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# Acceptability of Smoked Rice Eel *(Monopterus albus)* Flavored with Lemongrass Extract in Different Levels of Brine Solution

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## Abstract

The study evaluated the acceptability of smoked Rice eel (*Monopterus albus*) flavored with lemongrass extract in different levels of brine solution in terms of color, aroma, texture, and taste. In addition, the acceptability composite index, proximate analysis and nutritional composition, and economic feasibility of the product were evaluated. Developed packaging, name and logo of the product were also made. There were three treatments in this study. Based on the overall acceptability, Control was increased by 12%, 6% and 2% as compared to T3, T1 and T2, respectively. In terms of color acceptability, Control was increased by 13%, 10%, and 3% as compared to T3, T1, and T2, respectively. In terms of aroma acceptability, Control and T2 were increased by 4% as compared to T1 and T3. In terms of texture acceptability, C was increased by 12%, 4% and 2% as compared to T3, T1 and T2, respectively. In terms of taste acceptability, Control was increased by 22%, 7% and 3% as compared to T3, T1 and T2, respectively. Overall, Control was the most accepted among all the treatments in terms of color, aroma, texture and taste. Control is ranked first, T2 ranked second, T1 (third) and last is T3. The proximate composition of smoked rice eel flavored with lemongrass extract in 10% brine solution revealed that smoked Rice eel contains 21.68% crude protein, 0.79% crude fiber, 1.07% crude fat, 67.26% moisture and 5.73% ash. The shelf life of smoked eel is safe within four weeks in a vacuum-sealed pack stored in refrigerated 4 °C.Processing of smoked rice eel is economically feasible with 53.17% ROI.

**Keywords:** Rice Eel, Lemongrass Extract, Smoking, *Monopterus albus sp*., Zero Hunger

## 1. Introduction

Rice paddy eel or Asian swamp eel, *(Monopterus albus)*, locally known as “kiwet,” is a commercially important but ecologically problematic aquatic species in the Philippines. Although it has economic value in local and international markets, it is also considered invasive and destructive to rice paddies and pond dikes, particularly in Cagayan Valley. This study focuses on transforming rice eel into a value-added smoked product flavored with lemongrass extract and prepared using different levels of brine solution. By integrating fish processing, smoking, sensory evaluation, proximate analysis, shelf-life determination, packaging development, and economic feasibility assessment, the study addresses both product acceptability and potential livelihood contribution.

Rice paddy eel or Asian swamp eel, *(Monopterus albus),* belongs to the family Synbranchidae and is locally known as “kiwet.” It exhibits protogynous hermaphroditic reproductive behavior, undergoing natural sex reversal from female to male through an intersex stage accompanied by morphological and physiological changes in the gonad (Zhou et al., 2003; He et al., 2010). Chan and Phillips (1967) reported that the sex change is completed within 8–30 weeks and that an intersex period occurs when individuals contain both male and female gonads. This transformation commonly occurs when individuals are 35–45 cm long and at least 1–2 years old, while individuals reaching 55 cm or greater are mostly male. Rice eel was introduced in the Philippines for aquaculture in 1905 without sufficient consideration of environmental impact, which contributed to its invasive status (Juliano et al. 1989; Guerrero, 2014). Its invasiveness has been associated with damage and economic losses in rice farming, especially in Cagayan Valley (BFAR R02, 2017). Despite this concern, rice eel has also provided economic opportunities for fishers involved in collection, consolidation, and trading. In the first semester of 2013, rice eel contributed PHP 517 million to the country’s export value, with markets in Singapore, China, Japan, Taiwan, and other Asian countries (Domingo, 2013). It has also been viewed as a continuing livelihood source for fisherfolk (Business World, 2013). Globally, M. albus production reached 738,380 MT in 2015, valued at USD 6.87 billion, with China as the leading producer (Tridge, n.d.). In the Philippines, eel production from 2017 to 2019 reached 1,718.17 MT, 1,604.17 MT, and 1,564.45 MT, respectively, with Cagayan Valley contributing the highest share and Isabela recording the largest provincial production (PSA).

Fish is an important source of protein, vitamins, and omega-3 fatty acids, which support brain function and may reduce the risk of heart attacks, strokes, and osteoporosis (Clover, 2005). It also contains essential amino acids such as lysine, methionine, and tryptophan, which are often limited in plant proteins (Akinwumi and Adegbehingbe, 2015). However, fish is highly perishable and deteriorates rapidly after harvest, especially under high ambient temperatures, requiring immediate preservation (Aberoumand, 2010). Rice eels are nocturnal, aggressive, and voracious predators that burrow in mud or vegetation during the day and can reproduce through unique sex-changing behavior ( Erzen, 2019). Their ability to survive in low-oxygen conditions, breathe through gills or skin, move across land, and burrow into muddy substrates strengthens their persistence in aquatic and agricultural environments. Rainboth (1996) noted that they can survive out of water for extended periods if the skin remains moist, while related accounts describe their capacity to burrow as deep as 1.5 m and withstand dry periods ("Fishes of the Cambodian Mekong", 1996; Matsumoto et al., 2010). Nutritionally, eel meat is considered a high-value food used in various dishes and is reported to contain protein, fat, phosphorus, calcium, iron, vitamins A and D, B vitamins, and other minerals beneficial to health (Accessed on September 8, 2024: Date retrieved September 8, 2024). It is also described as having zero sugar, low sodium, high potassium and phosphorus, 18 amino acids, and vitamins A, B12, B1, B2, D, and E, although its cholesterol content may be a concern (Accessed on September 8, 2024: Date retrieved September 8, 2024). Data from the RI Ministry of Health also indicate that fried Asian swamp eel contains notable amounts of calcium, niacin, phosphorus, energy, protein, copper, and riboflavin, which may contribute to energy production, tissue growth, nutrient transport, body fluid balance, and body development (Accessed on September 8, 2024: Date retrieved September 8, 2024). Fish processing involves transforming aquatic products from harvest to finished form for consumption or marketing (Edinburgh, 2004). Its primary goal is to prevent spoilage and preserve quality, with long-standing practices such as keeping fish alive until consumption used in China for thousands of years (FAO; 2011). Processing may remove toxins, preserve food, improve uniformity, increase seasonal availability, support long-distance transport, and make food safer by preventing spoilage and pathogenic microorganisms (Laudan, 2010). Common fish preservation methods include freezing, salting, sun-drying, oven-drying, fermentation, and smoking (Asiedu and Sanni, 2002; Clucas and Ward, 1996). In many fishing communities, fish smoking has served as a primary economic activity, especially among women (Essuman, 1992), and has been recognized as a dominant preservation method in some contexts (Orraca- Tetteh and Nyanteng, 1971; Plahar et al., 1995:1996:1997). Smoking contributes to preservation through drying and the deposit of smoke-derived compounds such as phenols and aldehydes, which suppress microorganisms (Garrow and James, 1994). It improves taste and extends shelf life (Maddison et al., 1993). Depending on the fish type, use, and storage period, smoking may involve wet hot or dry hot methods (Alhassan et al., 2014), and Clucas, (1982) noted that these methods require temperature sufficient to cook the fish. Smoking also improves taste, smell, shelf life, color, drying, and resistance to spoilage agents (Abolagba and Melle, 2008; Olokor et al., 2007; Sengor et al., 2004), while helping reduce chemical deterioration (Sowumi, 2007). According to Akinwumi, (2014), smoking is a healthier and inventive method of processing because it helps retain protein value and reduce moisture content.

Related smoked fish studies support the relevance of brine concentration, lemongrass treatment, and hot smoking. Hot-smoked tilapia stored at 4 °C was examined using 5%, 10%, and 15% NaCl brine, and 5% brine was found optimal for storage while the product remained safe for over 35 days under refrigeration (Yanar et al., 2006). Smoked catfish fillets treated with crude lemongrass extract and salt achieved high acceptability and extended shelf life by approximately three times at ambient temperature and four times under chilled storage (Chaiyawat et al., 2008). Hot smoking also improved the nutritional quality of Pangasius hypophthalmus fillets by increasing protein and ash content and improving PUFA proportion (Sokamte et al., 2020). Lemongrass (Cymbopogon citratus) is a fragrant tropical perennial plant rich in aromatic oils and secondary metabolites such as terpenoids, benzenoids, organic sulfur, and nitrogenous compounds (Joy, 2003). It contains citral and bioactive compounds, including flavonoids and vitamin C, with natural flavonoids gaining attention for anti-carcinogenic and anti-inflammatory effects linked to lipid anti-peroxidation (Martin et al., 2002). Cymbopogon citratus is also known for flavonoids, essential oils, phenolic compounds, and phytochemical constituents with anti-obesity, anti-bacterial, anti-fungal, anti-nociceptive, antioxidant, anti-diarrheal, and anti-inflammatory properties (Oluwole et al., 2019). Lemongrass is widely used as a culinary herb, flavoring agent, aromatic drink, and traditional medicinal plant. It is also described as antibacterial, antifungal, antioxidant, antiseptic, anti-inflammatory, analgesic, and antipyretic (Goyal and Ananad, 2013). Its crushed leaves produce fragrant essential oil (Adejuwon and Esther, 2007), and its aqueous extract is used in traditional dishes and folk medicine (Figueirinha et al., 2008). Lemongrass also has nutritional and health-related relevance. It is used in teas, marinades, curries, broths, and medicinal applications for gastrointestinal discomfort (Frey, 2022). USDA data indicate that fresh lemongrass contains small amounts of calories, protein, fiber-rich carbohydrates, calcium, potassium, manganese, magnesium, iron, vitamin A, vitamin C, folate, and niacin (Frey, 2022). Although there is limited scientific evidence for some traditional uses, lemongrass is used as a food and beverage flavor, herbal tea ingredient, fragrance, and source of vitamin A and natural citral. It contains flavonoids and phenolic compounds with antibacterial, antifungal, anti-inflammatory, and antioxidant qualities. Lemongrass may also be used orally, topically, or through aromatherapy for conditions such as anxiety, colds, fever, inflammation, insomnia, nausea, cramps, headaches, musculoskeletal discomfort, infections, colds, and flu symptoms (Frey, 2022). The growing interest in plant extracts is connected to their bioactive components and antibacterial applications in food preservation, pharmaceuticals, alternative treatments, and natural remedies (Lis-Balchin and Deans, 1997).

Locally, the study responds to the situation in Cagayan Valley and Isabela, where rice eel is both abundant and problematic. Its ability to damage rice paddies and pond dikes causes water leakage and nutrient loss, affecting the production of farmers and fisherfolk. As one of the major rice eel-producing areas in the country, BFAR Region 2 has initiated the development and processing of rice eel into value-added products to extend shelf life and improve utilization. This makes rice eel processing relevant not only to product development but also to agricultural damage mitigation, post-harvest technology, and local livelihood. Nationally, the study is linked to the economic value of eel production and trade in the Philippines. Rice eel contributes to exports, provides livelihood to collectors and traders, and has established domestic and international markets. However, its odor and slimy texture limit consumer recognition of its nutritional value. Processing it into smoked rice eel flavored with lemongrass extract may improve consumer acceptability by enhancing aroma, flavor, texture, and overall product appeal. Globally, the study connects with established practices in fish smoking, value-added seafood production, natural flavor enhancement, food preservation, and product safety. In Ghana, smoked fish contributes to employment, income generation, food security, and foreign exchange earnings (Asiedu et al., 2018). About seventy percent (70%) – eighty percent (80%) of smoked fish in Ghana is locally consumed (Asiedu et al., 2018), and several fish species are commonly processed by smoking (FAO, 2017; Asiedu et al., 2018). The broader literature indicates that smoking methods, brine levels, plant extracts, and storage conditions can affect acceptability, shelf life, and nutritional quality.

The conceptual basis of this study is anchored on value-added fish processing, sensory acceptability, preservation, nutritional assessment, packaging, and economic feasibility. Fish smoking is conceptualized as a preservation and product-enhancement method because it combines salting, drying, heating, and smoke exposure to improve flavor, aroma, color, texture, and shelf life (Kjallstrand and Petersson, 2001). Smoke contains volatile aromatic compounds that provide desirable product characteristics while also acting as a bactericide (Belichovska et.al,. 2019). Brine solution functions as a preserving, tenderizing, and flavoring medium, while lemongrass extract functions as a natural flavoring and aroma-enhancing ingredient that may help mask the unpleasant odor of rice eel. Sensory evaluation provides the acceptability basis of the study. It is a scientific method used to evoke, measure, analyze, and interpret responses to products as perceived through sight, hearing, touch, smell, and taste (Stone and Sidel 1993; IFT 2007). In this study, sensory acceptability focuses on color, aroma, texture, and taste. Proximate analysis supports the nutritional basis of the product by estimating food components such as moisture, crude protein, total fat, total carbohydrate, and dietary fiber (Ganogpichayagrai et al., 2020) as cited in Journal of Advance Pharmaceutical Technology and Research (2020). Shelf-life assessment supports the safety and quality dimension, as shelf life is important for production, transport, distribution, packaging, and "best before" decisions (Piergiovann et al., 2019). Shelf-life studies also help manufacturers and consumers ensure product quality during storage by considering safety, physical quality, chemical quality, and sensory properties (Phimolsiripol et al., 2016). Packaging and labeling support market readiness because they help products meet consumer and market requirements while communicating product information (Gordon et al., 2020).

Although rice eel has economic and nutritional potential, it is often underutilized as a food product because of its unpleasant odor, slimy texture, and pest-like status among farmers and fisherfolk. Existing literature supports fish smoking, brining, and the use of lemongrass extract in other smoked fish products, but there is a need to evaluate smoked rice eel specifically when flavored with lemongrass extract and prepared using different levels of brine solution. The study addresses this gap by determining product acceptability in terms of color, aroma, texture, and taste; computing the acceptability composite index; analyzing proximate composition; determining shelf life; developing packaging, name, and logo; and assessing economic feasibility. The study is justified by the need to convert an invasive and damaging aquatic species into a potentially acceptable, nutritious, and marketable food product. It also responds to the need for post-harvest innovation in fisheries, particularly in regions where rice eel is abundant. Since food loss refers to food that is spilled or spoiled before reaching final product or retail stage, while food waste refers to edible food not consumed because it is discarded or left to spoil (FAO, 2011), processing rice eel into a smoked and packaged product may help improve resource utilization and reduce avoidable losses.

The study is aligned with relevant Sustainable Development Goals (SDGs), particularly SDG 2 – Zero Hunger, SDG 3 – Good Health and Well-Being, SDG 8 – Decent Work and Economic Growth, and SDG 12 – Responsible Consumption and Production. It supports SDG 2 by exploring the development of a nutritious fish-based product that may contribute to food availability, local food security, and alternative protein sources through the use of rice eel, a locally available aquatic resource, transformed into smoked rice eel flavored with lemongrass extract. It also contributes to SDG 3 by considering the nutritional value of rice eel and lemongrass, including protein, vitamins, minerals, and other beneficial compounds, while the assessment of proximate composition and shelf life supports the development of a food product that considers both nutrition and safety. Furthermore, the study is relevant to SDG 8 because it examines the economic feasibility of smoked rice eel production and its potential as an additional livelihood source for fisherfolk, processors, and local entrepreneurs, thereby supporting income generation and small-scale enterprise development. Lastly, it contributes to SDG 12 by promoting the value-added processing of an underutilized and problematic species, where smoking, brining, packaging, labeling, and shelf-life evaluation support responsible post-harvest handling, product development, and improved use of local resources.

This study contributes to multidisciplinary sustainability by linking fisheries science, food technology, nutrition, entrepreneurship, environmental management, and community livelihood. From a food sustainability perspective, it promotes the use of rice eel as a nutritious and value-added product. From an environmental and agricultural sustainability perspective, it offers a productive use for a species associated with rice paddy and pond dike damage. From a socio-economic sustainability perspective, it may create additional livelihood opportunities and support the aquaculture and fisheries sector. From a technological and product innovation perspective, it integrates smoking, brining, lemongrass extract, sensory evaluation, proximate analysis, microbial shelf-life testing, and packaging development into a single product-development approach. Overall, the study demonstrates how a locally available aquatic species may be transformed into a consumer-acceptable, nutritionally relevant, and economically feasible smoked fish product.

## 2. Material and methods

### 2.1 Research Design

The study employed an experimental product-development design to evaluate the acceptability of smoked rice eel flavored with lemongrass extract using different brine solution levels. The product was assessed in terms of color, aroma, texture, and taste, while additional evaluations included acceptability composite index, proximate composition, shelf life, packaging and labeling, and economic feasibility. The treatments consisted of a control using smoked tilapia in 20% brine solution and three smoked rice eel treatments using lemongrass extract with 5%, 10%, and 20% brine solutions.

### 2.2 Locale of the Study

The study was conducted at A.R. Santiago Fish Farm, Gaddanan, San Mateo, Isabela in April 2023. The rice eel was purchased from a kiwet consolidator in Barangay Victoria, San Mateo, Isabela, and transported to the processing site. The microbial analysis was conducted at the Protein Chemistry and Biosensor Laboratory, Central Laboratory, College of Arts and Sciences, Isabela State University – Main Campus, San Fabian, Echague, Isabela from April to May 2023. Samples for proximate composition were submitted to the Integrated Laboratory Division, Department of Agriculture Regional Field Office II, Tuguegarao City, Cagayan.

### 2.3 Respondents of the Study

The respondents of the study were 50 sensory panelists who evaluated the acceptability of the smoked fish products. They were composed of students, professionals, non-professionals, and housewives, with ages ranging from 15 to 50 years old. The respondents evaluated the prepared products based on color, aroma, texture, and taste using the hedonic scale rating system.

### 2.4 Sample and Sampling Procedure

The raw materials consisted of rice eel with an average weight of 250–300 grams each and tilapia used as the control. Approximately 1.5 kilograms of fish was used per treatment. The control treatment used 1.5 kilograms of tilapia with 200 grams of salt and 1000 ml of water, while the rice eel treatments used 1.5 kilograms of rice eel with 1000 ml of lemongrass extract and varying salt levels: 50 grams for the 5% brine solution, 100 grams for the 10% brine solution, and 200 grams for the 20% brine solution. The manuscript identified the panelists by category and age range but did not specify a named sampling technique for respondent selection.

### 2.5 Research Instrument

The primary research instrument was the sensory evaluation form using the 9-point hedonic scale rating system. The panelists rated the product based on color, aroma, texture, and taste, with ratings ranging from “dislike extremely” to “like extremely.” The acceptability composite index was also used to determine the general acceptability and ranking of each treatment based on the weighted percentage allotted to color, aroma, texture, and taste. The ACI procedure was based on Reyes (2019). Laboratory procedures were also used for proximate analysis and microbial shelf-life testing, including Total Plate Count following FAO 1992 procedures (FAO, 1992).

### 2.6 Data Gathering Procedure

The rice eel was cleaned by applying salt to remove slime, then beheaded, gutted, split, washed thoroughly, and drained. Tilapia was eviscerated and used as the control. Lemongrass was obtained from the vicinity of A.R. Santiago Fish Farm, chopped, weighed, and boiled in water for 30 minutes using a 1:1 ratio of 100 grams of chopped lemongrass to 1 liter of water. The mixture was strained to obtain the lemongrass extract. Preliminary testing initially used 10%, 20%, and 30% brine solutions, but the 30% solution was considered too salty; therefore, the treatments were adjusted to 5%, 10%, and 20% brine levels. The prepared fish samples were soaked in their respective brine solutions for 20 minutes, with flipping after 10 minutes. The soaked fish was steamed for 5–10 minutes, arranged in smoking trays, and sun-dried for 15–30 minutes to remove excess moisture. The smoking chamber was preheated using sawdust as fuel, and the steamed and dried rice eel was smoked for 1–2 hours at 66°C to 88°C or until golden brown (BFAR). After smoking, the product was weighed to determine recovery weight, cooled, and packed in vacuum-sealed polyethylene bags. After product preparation, sensory evaluation was conducted with 50 respondents. The cooked product was served to the panelists, who rated each treatment based on color, aroma, texture, and taste. The respondents were instructed to drink water before and after rating each treatment. The treatment with the highest acceptability among the rice eel products was subjected to proximate analysis for moisture, ash, protein, fat, and fiber. Shelf-life testing was conducted by storing the vacuum-packed smoked rice eel at 4°C and analyzing microbial quality at 0, 8, 16, 24, and 32 days. The microbial analysis involved serial dilution, spread plate counting, incubation, and colony counting. Packaging, labeling, name, and logo were also developed to support product recognition, quality consistency, and market presentation.

### 2.7 Data Analysis Techniques

The sensory evaluation results were analyzed using the mean scores based on the 9-point hedonic scale. The acceptability composite index was computed using the weighted percentages for color, aroma, texture, and taste to determine the overall ranking of the treatments. Proximate composition was analyzed through laboratory testing, while shelf life was evaluated through Total Plate Count and microbial monitoring. Economic feasibility was determined through cost and return analysis, including gross sales, total projected cost, net income after tax, return on investment, and payback period. All data were analyzed using analysis of variance through the Statistical Package for Social Sciences (SPSS) 10.0 for Windows at $p<0.05$ significance level, and Tukey HSD Test was used after ANOVA to determine specific significant group differences.

## 3. Results and Discussion

### 3.1 Sensory Acceptability of Smoked Rice Eel Flavored with Lemongrass Extract

#### 3.1.1 Color Acceptability

The color acceptability results showed that the control treatment obtained the highest mean rating of 7.80, interpreted as "like very much," followed by Treatment 2 with 7.54, Treatment 1 with 7.12, and Treatment 3 with 6.88. The control, Treatment 1, and Treatment 2 were all described as "like very much," while Treatment 3 was described as "like moderately." In terms of color acceptability, the control was higher by 13%, 10%, and 3% compared to Treatment 3, Treatment 1, and Treatment 2, respectively. The result suggests that color remained an important sensory factor in determining the acceptability of smoked fish products. Color has a direct influence on flavor perception because visual cues may lead consumers to anticipate taste and quality even before actual consumption. This supports the idea that color, aroma, texture, taste, chemical components, and food safety are among the factors used to identify the quality of fish fillets (Robb, 2010). The favorable color rating of Treatment 2 also indicates that smoked rice eel with 10% brine solution and lemongrass extract produced a visually acceptable product among the rice eel treatments.

#### 3.1.2 Aroma Acceptability

The aroma acceptability results showed that the control treatment obtained the highest mean rating of 7.52, followed closely by Treatment 2 with 7.50, Treatment 3 with 7.26, and Treatment 1 with 7.06. All treatments were interpreted as "like very much," indicating that the respondents generally accepted the aroma of both the control and smoked rice eel treatments. In terms of aroma acceptability, the control and Treatment 2 were higher by 4% compared to Treatment 1 and Treatment 3. The findings indicate that lemongrass extract may have helped improve the aroma of smoked rice eel, particularly because rice eel is known for its strong odor. The addition of plant leaves enhanced the odor of the fish, and lemongrass is described as a native aromatic tall sedge/grass (Srivastava et al., 2013). Since lemongrass contains aromatic oil and bioactive compounds associated with flavoring and natural preservation, its use in smoked rice eel may have contributed to improved sensory appeal. This is consistent with the observation that smoked surgeon fish Acanthurus sp. treated with lemongrass was the most preferred and generally accepted by cook panelists (Openia et al., 2017).

#### 3.1.3 Texture Acceptability

The texture acceptability results showed that the control treatment obtained the highest mean rating of 7.64, interpreted as "like very much," followed by Treatment 2 with 7.46 and Treatment 1 with 7.34, both also interpreted as "like very much." Treatment 3 obtained the lowest mean rating of 6.80, interpreted as "like moderately." In terms of texture acceptability, the control was higher by 12%, 4%, and 2% compared to Treatment 3, Treatment 1, and Treatment 2, respectively. The result implies that the smoked rice eel treatments were generally acceptable in texture, although higher brine concentration may have reduced acceptability in Treatment 3. Smoking has been known to affect the weight, texture, color, flavor, aroma, and general acceptability of finished products (Cardinal et al., 2001; Abolagba and Osifo, 2008; Tawari and Abowei, 2011; Nwakuba et al., 2018). The preparation of smoked rice eel through salting, drying, heating, and smoking may have contributed to textural development, while the 10% brine level appeared to produce the most acceptable texture among the rice eel treatments.

#### 3.1.4 Taste Acceptability

The taste acceptability results showed that the control treatment obtained the highest mean rating of 7.68, interpreted as "like very much," followed by Treatment 2 with 7.48, also interpreted as "like very much." Treatment 1 obtained a mean rating of 7.18, interpreted as "like moderately," while Treatment 3 had the lowest rating of 6.30, interpreted as "like slightly." In terms of taste acceptability, the control was higher by 22%, 7%, and 3% compared to Treatment 3, Treatment 1, and Treatment 2, respectively. The findings suggest that the 10% brine solution with lemongrass extract produced the most acceptable taste among the smoked rice eel treatments. Lemongrass oil is used to flavor foods and is found in major food categories, including beverages, desserts, baked goods, meat and animal products, and fats and oils (Chevallier, 2001). The presence of antibacterial and antioxidant chemicals in smoke also contributes to the preservative effect and gives smoked fish its distinct color and flavor (Hattula et al., 2001; Martinez et al., 2007; Muratore et al., 2007). Thus, the combination of smoking, brining, and lemongrass extract may have contributed to the favorable taste acceptability of Treatment 2.

#### 3.1.5 Overall Acceptability and Acceptability Composite Index

The overall acceptability results showed that the control treatment obtained the highest rating of 7.66, followed by Treatment 2 with 7.50, Treatment 1 with 7.23, and Treatment 3 with 6.81. The control and Treatment 2 were interpreted as "like very much," while Treatment 1 and Treatment 3 were interpreted as "like moderately." Based on the Acceptability Composite Index, the control ranked first, Treatment 2 ranked second, Treatment 1 ranked third, and Treatment 3 ranked fourth. The overall findings indicate that while the control treatment remained the most accepted product, Treatment 2 was the most preferred among the smoked rice eel treatments. The higher acceptability of Treatment 2 suggests that the 10% brine solution with lemongrass extract provided a better balance of color, aroma, texture, and taste. Brining is a preliminary preparatory stage before eels are smoked, and larger eels should be immersed in a 10% brine solution for half an hour (Forrest, 1976; Lane, 1978) as cited by Karakoltsidis, et al., 1995. Overall, smoked eel flavored with lemongrass extract in different levels of brine solutions could potentially contribute to improved hedonic acceptability, particularly when the brine concentration is properly controlled.

### 3.2 Proximate and Nutritional Composition of Smoked Rice Eel

#### 3.2.1 Proximate Composition

The treatment with the highest acceptability among the rice eel products, Treatment 2, was subjected to proximate analysis. The results showed that smoked rice eel flavored with lemongrass extract in 10% brine solution contained 21.68% crude protein, 0.79% crude fiber, 1.07% crude fat, 67.26% moisture, and 5.73% ash. The proximate composition indicates that the product had notable protein content and high moisture content, with relatively low crude fat. The chemical composition of fish varies greatly from one species and individual to another depending on sex, age, environment, and season, resulting in normal variation in fish muscle constituents (Yeannes and Almandos 2003). Moisture, protein, fat, and ash constitute 96–98% of fish body composition (Rani et al., 2016). Crude protein represents the total nitrogen content of the product (Jiang et al., 2014), crude fiber quantifies cellulose, hemicellulose, and lignin and contributes to the nutritional value of food (Ogunlakin et al., 2012), crude fat may be associated with oxidative spoilage and shelf-life quality (Ojo et al., 2014), and moisture proportion is an indicator of calorie, protein, and fat levels (Barua et al., 2012).

#### 3.2.2 Nutritional Composition

The nutritional composition of smoked rice eel in 10% brine solution showed that a 130-gram serving provided 6% of the recommended energy intake and 40% of the recommended protein intake. The product contained 147 kcal of energy, 13 kcal from fat, 1 gram of total fat, 6 grams of total carbohydrates, 1 gram of crude fiber, and 28 grams of total protein. These findings indicate that smoked rice eel flavored with lemongrass extract may serve as a protein-rich value-added fish product. Its 28 grams of total protein per serving supports its nutritional relevance, while the low total fat content suggests that the product may be acceptable for consumers seeking fish-based protein sources. The nutritional result further supports the potential of rice eel processing as a means of improving the use of a locally available aquatic resource.

### 3.3 Shelf Life and Microbial Quality

The microbial test showed that the total plate counts of smoked tilapia and smoked rice eel treatments packed individually in vacuum-sealed packaging and stored at refrigerated temperature of 4°C were less than 100 colony-forming units from week one to week four. This indicates that the smoked eel remained microbiologically acceptable within four weeks of refrigerated storage. The result suggests that vacuum sealing, refrigeration, smoking, brining, and lemongrass extract may have contributed to product stability during storage. Vacuum packaging may reduce microbial counts and extend shelf life (Daley and Deng, 1978) as cited by Kumar and Ganguly (2014) and may delay microbial spoilage (Mendonca et al., 1989). Lemongrass (Cymbopogon citratus) leaves essential oil has been found to help extend the shelf life of fish balls during refrigerated storage by decreasing microbial load and improving sensory attributes such as flavor, taste, color, texture, and overall acceptability (Kamona et al., 2021). Lemongrass essential oil has also been reported to prolong the shelf life of seafood by retarding bacterial growth and lipid oxidation while maintaining sensory quality (Masniyom et al., 2012). Related findings also show that smoked tilapia can be safely stored under refrigerated conditions for over 35 days (Yanar et al., 2006), and treatment with lemon grass extract could extend shelf life by approximately three times at ambient temperature and four times at chilled storage (Chaiyawat et al., 2008). Several studies have examined the effectiveness of lemongrass essential oil as a substitute for synthetic preservatives in food industries (Abd-El Fattah et al., 2010; Belewu et al., 2012), and its antimicrobial, antifungal, and organoleptic conserving activities make it a good candidate for biopreservation and storage of food (Abdulazeez, M. A., 2016).

### 3.4 Packaging, Labeling, Name, and Logo

The product packaging and labeling included a logo, trademark name, list of ingredients, manufacturing date, manufacturer information, nutrition facts, net weight, contact details, and storage instruction indicating that the product should be kept frozen. These elements were designed to support product recognition, quality consistency, and consumer information.

The packaging result indicates that the product was developed not only as a laboratory-tested food item but also as a market-oriented value-added product. The finished product was packed in vacuum-sealed and properly labeled packaging. Vacuum packaging is a static form of hypobaric storage widely used in the food industry because it reduces oxidative reactions at relatively lower cost by sealing the product in low-oxygen-permeability material after air evacuation, Kumar, Purushotam and Ganguly, Subha (2014). Effective vacuum packaging reduces oxygen and limits the growth of microorganisms that require oxygen, while proper packaging can also minimize physical damage and help control enzymatic and biochemical reactions. As consumers focus more on healthier and more natural foods, they demand packaging that is better aligned with the ingredients contained in the product (Evergreen Packaging, 2018; Wiley, 2018) as cited in Gordon Adré (2020).

### 3.5 Cost and Return Analysis

The cost and return analysis showed that all treatments were economically feasible, with return-on-investment values above 50%. The control treatment obtained the highest ROI at 53.23%, followed by Treatment 1 with 53.17%, Treatment 2 with 53.09%, and Treatment 3 with 52.94%. Although the control treatment had the highest financial return, the differences among treatments were minimal, indicating that smoked rice eel flavored with lemongrass extract remained profitable under the conditions of the study. The higher ROI of the control treatment may be attributed to lower processing cost and the wider market familiarity of tilapia as a processed fish product. In aquaculture and fish processing enterprises, profitability is influenced by raw material cost, labor, processing inputs, and market demand (Tran et al., 2022). The slightly lower ROI of smoked rice eel treatments may be associated with additional inputs, such as lemongrass extract preparation and varying brine solution levels, which may increase production cost and slightly reduce net returns in value-added fish products (Johnson et al., 2023). Nevertheless, the profitability of all treatments indicates commercialization potential. Cost and return analysis is important in determining the economic feasibility of fish processing enterprises because it allows producers to assess whether product income can cover expenses and generate profit (Sabandana, 2016).

## 4. Conclusion & Recommendations

Based on the findings, the processing of smoked rice eel flavored with lemongrass extract was found to be viable, acceptable, nutritious, shelf-stable under refrigerated storage, and economically feasible. The control treatment remained the most preferred in terms of color, aroma, texture, and taste; however, among the smoked rice eel treatments, Treatment 2, prepared with lemongrass extract and 10% brine solution, obtained the highest acceptability. The Acceptability Composite Index ranked the control first, followed by Treatment 2, Treatment 1, and Treatment 3. The proximate analysis showed that smoked rice eel in 10% brine solution contained 21.68% crude protein, 0.79% crude fiber, 1.07% crude fat, 67.26% moisture, and 5.73% ash. The product was also found safe for up to four weeks when vacuum-sealed and stored at 4°C, while the processing of smoked rice eel showed economic feasibility with a 53.17% return on investment.

Further studies should be conducted to improve smoked rice eel flavored with lemongrass extract using different levels of brine solution. Specifically, future research should conduct microbiological analysis beyond one month to determine the product's longer storage stability and should also explore brine concentrations between 10% and 20% to further improve the acceptability, quality, and overall processing potential of smoked rice eel flavored with lemongrass extract.

The study was limited mainly to the acceptability evaluation of smoked rice eel flavored with lemongrass extract in different levels of brine solution, specifically in terms of color, aroma, texture, and taste. The sensory evaluation was conducted among selected panelists composed of students, professionals, non-professionals, and housewives aged 15 to 50 years old; therefore, the findings reflect the responses of these evaluator groups only. The study was also limited to the product formulations, processing conditions, storage period, and laboratory analyses conducted within the stated scope of the manuscript.

## Compliance with ethical standards

The study was conducted in accordance with institutional ethical standards and responsible research practices. Participation in the sensory evaluation was voluntary, and the respondents were properly informed about the purpose of the study and their role in evaluating the product before giving their consent to participate. All information gathered from the respondents was treated with confidentiality and used solely for academic and research purposes. The conduct of the study, including product preparation, sensory evaluation, laboratory analysis, and data treatment, followed appropriate institutional procedures and ethical considerations. The author declares that there was no conflict of interest in the conduct, analysis, and reporting of the study

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