process was conducted with strict adherence to food safety and sanitation protocols to ensure the quality, safety, and integrity of the experimental product.

The ingredients used in the preparation of the vacuum-packed fish pastil were carefully selected to ensure quality and safety. The primary protein sources for the different formulations consisted of fresh tilapia, mudfish, catfish, and pangasius, each of which received special attention during selection given their central role in the product. These fish and all other ingredients, including spices and seasonings, were procured from trusted vendors to maintain consistency and uphold food safety standards. All formulations were prepared using a uniform set of supporting ingredients. Each of the five formulations, namely Formulation 0 or the control which used chicken, Formulation 1 which used tilapia, Formulation 2 which used catfish, Formulation 3 which used mudfish, and Formulation 4 which used pangasius,

contained 400 grams of the respective protein source. Common ingredients used across all formulations included 300 grams of cooking oil, 30 grams of soy sauce, 10 grams of vinegar, 20 grams of chopped onion, 40 grams of minced garlic, 20 grams of ginger, 2 grams of black pepper, 40 grams of sugar, and 4 grams of seasonings.

In preparing the pastil, the fishes were cleaned and washed thoroughly before being fried until light brown. The amount of oil used, the temperature, and the time of frying were kept uniform across all treatments to ensure consistency. Each treatment was cooked separately to prevent cross-contamination and to preserve the distinct characteristics of each formulation. Other ingredients, including garlic, onion, and ginger, were peeled and chopped finely prior to use.

The fried fish for each formulation were subsequently weighed, deboned, and processed into flakes. The resulting fish flakes were sautéed together with the chopped garlic, onion, ginger, and other seasonings, and stirred continuously until the mixture reached a dry consistency. The finished products were allowed to cool before being packed in plastic and sealed using a vacuum sealer. Throughout the preparation, handling, and storage of the product, the researcher strictly observed food safety and sanitation protocols to maintain the safety and quality of the output.

Sensory evaluation was conducted at Isabela State University, main campus, Echague, Isabela, to determine the consumer acceptability of the experimental product. The evaluation covered five sensory attributes: appearance/color, odor/aroma, taste/flavor, firmness/texture, and general acceptability. Data were collected using the 9-Point Hedonic Scale, the descriptive interpretation of which is as follows: a score of 9, corresponding to a range of 8.5 to 9.0, was interpreted as Like Extremely; a score of 8, with a range of 7.5 to 8.49, as Like Very Much; a score of 7, with a range of 6.5 to 7.49, as Like Moderately; a score of 6, with a range of 5.5 to 6.49, as Like Slightly; a score of 5, with a range of 4.5 to 5.49, as Neither Like Nor Dislike; a score of 4, with a range of 3.5 to 4.49, as Dislike Slightly; a score of 3, with a range of 2.5 to 3.49, as Dislike Moderately; a score of 2, with a range of 1.5 to 2.49, as Dislike Very Much; and a score of 1, with a range of 1.0 to 1.49, as Dislike Extremely.

A sensory panel composed of fifty (50) individuals was selected through purposive sampling from among the students and faculty of Isabela State University, main campus. The respondents ranged in age from 18 to 60 years old. Prior to participation, all panelists were screened to confirm that they were non-smokers, non-liquor drinkers, and in good health at the time of the evaluation. Each panelist was asked to sign an informed consent form and was then instructed on the proper conduct of sensory evaluation, with particular emphasis on the correct use of the 9-Point Hedonic Scale. Treatment samples were presented with 3-digit codes, and panelists were asked to carefully evaluate and rate each sample based on color, aroma, taste, texture, and overall acceptability. As a standard procedure strictly observed throughout the evaluation, respondents were required to rinse their mouths before tasting each sample to ensure the credibility and validity of the results.

The treatment products were subjected to proximate analysis to determine their nutrient composition. This analysis was conducted at the College of Health Sciences Laboratory of Quirino State University, Andres Bonifacio, Diffun, Quirino, Philippines.

Storage studies were conducted using real-time testing, which involved monitoring product quality and safety over the actual storage period. Ten small samples weighing 10 grams each were drawn from each formulation and packed and sealed in small plastic bags. Five samples from each treatment were stored at room temperature. One sample from each treatment was opened and evaluated every two days for appearance, aroma, taste, and texture. The day on which the appearance of molds or other unusual characteristics was first observed was recorded. All observations made over the storage period were documented and analyzed systematically.

The results of the sensory evaluation were statistically analyzed using one-way Analysis of Variance (ANOVA). The F-test, mean, and descriptive statistics were employed to determine significant differences among treatments in terms of color/appearance, texture, taste/flavor, odor/aroma, and general acceptability. The Least Significant Difference (LSD) test was further applied to identify which treatment means differed significantly from one another.

To assess the economic feasibility of the product, a cost and return analysis was performed to evaluate its market potential. This was accomplished by listing all costs, labor, and other expenses incurred in producing the different treatments for the vacuum-packed pastil made from different kinds of fishes, and subsequently computing the unit cost and Return on Expenses (ROEx) per treatment.

The researcher declares that there is no conflict of interest in the conduct of this study. The research was self-funded and was not influenced by any financial or personal interests, having been carried out purely for academic purposes. Furthermore, the researcher declares that the use of artificial intelligence tools, such as Quillbot, Grammarly, Perplexity, ChatGPT, and AI detectors, was limited and responsible in nature. All outputs generated through these tools were reviewed and revised by the researcher to ensure accuracy, coherence, and adherence to academic standards.

RESULTS AND DISCUSSION

This study involved a sensory panel of fifty (50) respondents selected through purposive sampling from among the students and faculty of Isabela State University, main campus, Echague, Isabela. The study employed a developmental research design aimed at producing a processing technology for vacuum-packed pastil made from freshwater fishes, utilizing five formulations: F0 (Chicken) as the control, F1 (Tilapia), F2 (Catfish), F3 (Mudfish), and F4 (Pangasius). Data were gathered through proximate analysis, a 9-Point Hedonic Scale instrument for sensory evaluation, subjective shelf-life observation, and cost and return analysis. Statistical analyses included one-way Analysis of Variance (ANOVA), Tukey's Honest Significant Difference (HSD) post hoc test, and descriptive statistics. The results are interpreted in direct relation to the objectives of the study, and all discussions are grounded in the data gathered through these procedures.

Proximate composition of vacuum-packed pastil made from freshwater fishes

The proximate nutrient composition of the five fish pastil formulations revealed statistically significant differences across most parameters, with the exception of total fiber and metabolizable energy. Moisture content ranged from 35.54% to 45.38%, with F0 (Chicken) recording the highest value at 45.38% and F2 (Catfish) recording the lowest at 35.54%. Tukey's HSD placed F0 in a distinct grouping (a), showing a significant difference from all fish-based formulations, which shared the common grouping (b). The relatively higher moisture content observed in the chicken formulation may be attributed to the greater water-holding capacity of poultry muscle tissues, which retain more intracellular water during thermal processing. In contrast, the lower moisture content in catfish-based pastil suggests that catfish muscle undergoes greater water loss during cooking, likely due to differences in muscle fiber density and fat distribution. Moisture content is an important quality parameter because it influences texture, palatability, microbial stability, and shelf life, and products with higher moisture generally exhibit a softer texture but may have shorter storage stability because water supports microbial growth.

Ash content, which represents the total mineral residue after combustion, ranged from 3.46% to 5.59%. The highest ash value was recorded in F2 (Catfish) at 5.59%, while F0 (Chicken) showed the lowest value at 3.46%. Tukey's HSD identified F2 within a statistically superior group (c), clearly distinguishing it from F0 (a), while F3 and F4 represented mid-range results characterized by their overlapping bc and ab classifications, respectively. This pattern suggests that catfish contributed a greater amount of inorganic minerals compared with the other protein sources. Mineral content may be influenced by the inherent composition of fish tissues, including calcium, phosphorus, potassium, and trace elements naturally present in freshwater fish species. The relatively elevated ash content in catfish indicates that this treatment may provide better mineral contribution to the diet, a finding consistent with FAO (2020), which stated that fish such as *Clarias gariepinus* are abundant sources of essential minerals including calcium and phosphorus, with differences reliant on species and habitat.

Lipid content ranged from 12.38% to 19.55%, with F2 (Catfish) recording the highest value at 19.55%, followed by F4 (Pangasius) at 17.32%, while F0 (Chicken) had the lowest lipid value at 12.38%. Post hoc analysis assigned F2 to the highest fat category (c) and F4 to an intermediate group (b), setting them significantly apart from F0, which was placed in the lowest-ranking group (a). This result reflects the natural fat composition of catfish and pangasius, both of which are known to possess relatively higher intramuscular fat than leaner fish species, a finding consistent with Mohanty et al. (2019), who reported that catfish and other freshwater fish naturally encompass higher fat levels because of their biological composition and feeding behavior. Lipids contribute significantly to flavor, mouthfeel, and caloric density of food products, and a higher lipid content may enhance sensory acceptability because fats improve tenderness and richness, although excessive lipid content may also affect oxidative stability during storage.

Protein content ranged from 20.39% to 27.50%, with F3 (Mudfish) recording the highest protein concentration at 27.50%, followed closely by F2 (Catfish) at 26.90% and F4 (Pangasius) at 25.57%, while F0 (Chicken) exhibited the lowest protein value at 20.39%. Post hoc analysis demonstrated that F3 and F2 belonged to the top-tier protein categories (bc and c), making them significantly more protein-rich than F0 in group (a). The shared b designation in F3's bc superscript further reflects its partial statistical similarity to the intermediate results of the other fish formulations. The elevated protein level in mudfish is consistent with the findings of Prastari et al. (2017) and Funmilayo (2016), who recognized mudfish as a rich source of high-quality protein and necessary amino acids vital for development and body functions. Protein is one of the most critical nutrients in fish-based products because it contributes to muscle development, tissue repair, enzyme formation, and immune function, and the high protein content of mudfish indicates that it may be the most nutritionally desirable among the treatments for populations requiring increased dietary protein.

Total fiber content remained very low across all treatments, ranging from 0.40% to 0.62%. Post hoc results for fiber placed all formulations within the same statistical grouping (a), indicating that the choice of protein source did not significantly affect the fiber profile. This result is expected because fish and meat naturally contain negligible dietary fiber, and the minimal fiber present in the formulations likely originated from plant-based ingredients such as garlic, onion, and ginger included in the recipe. Although fiber values were low, they still contribute slightly to digestive health.

Carbohydrate content ranged from 11.39% to 17.84%, with F0 (Chicken) showing the highest carbohydrate value and F2 (Catfish) the lowest. Tukey's HSD verified that F0 occupied a statistically superior position (a) in carbohydrate content, distinct from F2 (c), while fish-based variants clustered in lower overlapping groups (ab and bc). Carbohydrates in the formulations primarily originated from added sugar, seasonings, and condiments rather than from the animal protein source itself, and the slightly higher carbohydrate value in the chicken

formulation may be associated with reduced lipid displacement and proportionally greater non-protein solids retained after cooking.

Metabolizable energy values ranged from 264 kcal to 329 kcal, with F2 (Catfish) recording the highest value at 329 kcal and F1 (Tilapia) the lowest at 291 kcal, while F0 (Chicken) recorded 264 kcal. Despite the numerical differences, the ANOVA result for metabolizable energy was not significant (ns), indicating that no statistically significant differences existed among formulations in terms of caloric content. The higher energy value of the catfish formulation is directly associated with its elevated lipid content, since lipids provide approximately 9 kcal per gram compared with 4 kcal per gram from protein and carbohydrates, as corroborated by the findings of Mohanty et al. (2019). This indicates that catfish-based fish pastil may serve as a more energy-dense food product suitable for individuals with increased caloric requirements. Overall, the results demonstrate that each formulation possesses distinct nutritional advantages depending on the protein source used, with mudfish exhibiting the highest protein content, catfish showing the highest lipid, ash, and energy values, and chicken retaining the greatest moisture content.

The Tukey's HSD pairwise comparison further confirmed the nutritional differentiation among the five formulations. For moisture content, F0 (Chicken) significantly differed from all fish-based formulations, indicating that chicken meat retained more water during thermal processing, likely due to differences in muscle fiber composition and water-binding capacity between poultry and fish tissues. For total ash, F2 (Catfish) exhibited the highest mineral content and significantly differed from F4 (Pangasius), suggesting that catfish contributed more mineral residue due to its tissue density and inherent mineral composition. For total lipid, F2 (Catfish) and F4 (Pangasius) formed the higher statistical group and significantly differed from lower-fat formulations F0 (Chicken) and F1 (Tilapia), confirming that certain fish species naturally possess higher fat deposits that contribute to richer energy value and flavor. For protein content, F3 (Mudfish) obtained the highest mean and significantly differed from F0 (Chicken) and F2 (Catfish), indicating that mudfish provided superior protein concentration among treatments. For fiber content, no significant pairwise differences were observed among formulations, confirming that the fish species did not materially affect fiber level because dietary fiber mainly originated from uniform non-fish ingredients. For total carbohydrate, F0 (Chicken) significantly differed from F2 (Catfish), with this variation likely resulting from corresponding changes in moisture, protein, and lipid composition, given that carbohydrate was computed by difference. For metabolizable energy, F2 (Catfish) recorded the highest value and the numerical differences were directly associated with higher lipid concentration, since fat contributes more calories per gram than protein or carbohydrate. Taken together, the Tukey's HSD results confirm that F3 (Mudfish) and F2 (Catfish) emerged as nutritionally strong formulations, with mudfish excelling in protein and catfish in mineral and energy contribution.

The Recommended Energy and Nutrient Intake (RENI) analysis conducted on the best-performing formulation, F3 (Mudfish), per 100 g serving, demonstrated that the product contains 307 kcal of energy, 27.50 g of protein, 16.22 g of total fat, 12.94 g of total carbohydrates, 0.62 g of dietary fiber, 4.93 g of ash, and 38.40 g of moisture content. Based on the Philippine adult RENI, a single 100 g serving of the mudfish fish pastil contributes 15.35% of the daily energy requirement of 2000 kcal, 41.04% of the daily protein requirement of 67 g, 24.95% of the daily fat requirement of 65 g, 4.31% of the daily carbohydrate requirement of 300 g, and 3.1% of the daily fiber requirement of 20 g. The protein contribution of 41.04% is particularly notable, as it indicates that one serving already provides more than one-third of daily protein needs, highlighting its strong nutritional value especially for populations requiring

affordable protein sources. The energy contribution of 15.35% shows that the product can meaningfully supplement daily energy intake without being excessively calorie-dense, while the fat contribution of 24.95% reflects adequate dietary fat needed for energy reserve, hormone synthesis, and nutrient absorption. The 4.31% carbohydrate contribution supports short-term energy needs, and although the fiber contribution is relatively low at 3.1%, this is expected because fish-based foods naturally contain minimal fiber. These findings are supported by Baehaki et al. (2018), who noted that mudfish also consists of essential minerals including iron, zinc, and copper that enhance its nutritional value, and by the broader nutritional profile of *Channa striata*, whose high protein and albumin content contribute to its health-promoting properties. Based on these results, the mudfish fish pastil formulation can be classified as a high-protein, moderate-energy, nutrient-dense food product with strong potential for community-level food innovation and small-scale commercialization, including applications as a supplementary food, school feeding product, livelihood-based processed fish product, and protein-enriched local delicacy.

Sensory evaluation of vacuum-packed pastil made from freshwater fishes

The sensory evaluation of the five vacuum-packed fish pastil formulations was conducted using the 9-Point Hedonic Scale across five attributes: color/appearance, odor/aroma, taste/flavor, texture/firmness, and general acceptability. Statistical analysis using one-way ANOVA revealed significant differences among formulations in all five attributes.

In terms of color/appearance, F0 (Chicken) obtained the highest mean score of 7.92, described as "Like Very Much," followed by F2 (Catfish) with a mean score of 7.70, which was statistically comparable to F0 as reflected in their shared superscript (a and ab, respectively). F3 (Mudfish) received a mean score of 7.22, described as "Like Moderately," while F1 (Tilapia) and F4 (Pangasius) received mean scores of 6.90 and 6.84, respectively, both described as "Like Moderately" and placed in the lowest statistical group (c). The overall mean of 7.32 indicated that respondents generally liked the product's appearance. Statistical analysis revealed a highly significant difference among formulations ($p=0.0005$), indicating that the type of raw material significantly affected color acceptability. The higher rating of the chicken formulation may be attributed to consumers' familiarity with the traditional chicken pastil appearance. As highlighted by FAO (2020), the process of cooking raw materials strongly influences the visual quality of fishery products that serve as an initial basis for consumers' acceptance. Moreover, according to Jim et al. (2017) and Matos et al. (2019), variations among species affect the muscle composition and pigment concentration, which influence differences in color development after cooking. Despite the control receiving the highest rating for appearance, F2 (Catfish) obtained a mean score comparable to the control, and all other fish formulations were generally accepted and demonstrated potential as alternatives to traditional meat-based pastil.

For odor/aroma, F0 (Chicken) again obtained the highest mean score of 8.12, described as "Like Very Much," followed by F2 (Catfish) with 7.46 and F3 (Mudfish) with 7.42, both described as "Like Moderately" and sharing statistically comparable ratings under superscript (b). F1 (Tilapia) received a mean score of 7.00, described as "Like Moderately" and placed under superscript (bc), while F4 (Pangasius) received the lowest mean score of 6.56, described as "Like Slightly," and placed in the lowest group (c). The results in terms of aroma were highly significant, suggesting that formulation significantly influenced aroma perception. Mohanty et al. (2019) argued that the flavor and aroma characteristics of fish during cooking are significantly influenced by their fatty acid profiles. Furthermore, as reported by Masniyom et al. (2011), vacuum-packaging reduces oxygen exposure and slows oxidative reactions responsible for off-odors in fish products. Similarly, vacuum-packaging helps maintain sensory

freshness by preserving aroma compounds, particularly when combined with appropriate storage conditions, because it limits the oxygen exposure that reduces microbial activity, as noted by Nosedá et al. (2012), De Witt and Oliveira (2016), and Duran and Kahve (2020). Wang et al. (2024) further emphasized that appropriate packaging materials with high oxygen barriers are a good factor in maintaining product quality of the aroma.

For taste/texture, F2 (Catfish) obtained the highest mean score of 7.62, interpreted as "Like Very Much" and assigned superscript (a), making it significantly superior to F4 (Pangasius) and F0 (Chicken). F1 (Tilapia) and F3 (Mudfish) tied with a mean score of 7.46 each, both described as "Like Moderately" and assigned superscript (ab), indicating statistical comparability with F2 (Catfish). F4 (Pangasius) showed moderate acceptability with a mean score of 6.98, described as "Like Moderately" and placed under superscript (bc), while F0 (Chicken) received the lowest mean score of 6.66, also described as "Like Moderately" and assigned the lowest grouping (c). The results were significant, indicating that formulation affected flavor acceptability. The highest flavor acceptability of F2 (Catfish) may be due to the naturally rich flavor and higher fat distribution of catfish, which enhances seasoning absorption during cooking. According to Man et al. (2019) and Kim et al. (2020), amino acids such as glutamic acid contribute to umami taste, improving the palatability of fish-based foods. Mohanty et al. (2019) also noted that freshwater species such as catfish are known for mild yet savory flavor profiles that adapt well to traditional seasoning, which likely explains the preference for F2 over the control and other formulations.

For texture/firmness, F1 (Tilapia), F2 (Catfish), F3 (Mudfish), and F4 (Pangasius) all shared the same superscript (a), with mean scores of 7.02, 7.42, 7.08, and 6.80, respectively, all described as "Like Moderately," demonstrating that there was no significant difference among fish-based formulations in this attribute. In contrast, F0 (Chicken) received a mean score of 5.76, described as "Like Slightly" and assigned superscript (b), significantly differing from all fish treatments. The results were highly significant. Fish muscles, compared to poultry muscles, are generally more delicate, resulting in improved tenderness after cooking. As explained by Venkatesan et al. (2017), fish proteins form softer gel structures, contributing to better mouthfeel. Matos et al. (2019) further cited that the higher moisture capacity of fish muscle enhances tenderness, which may explain why all fish-based formulations were rated more favorably than the chicken control in terms of texture.

In terms of general acceptability, F2 (Catfish) received the highest mean score of 7.72, described as "Like Very Much" and assigned superscript (a), followed by F1 (Tilapia) at 7.48 and F3 (Mudfish) at 7.40, both described as "Like Moderately" and statistically comparable to F2 under superscript (a). F4 (Pangasius) obtained a mean score of 6.78, described as "Like Moderately" and assigned superscript (b), while F0 (Chicken) received the lowest mean score of 6.48, described as "Like Slightly" and assigned superscript (b), placing both in a statistically lower group than the three highest-rated fish formulations. The results were highly significant. General acceptability reflects the combined perception of all sensory attributes of the vacuum-packed pastil made from freshwater fishes, and the superior performance of F2 (Catfish) across flavor, texture, and aroma collectively contributed to its leading position. As argued by FAO (2020) and Relaktar et al. (2020), consumers' acceptance of value-added fish products can be increased when preservation technologies maintain both sensory quality and nutritional integrity of the products. The findings therefore reveal that catfish pastil (F2) is the most promising alternative to traditional chicken pastil among the tested formulations.

Subjective shelf-life observation of vacuum-packed fish pastil

The shelf-life evaluation of the vacuum-packed fish pastil stored at room temperature was conducted through subjective assessment of four sensory characteristics: appearance, aroma, taste, and texture. At Day 0, the vacuum-packed pastil was normal and acceptable in all quality attributes, with a normal appearance, fresh aroma, acceptable taste, and firm texture, classified as Acceptable. After two days of storage at room temperature (Day 2), the product showed slight discoloration, a slight fishy odor, and slight softness, while the taste remained acceptable, and the product was still classified as Acceptable overall. However, by Day 4, visible molds had appeared, off-odor was detected, the taste had become unacceptable, and the texture had become slightly slimy, leading to a classification of Spoiled. These changes within the fourth day indicated microbial spoilage and quality degradation of the fish-based pastil product over time. Based on these observations, the fish pastil product is of acceptable quality and best consumed within 1 day after processing when stored at room temperature, confirming that the shelf life of the product is just 1 day under ambient conditions.

Cost and return analysis

The cost analysis of the five vacuum-packed fish pastil formulations accounted for the cost of all ingredients and operating expenses incurred during production. All formulations shared uniform costs for the following ingredients: ginger at ₱10.00, onion at ₱10.00, garlic at ₱15.00, soy sauce at ₱6.00, vinegar at ₱6.00, oil at ₱40.00, sugar at ₱8.00, pepper at ₱2.00, and seasonings at ₱4.00. The primary protein sources differed in cost: chicken for F0 at ₱80.00, tilapia for F1 at ₱48.00, catfish for F2 at ₱80.00, mudfish for F3 at ₱94.00, and pangasius for F4 at ₱72.00. These differences produced varying ingredient subtotals of ₱181.00 for F0, ₱149.00 for F1, ₱181.00 for F2, ₱195.00 for F3, and ₱173.00 for F4. Operating expenses, consisting of packaging at ₱50.00, gas at ₱50.00, and labor at ₱100.00, were uniform across all formulations at a subtotal of ₱200.00 per formulation. Consequently, total production costs were ₱381.00 for F0, ₱349.00 for F1, ₱381.00 for F2, ₱395.00 for F3, and ₱373.00 for F4. Formulation 1 (Tilapia) recorded the lowest total production cost of ₱349.00, indicating that tilapia is a relatively affordable raw material for pastil production compared with the other fish species used in the study. Formulation 3 (Mudfish) garnered the highest total production cost of ₱395.00, reflecting the higher market price of mudfish relative to all other fish used in the study. The results suggest that the overall production cost of vacuum-packed fish pastil is largely influenced by the price of the main ingredient used in each formulation, while all other ingredients and packaging materials were held constant to ensure consistency in the preparation process.

The computation of Return on Expenses (ROEx) was based on a production yield of 50 packs at 2 oz per pack per formulation, with a uniform selling price of ₱10.00 per pack, resulting in a total sale of ₱500.00 for all formulations. Unit costs were computed by dividing the total production cost by the number of pieces produced, yielding unit costs of ₱7.64 for F0, ₱6.98 for F1, ₱7.64 for F2, ₱7.90 for F3, and ₱7.46 for F4. Income, computed as total sales minus total production cost, was ₱118.00 for F0, ₱151.00 for F1, ₱118.00 for F2, ₱105.00 for F3, and ₱127.00 for F4. The ROEx, computed as income divided by total production cost multiplied by 100, yielded values of 30.89% for F0, 43.26% for F1, 30.89% for F2, 26.58% for F3, and 34.04% for F4. Tilapia pastil (F1) obtained the highest ROEx of 43.26% among all formulations, demonstrating the greatest financial return relative to its production cost. The lowest total production cost of ₱349.00 for F1 directly produced the lowest unit cost of ₱6.98 and the highest total income of ₱151.00 per production batch. Pangasius pastil (F4) recorded the second most profitable formulation with an ROEx of 34.04%, a unit cost of ₱7.46, and an

income of ₱127.00 per production batch despite a total production cost of ₱373.00. F0 (Chicken) and F2 (Catfish) recorded identical ROEx values of 30.89% each, with a total production cost of ₱381.00 and an income of ₱118.00, placing them below F1 and F4 in terms of profitability. F3 (Mudfish) obtained the lowest ROEx of 26.58% as a direct consequence of its highest production cost of ₱395.00, resulting in a unit cost of ₱7.90 and a total income of ₱105.00. The results signify that the profitability of vacuum-packed pastil is largely influenced by the cost of the primary ingredient used in every formulation, and that formulation 1 (Tilapia) demonstrates the greatest advantage in achieving the highest Return on Expenses among the five pastil formulations, making it the most desirable option for generating higher income when establishing a small-scale food production enterprise.

The collective findings of this study demonstrate that vacuum-packed pastil made from freshwater fishes presents significant nutritional, sensory, and economic potential as a viable alternative to traditional chicken-based pastil. Nutritionally, mudfish (F3) emerged as the most protein-rich formulation, contributing 41.04% of the daily adult protein RENI per 100 g serving, while catfish (F2) excelled in lipid, ash, and energy content. Sensorially, catfish (F2) achieved the highest ratings for taste/texture and general acceptability, positioning it as the most preferred formulation among the respondents. In terms of economic feasibility, tilapia (F1) demonstrated the highest ROEx of 43.26% and the lowest unit cost of ₱6.98, making it the most cost-efficient formulation for small-scale production. Shelf-life observations confirmed that the product remains acceptable for 1 day at room temperature, underscoring the need for appropriate storage conditions or further processing interventions to extend commercial viability. These findings collectively address all research objectives of the study and contribute to the growing body of knowledge on value-added fish product development in the Philippines, offering a scientifically grounded basis for the promotion of freshwater fish species as accessible, nutritious, and economically viable raw materials for local food innovation and livelihood enterprise development.

CONCLUSION

This study aimed to develop and evaluate vacuum-packed pastil made from freshwater fishes, specifically tilapia (F1), catfish (F2), mudfish (F3), and pangasius (F4), with chicken (F0) serving as the control formulation. The products were assessed in terms of their proximate nutrient composition, sensory acceptability, shelf-life under ordinary room temperature conditions, and economic viability through the computation of Return on Expenses. Proximate analysis was conducted to determine the percentage moisture content, percentage ash, percentage lipid, percentage protein, percentage fiber, percentage carbohydrate, and metabolizable energy in kilocalories. Statistical analysis using one-way Analysis of Variance (ANOVA) and Tukey's Honestly Significant Difference (HSD) post hoc test was applied to determine significant differences among treatments.

Results of the proximate analysis revealed clear nutritional variations among the five formulations. Catfish recorded the highest ash content and lipid content, indicating superior mineral contribution and greater natural fat deposition among treatments. Mudfish had the highest protein concentration, followed closely by catfish and pangasius, while chicken recorded the lowest protein content. Fiber values remained uniformly low across all treatments, indicating that fiber contribution originated mainly from plant-based ingredients such as spices and condiments rather than from the fish or meat itself. Carbohydrate values were highest in chicken and lowest in catfish, and since carbohydrate was computed by difference, the variation reflected changes in moisture, lipid, and protein proportions. Metabolizable energy was highest

in catfish due to its elevated lipid content. The ANOVA results demonstrated that moisture, ash, lipid, protein, carbohydrate, and metabolizable energy differed significantly among formulations at the 0.05 level of significance, while fiber showed no significant difference. Tukey's HSD further identified that mudfish and catfish emerged as nutritionally superior treatments, with mudfish excelling in protein and catfish in lipid, ash, and energy. Based on nutritional facts computed per 100 g serving, the mudfish formulation provided 307 kcal, 27.50 g of protein, 16.22 g of fat, and 12.94 g of carbohydrate. RENI analysis showed that one serving contributes 41.04% of the adult daily protein requirement, confirming its strong nutritional value.

The results of the sensory evaluation revealed that F2 (Catfish) garnered the highest general acceptability score, described as "Like Very Much," making it the most preferred formulation overall. Among the five formulations, F0 (Chicken) performed highest in terms of appearance and aroma, which may be attributed to consumer familiarity with the traditional chicken-based pastil. Meanwhile, fish-based formulations exhibited better results in taste, texture, and overall acceptability. Significant differences were observed across most sensory attributes, indicating that the type of raw material used significantly influenced consumer perceptions. The storage study conducted at room temperature showed that the sensory qualities of the fish pastil deteriorated over time within the 4-day observation period, and based on these observations, the shelf life of the vacuum-packed pastil was determined to be just 1 day at room temperature. The computed economic viability of the product indicated that F1 (Tilapia) yielded the greatest profitability among the five formulations, with the highest Return on Expenses of 43.26%, making it the most economically feasible option for potential business application.

Based on the foregoing findings, several conclusions can be drawn. F2 (Catfish) and F3 (Mudfish) emerged as nutritionally strong formulations, with catfish excelling in mineral, fat, and energy content, and mudfish excelling in protein contribution. The RENI analysis confirmed that fish pastil, particularly the mudfish-based formulation, contributes substantially to daily nutritional requirements, positioning it as a high-protein, moderate-energy, nutrient-dense food product. In terms of sensory acceptability, F2 (Catfish) emerged as the most preferred formulation across most sensory attributes and demonstrated performance comparable to mudfish and tilapia, collectively implying that fish-based formulations are promising alternatives to traditional chicken pastil. The vacuum-packed fish pastil has a very short shelf life of 1 day when stored at room temperature, underscoring the need for improved storage conditions or processing interventions to extend commercial viability. In terms of Return on Expenses, F1 (Tilapia) obtained the highest value of 43.26%, confirming it as the most financially promising formulation for small-scale business enterprise.

In light of these conclusions, the following recommendations are advanced. Mudfish should be prioritized for fish pastil production when protein enrichment is the primary nutritional objective, given its demonstrated superiority in protein concentration and its substantial RENI contribution. For populations with higher energy demands, catfish should be considered as the preferred formulation given its higher caloric density and greater mineral contribution. Future studies should include microbiological shelf-life evaluation to determine storage stability under various temperature and packaging conditions, as subjective observation alone is insufficient for establishing scientifically defensible shelf-life claims. Furthermore, future product development should explore the fortification of fish pastil with dietary fiber sources to improve overall nutrient balance while maintaining sensory acceptability. Overall, the findings of this study establish that vacuum-packed fish pastil made from freshwater fishes is a nutritionally valuable, sensorially acceptable, and economically feasible product, with specific formulations offering targeted benefits for both health enrichment and commercial profitability, thereby providing a scientifically grounded basis for promoting freshwater fish

species as viable raw materials for local food innovation and livelihood enterprise development.

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