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Calcium-fortified pasta from milkfish bone powder: A sustainable food innovation

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Abstract

Fishery production generates significant solid waste, primarily fish bones, which remain largely underutilized and contribute to environmental concerns despite being rich sources of protein, collagen, calcium, and phosphorus. The utilization of milkfish (Bangus) bones offers a sustainable alternative for developing nutrient-rich food products because of their high mineral content, particularly calcium and phosphorus, which are essential for bone development and overall health. This study aimed to investigate the utilization of milkfish bone powder in pasta production as a value-added product derived from fish-processing by-products. Specifically, the study evaluated the nutritional enhancement, physicochemical properties, microbial safety, and sensory acceptability of milkfish bone–fortified pasta. The study employed an experimental research design with four levels of milkfish bone powder incorporation, namely Treatment A (Control) with 0% milkfish bone powder, Treatment B with 25% milkfish bone powder (60 g), Treatment C with 50% milkfish bone powder (120 g), and Treatment D with 75% milkfish bone powder (180 g). The pasta formulations were prepared by mixing wheat flour, milkfish bone powder, eggs, salt, and water, followed by dough kneading, rolling, cutting, drying, and packaging. Chemical analyses were conducted to determine moisture content, ash content, crude protein, crude fat, crude fiber, carbohydrate, calcium, and phosphorus levels. Sensory evaluation was conducted among thirty (30) selected Hospitality Management students and faculty members using a 5-point Likert scale to assess appearance, aroma, texture, taste, and overall acceptability. Rank preference testing and statistical analyses, including ANOVA, Kruskal-Wallis, Mann-Whitney, and Duncan's Multiple Range Test (DMRT), were also performed. Results revealed that increasing the concentration of milkfish bone powder significantly improved the mineral composition of the pasta, particularly calcium and phosphorus content. The fortified pasta also demonstrated increased ash, crude protein, and crude fiber content while showing lower moisture and carbohydrate levels, indicating an improved nutritional profile and enhanced shelf stability. Among the treatments, Treatment C

(50% milkfish bone powder) obtained the highest average mean score of 4.33, interpreted as "Very Acceptable," due to its balanced appearance, aroma, texture, and taste without producing an overpowering fish flavor. In contrast, the highest concentration (75%) resulted in lower sensory acceptability because of its darker appearance and stronger fish taste. The findings indicate that milkfish bone powder can be effectively incorporated into pasta production as a functional food ingredient while maintaining consumer acceptability. Furthermore, the study highlights the potential of utilizing fishery by-products as sustainable and economically valuable food ingredients. The production of calcium-enriched pasta using milkfish bone powder may contribute to improved nutrition, waste reduction, and sustainable food innovation. Since consumers increasingly prefer healthier and functional food products, milkfish bone–fortified pasta has strong potential for commercialization as a nutritious alternative to conventional pasta products while supporting environmental sustainability and circular economy practices.

Keywords: calcium-fortified, milkfish bone powder pasta, sensory evaluation, product development, food innovation, sustainable utilization

Calcium-fortified pasta from milkfish bone powder: A sustainable food innovation

1. Introduction

Pasta is a staple cereal-based product made from durum wheat semolina or alternative flours, widely consumed because it is affordable, versatile, and easy to prepare, making it a key component of modern diets across many regions of the world (Global Tribune, 2025; EBSCO, 2022). In recent years, pasta has also become a platform for innovation, with producers offering whole-grain, high-fiber, gluten-free, and high-protein variants to respond to changing consumer preferences and health concerns (Biernacka et al., 2022; Maximize Market Research, 2026). From 2020 onward, global pasta consumption and market size have shown steady growth, driven by the demand for convenient foods and by the recovery of the foodservice sector after the pandemic (Global Tribune, 2025; Mordor Intelligence, 2026). Industry analyses indicate that the global pasta market is expected to continue expanding at around 4–5% compound annual growth rate from the mid-2020s to early 2030s, reaching well over 100 billion USD in value, reflecting robust consumer demand in both retail and catering channels (Fortune Business Insights, 2024; Mordor Intelligence, 2026). Household survey data also show that in some countries more than half of consumers report eating pasta regularly, underlining its role as a common, repeat-purchase food item (Statista, 2025).

Nutritionally, pasta provides complex carbohydrates as a primary energy source and, when produced from whole grains or enriched flours, can contribute meaningful amounts of fiber, B vitamins, iron, and other micronutrients (Marcin, 2020; EBSCO, 2022). Recent research on "innovative" or reformulated pasta highlights that high-fiber and functional pasta products may help improve satiety and support reductions in blood pressure, cholesterol levels, and risks associated with certain chronic diseases when included as part of an overall balanced diet (Biernacka et al., 2022). These nutritional advantages, combined with compatibility with vegetables, lean proteins, and healthy oils, help explain pasta's popularity in dietary patterns that aim for both health and convenience (Marcin, 2020; EBSCO, 2022).

One of the important advantages of pasta from a technological and economic point of view is its relatively long shelf life, especially in dried form, which facilitates storage, transport, and stock management for both households and the food industry (Circle Economy, 2026; Epicurious, 2022). Technical references estimate that properly packaged dried pasta typically maintains quality for around two years, and sometimes longer if kept in dry, airtight conditions, whereas fresh refrigerated pasta has a much shorter safe storage time of only a few days (Epicurious, 2022). This long shelf life contributes to pasta's role as a "pantry staple" and supports its use in emergency stocks, institutional catering, and large-scale food distribution systems (Circle Economy, 2026).

Overall, recent market reports portray pasta as a mature but growing product category in which demand is being strengthened not only by its affordability and long shelf life but also by evolving consumer interest in healthier, more sustainable, and more specialized products (Maximize Market Research, 2026; Torg, 2026). The combination of rising consumption rates in many markets, continuous product innovation, and its favorable nutritional and storage characteristics suggests that pasta will remain an important commodity in the global food system in the coming years (Fortune Business Insights, 2024; Mordor Intelligence, 2026). Malnutrition and calcium deficiency remain important public health concerns, particularly among children, adolescents, and older adults. Calcium is an essential mineral needed for bone formation, muscle function, nerve transmission, and prevention of bone-related diseases such as osteoporosis. However, many populations fail to meet the recommended dietary calcium intake because of limited access to calcium-rich foods or the high cost of commercial supplements. One practical strategy to address this issue is the development of affordable and nutrient-enriched food products using locally available resources.

In the Philippines, milkfish (*Chanos chanos*), locally known as bangus, is one of the most widely consumed fish species. During fish processing, large quantities of bones are discarded as waste, contributing to environmental pollution and inefficient utilization of fishery resources. Studies have shown that fish bones are rich sources of calcium, phosphorus, collagen, and other minerals, making them suitable for conversion into nutrient-rich powder for food fortification. Utilizing milkfish bone powder in food products supports sustainable food systems and promotes waste valorization in the fisheries sector.

Filipinos on the other hand, have a deep fondness for snacks and party foods, with pasta noodles like sweet spaghetti and stir-fried pancit being staples at celebrations and merienda. Ilocos Region features many pasta-based dishes, such as Linaddit (or Miki Laddit), a comforting noodle soup with flat miki noodles, annatto, and meat; Mami, a simple chicken or beef noodle soup; and Pansit Miki, a stir-fried variant popular in local eateries. These hearty, affordable noodles reflect the area's fusion of Chinese-influenced cuisine and local ingredients, often served at parties or as street food. The Ilocos Region excels in milkfish production through aquaculture, with facilities like Pangasinan's new hatchery supporting over 40,000 fisherfolk and cutting import reliance (Bureau of Fisheries and Aquatic Resources [BFAR], 2023). Milkfish accounts for a major share of the region's nearly 27,000 metric tons of annual aquaculture output (Philippine Statistics Authority, 2022). This abundance positions bangus bones as a sustainable byproduct, linking aquaculture to innovative food applications in a region where fisheries continue to rebound from challenges.

Milkfish (Chanos chanos), locally known as bangus, ranks among the most widely consumed fish in the Philippines. Its processing generates substantial by-products, especially fish bones, which are often discarded despite their high calcium and mineral content (Bureau of Fisheries and Aquatic Resources [BFAR], 2020). Improper disposal of these bones exacerbates environmental waste and overlooks potential for value-added food products. Milkfish bones are nutrient-dense, offering high calcium (up to 4% or 4820 µg/g in extracts), phosphorus (around 3%), and protein (32%), essential for bone health, preventing osteoporosis, and supporting growth. These minerals strengthen teeth and bones when added to pasta, enhancing the nutritional profile of Filipino favorites without significantly altering their taste. (Akbar, F. H., Salam, M., Latunra, A. I., et al. (2022).

Despite the increasing interest in food fortification and sustainable food innovation, limited studies have focused specifically on the incorporation of milkfish bone powder into noodle products. Existing studies often concentrate on other fish species or bakery products rather than staple noodle formulations. Therefore, this study seeks to develop calcium-fortified pasta from milkfish bone powder and evaluate their nutritional quality, sensory acceptability, and potential contribution to sustainable food innovation.

This study addresses several important research gaps related to food fortification and sustainable food innovation. Although milkfish processing generates a significant amount of bone waste, there is still limited research on transforming these by-products into valuable food ingredients suitable for human consumption. Previous studies have explored the use of fish bone powder in products such as crackers, bread, and snacks; however, only a few have investigated its incorporation into noodle or pasta production, particularly using milkfish bones. Moreover, there is insufficient information regarding the sensory acceptability of fortified pasta, specifically in terms of taste, texture, aroma, appearance, and overall consumer preference. The study also fills the gap in research integrating nutritional enhancement with environmental sustainability through the utilization of fishery by-products. Furthermore, most existing studies were conducted in foreign settings or focused on other fish species, highlighting the need for localized research using abundant Philippine milkfish resources.

The significance of this study extends to various sectors. For consumers, the research may provide a healthier and calcium-enriched pasta alternative that can help support bone health and overall nutrition. For the food industry, the findings may serve as a basis for the development of innovative functional food products utilizing fishery by-products. Fish processors and the fisheries sector may benefit from the productive use of milkfish bone waste, helping reduce environmental disposal issues while increasing the economic value of fish-processing residues. The study may also contribute to academic research by serving as a reference for future investigations related to food fortification, sustainable food innovation, and functional foods. Moreover, government agencies and nutrition programs may use the findings to support nutrition intervention initiatives and promote affordable nutrient-enriched food products. Lastly, the study supports environmental sustainability by encouraging circular economy practices through the conversion of fish waste into valuable and useful food ingredients.

The study will employ an experimental research design varying concentrations of milkfish bone powder incorporated into pasta formulation. The study aims to evaluate the nutritional enhancement, physicochemical properties, microbial safety, and sensory acceptability of calcium-fortified pasta.

2. Materials and Methods

Materials - Fresh milkfish (bangus) bones, wheat flour, eggs, salt, and water. While, the other Materials and Equipment – Grinder, sieve, mixing bowls, weighing scale, rolling pin or pasta maker, knife and chopping board, cooking pot, drying trays, stove, and packaging materials; sterile polyethylene bags

Preparation of Milkfish Bone Powder

- *Collection and Cleaning* - Milkfish bones were collected from the local market. The bones were washed thoroughly under running water to remove adhering flesh and impurities.
- *Boiling and Degreasing* - The cleaned bones were boiled for 30-60 minutes to remove residual fats and proteins. Excess oil and tissues were manually removed.
- *Sterilization and Drying* - Bones were pressure-cooked to soften them and reduce microbial contamination. Afterwards, bones will be dried in an oven at 60-80^{0} C for 12-24 hours until completely dehydrated.
- *Pulverization* - The dried bones were ground using a grinder and sieve to obtain fine milkfish bone powder with uniform particle size.

Formulation of Calcium-Fortified Pasta

Table 1
Four Pasta Noodle Treatments

TREATMENT	WHEAT FLOUR (%)	MILKFISH BONE POWDER (%)
T1 (control)	100	0
T2	180	60
T3	120	120
T4	60	180

The dry ingredients were mixed thoroughly, followed by the addition of eggs, water, and salt. Dough was kneaded until smooth and elastic.

Noodle Processing

- Dough resting for 20-30 minutes.
- Sheet rolling using a pasta noodle tool
- Cutting into noodle strands
- Drying at controlled temperature until desired moisture content is achieved
- Packaging in sterile polyethylene bags

Observed parameters - Parameters which were observed in the present consisted of chemical properties and sensory evaluation. Chemical analysis was performed by measuring moisture content, ash content, crude protein content, crude fat content, carbohydrate content and calcium levels of the pasta. Sensory evaluation such as appearance, aroma, taste, texture and overall acceptability.

Data Analysis - This research is experimental with a completely randomized design. The data obtained were analyzed using IBM Statistics SPSS version 22. The sensory evaluation was analyzed using the Kruskal-Wallis statistical test and then further tested with Mann-Whitney. The proximate analysis test data of pasta were analyzed using One-Way Analysis of Variance (ANOVA) and with Duncan's Multiple Range Test (DMRT) for further analysis at a 95% confidence level.

3. Results and Discussion

3.1 Chemical Properties

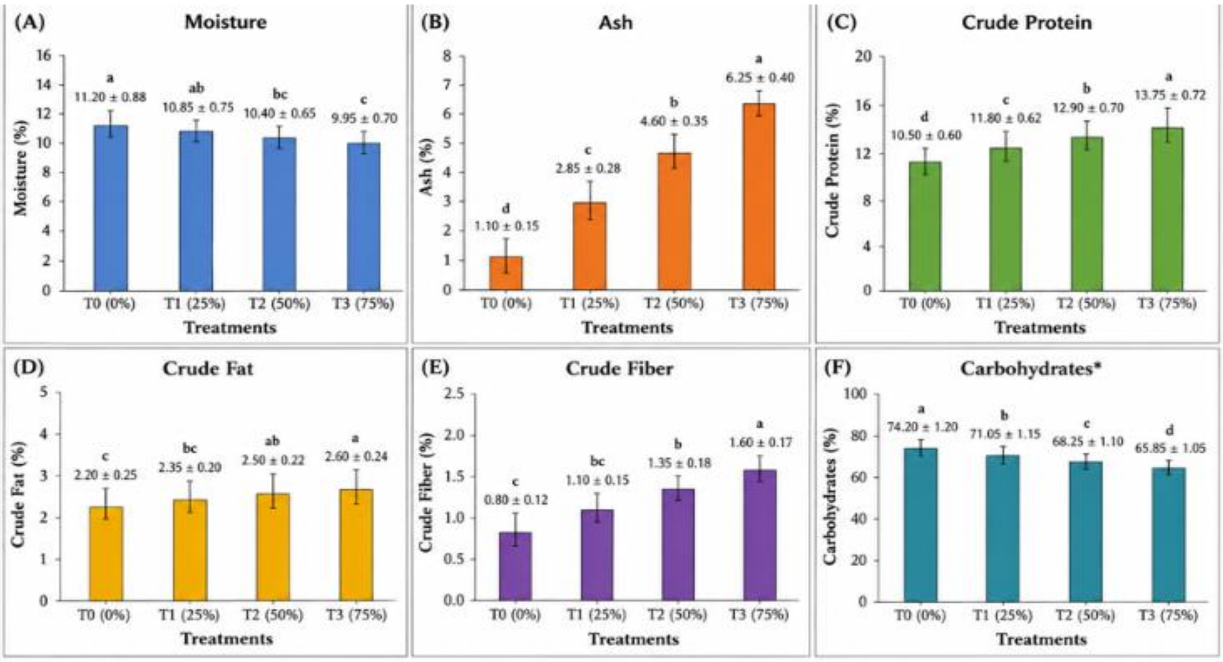

Figure 1. Proximate composition of the product as affected by the addition of milkfish bone powder at different concentrations. (A) Moisture, (B) Ash, (C) Crude Protein, (D) Crude Fat, (E) Crude Fiber, (F) Carbohydrates. Values are means ± standard deviation (n = 3). Bars with different letters are significantly different ($p < 0.05$) using ANOVA followed by Duncan's Multiple Range Test (DMRT).

Moisture content - The moisture content in pasta ranged from 11.20 to 9.95%, Figure 1. Results revealed that the moisture content decreases progressively with increasing levels of milkfish bone powder. The pattern may attribute to lower water-holding capacity of bone powder compared to wheat flour, which contributing to improved shelf stability and reduced microbial susceptibility (Bianchi et al., 2021).

Ash Content - The ash content in a product was closely related to the mineral content in an ingredient, the purity and cleanliness of a material produced (Sudarmadji (1997). The results show, there is a substantial increase of ash content among treatments, as seen on Figure 1. From 1.10 to 6.25% with the addition of milkfish bone powder. This reflects the high mineral content of milkfish bone powder, confirms their effectiveness as a fortifying agent. Similar findings have been reported in studies utilizing fishbone powder to enhance mineral composition in food products (Perez et al., 2024); Nemati et. al., (2016).

Crude Protein Content - ANOVA test result showed that the addition of milkfish bone powder significantly affected the levels of crude protein content in pasta $p<0.05$. Crude protein content gradually increased with higher substitution levels that indicates the contribution of residual protein from milkfish bone. However, the increase was moderate, it demonstrates an improvement in the nutritional profile of the pasta, consistent with previous research on fish-based fortification (Mathew et.al., 2022; Liaqat et al., 2022).

Crude Fat Content - The crude fat content of pasta in all treatments ranged from 2.20 to 2.60%, Figure 1. The highest crude fat content was obtained from pasta with the addition of milkfish bone powder, 2.60%. The results showed that the addition of milkfish bone powder significantly affected pasta fat content. The higher the concentration of the addition of milkfish bone powder, the lower the crude fat content. According to Pratama et al., 2014 the loss of fat content can occur due to protein unfolding in tissues to a degree that can cause a significant decrease in the emulsion stability of protein. Additionally, according to Windsor (2001), the protein will coagulate if the material is heated so that a lot of fat will come out.

Crude Fiber Content - The crude fiber content increased with higher addition of milkfish bone powder concentration may be associated with indigestible components present in bone powder. According to Paramita & Sahubawa (2022), an increased fiber content contributes to improve digestive health and enhances functional value of the product.

Carbohydrates Content - The content of carbohydrate decreases as the level of added milkfish bone powder increases. This is expected due to the partial replacement of wheat flour which is the primary carbohydrate source with milkfish bone powder. According to Paramita & Sahubawa (2022), the observed reduction indicates a shift toward a more nutrient-dense formulation.

Calcium Content - Calcium levels in pasta were measured at 0.00 to 18%, Figure 2. The highest level of calcium content was found in the pasta with the addition of 75% milkfish bone powder, with an average value of 18%. ANOVA test results showed that the addition of milkfish bone powder significantly affected the calcium content in pasta. The higher the concentration of the addition of milkfish bone powder, the higher the calcium content in the pasta. That is because milkfish bones contain high calcium. The Food and Nutrition Board of the National Academies of Sciences, Engineering, and Medicine established the Recommended Dietary Allowance (RDA) for calcium based on age and sex. The recommended intake for adults aged 19–50 years is approximately 1,000 mg (10grams) per day, while women aged 51 years and older and adults over 70 years require about 1,200 mg (12 grams) daily due to increased bone loss associated with aging. Adolescents aged 9–18 years require the highest intake at around 1,300 mg (13grams) per day because of rapid bone development during growth.

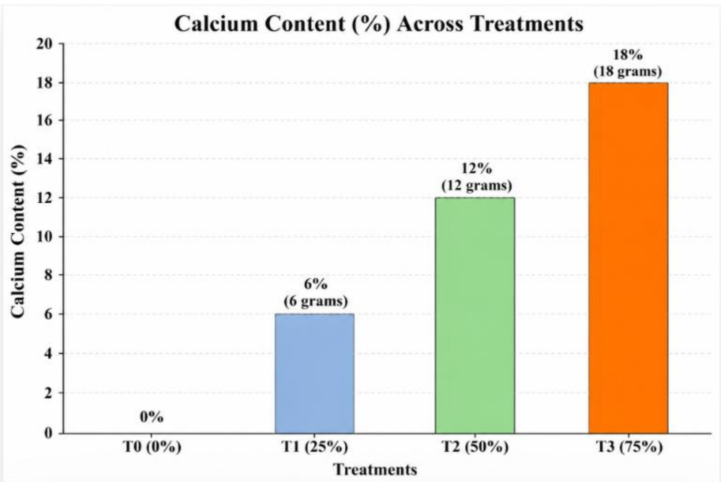

Figure 2. Calcium levels of the product affected by the addition of milkfish bone powder at different concentrations.

Phosphor Content - Chemical analysis showed that the phosphorus content in pasta was 0.18 - 0.63%, Figure 3. The highest level of phosphorus was found in pasta with the addition of 75% of milkfish bone powder, an average value of 0.63%. The test results showed the addition of fishbone meal significantly affected the pasta's phosphorus levels. The difference in concentration of addition of fishbone meal leads to different phosphorus levels of pasta. The higher the addition of milkfish bone powder concentration to the pasta, the higher the value of the phosphorus content. This could be due to a milkfish bone powder contains a high level of phosphorus. Fishbone meal contains nano calcium and calcium-phosphorus which have the highest availability among other calcium (Lestari, 2001).

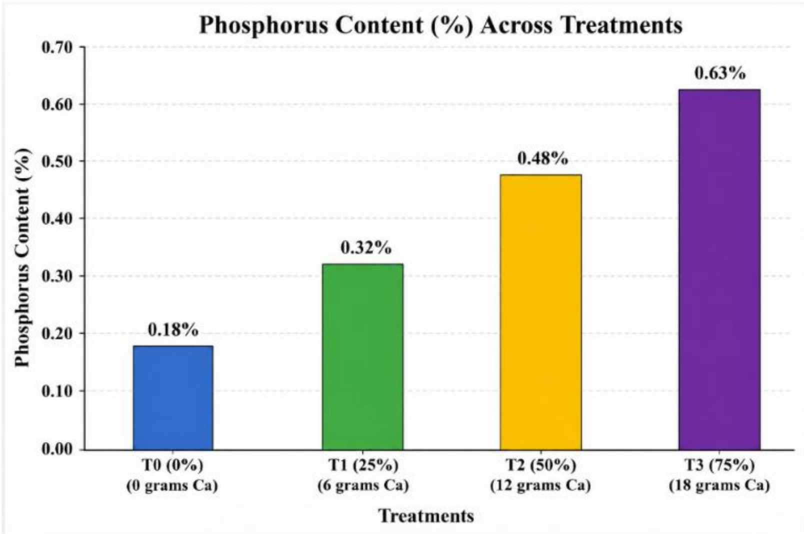

Figure 3. Phosphor content of pasta with addition of milkfish bone powder at four different concentrations.

3.2 Sensory Evaluation

Sensory evaluation was conducted among thirty (30) respondents composed of selected Hospitality Management food technology students and faculty/ teachers of the same institution. The responses were gathered using a structured sensory evaluation questionnaire based on a 5 Likert scale. The collected data were analyzed using the arithmetic mean to describe the sensory characteristics of each treatment. The study used Quantitative Description Analysis (QDA) score sheets, the milkfish bone powder treatment was evaluated according to the sensory attributes. The computed mean score was rounded off to determine the descriptive interpretation of each treatment. This presentation allows easy identification of similarities and differences among the three treatments.

Table 2
Presents the Average Mean and Descriptive Interpretation of the sensory characteristics of the milkfish bone powder

Quality Attributes	Treatment 1 (25%)	Descriptive Interpretation	Treatment 2 (50%)	Descriptive Interpretation	Treatment 3 (75%)	Descriptive Interpretation
Appearance	4.10	A Acceptable	4.35	VA Very acceptable	3.20	MA Moderately acceptable
Aroma	4.05	A Acceptable	4.40	VA Very acceptable	3.10	MA Moderately acceptable
Texture	3.95	A Acceptable	4.30	VA Very acceptable	3.05	MA Moderately acceptable
Taste	3.90	A Acceptable	4.25	VA Very acceptable	2.95	MA Moderately acceptable
Overall Acceptability	4.00	A Acceptable	4.33	VA Very acceptable	3.08	MA Moderately acceptable
Average Mean	4.00	A Acceptable	4.33	VA Very acceptable	3.08	MA Moderately acceptable

Results showed that Treatment 2 (50% milkfish bone powder) obtained the highest mean score of 4.33, which was interpreted as *Very Acceptable*. This treatment exhibited a balanced combination of appearance, aroma, texture, and taste. In comparison, Treatment 1 (25%) was rated as acceptable but was observed to be less tasteful, while

Treatment 3 (75%) demonstrated lower acceptability due to its stronger fish flavor and darker appearance.

Level of Acceptability - Based on the result Treatment 2 (50%) of added milkfish bone powder in pasta was identified the most preferred formulation among the three (3) treatments due to its balanced sensory characteristics. It achieved a desirable texture and flavor profile without producing an overpowering fish taste which contributed to its higher level of acceptability among respondents.

Significant Difference - ANOVA test results revealed that there is no significant difference among the treatments in appearance. However, significant differences were observed in aroma, texture, taste and overall acceptability at a 0.05 level of significance $p<.05$.

Rank Preference - In rank preference, the treatment 2 (50%) of concentrated milkfish bone powder was ranked first among the three treatments followed by treatment 1 (25%) while treatment 3(75%) of concentrated milkfish bone powder was ranked last. These findings indicate that increasing the concentration of milkfish bone powder significantly affects the overall quality and sensory attributes of the product, confirming that the 50% formulation was the most favored among the respondents.

4. Conclusion

The incorporation of milkfish bone powder into pasta successfully enhanced its nutritional value, significantly in terms of calcium, phosphorus, protein, and mineral content, while also promoting the sustainable utilization of fishery by-products. Among the treatments tested, the 50% milkfish bone powder formulation emerged as the most acceptable in terms of appearance, aroma, texture, taste, and overall consumer preference. The findings demonstrate that milkfish bone powdered pasta is a promising functional food product that combines nutrition, sustainability, and sensory acceptability, offering an innovative and healthier alternative to conventional pasta products.

Practical Educational Implications - The findings of this study have important practical implications for food technology education, science instruction, and school-based sustainability programs. Since the study showed that milkfish bone powder can significantly improve the calcium, phosphorus, protein, and mineral content of pasta while maintaining acceptable sensory qualities, particularly at the 50% formulation, the product can be used as a concrete example of how classroom-based food innovation can address both nutrition and environmental sustainability. This makes the study relevant not only as a food product development project but also as an educational model for applying scientific knowledge to real-life community needs.

For teachers and practitioners, the study provides a practical instructional example that can be integrated into lessons on food technology, nutrition, entrepreneurship, environmental science, and research methods. Teachers may use the development of calcium-fortified pasta as a project-based learning activity where students investigate food fortification, conduct simple sensory evaluation, analyze nutritional improvement, and reflect on waste reduction. This type of activity can help students connect scientific concepts such as mineral content, food processing, proximate analysis, and consumer acceptability with everyday food choices and local resources.

For students, the study demonstrates how locally available materials, such as milkfish bones, can be transformed into useful and value-added products. This can strengthen students' creativity, problem-solving skills, environmental awareness, and appreciation of sustainable food systems. By participating in similar food innovation projects, students may better understand the importance of nutrition, especially calcium intake for bone health, while also learning that food waste can be converted into functional ingredients. Such learning experiences can encourage students to become more health-conscious, resourceful, and socially responsible.

For schools, the findings suggest that food innovation projects can support broader educational goals related to health promotion, sustainability, and community engagement. Schools offering hospitality management, food technology, home economics, livelihood education, or science-related programs may adopt similar product development activities as part of laboratory work, research projects, or entrepreneurship training. The study also provides a possible model for school-community collaboration, particularly in areas where milkfish production is common and fish-processing by-products are readily available. Through this approach, schools can help promote local resource utilization, reduce waste, and encourage students to develop affordable and nutritious food products.

The study also has implications for school-based nutrition and feeding initiatives. Although further testing and product standardization are needed before large-scale implementation, the results suggest that calcium-fortified pasta may have potential as a nutritious alternative food product for learners, especially in contexts where calcium deficiency and limited access to nutrient-rich foods are concerns. The high acceptability of the 50% milkfish bone powder formulation indicates that nutrient enhancement can be achieved without seriously compromising taste, texture, aroma, and appearance. This is important because students are more likely to consume fortified foods when they remain familiar, affordable, and acceptable. Overall, the educational significance of the study lies in its demonstration that research, nutrition, sustainability, and entrepreneurship can be meaningfully combined in school settings. The findings encourage teachers, students, and schools to view food product development not merely as a technical activity, but as a practical educational strategy for promoting health, environmental responsibility, innovation, and community-based problem solving.

Declaration on the Use of Artificial Intelligence Tools - The authors declare that artificial intelligence-assisted tools were used only for language refinement, grammar checking, and improvement of the clarity and readability of the manuscript. The AI tool was not used to generate research data, conduct statistical analysis, interpret the findings independently, or replace the authors' scholarly judgment. All content, results, interpretations, and conclusions were carefully reviewed, verified, and approved by the authors. The authors take full responsibility for the accuracy, integrity, and originality of the final manuscript.

Author's Contribution: Joshua G. Gadiano- carried out the experiment and collected the data, helped supervise the project, and Elvira Shiey C. Correa- wrote the manuscript, verified theoretical and analytical methods and discussed the results and contributed to the final manuscript.

Conflict of Interest

The authors declare that they have no competing interests.

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