

Effect of Stirring Technique Variations and Roasting Time on the Chemical, Microbiological, and Sensory Characteristics of Shredded Spiced Fish

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ABSTRACT

Lampung Province is known as one of the producers of freshwater fish in Indonesia, with Ranau tilapia as its superior commodity. This fish is known for its thick, dense flesh and free from muddy odor, making it very suitable for use as a raw material for processed value-added products such as shredded spiced fish. However, traditional production methods still have limitations in terms of efficiency and risk of contamination. This study aims to determine the interaction and optimal results between mechanical and conventional stirring methods combined with five variations of roasting time (60, 75, 90, 105, and 120 min). Fresh Ranau tilapia was mixed with selected spices and processed based on these variations. The results showed that the interaction between stirring technique and roasting time significantly influenced the chemical, microbiological, and sensory characteristics of the final product. Optimal treatment, stirring using a machine for 105 min (M2S4), produces shredded spiced fish that meets the Indonesian National Standard (SNI), with a moisture content of 9.80%, ash content of 4.06%, protein content of 38.57%, and microbiological safety of 1.53 log CFU/g. Sensory evaluation also shows a high level of consumer acceptance. This technological innovation increases production efficiency, ensures consistent product quality, and becomes a reference model for MSMEs in developing a competitive and sustainable local food industry.

1. INTRODUCTION

Lampung Province is known as one of the producers of freshwater fish in Indonesia, which contributes to the national level. This is inseparable from each district or city in Lampung Province that produces several freshwater fish commodities. One of the famous areas is the Ranau Lake area, Lumbok Seminung District, which is located on the border of West Lampung Regency, Lampung Province, and South Ogan Komering Ulu (OKU) Regency, South Sumatra Province. The freshwater fish commodity that is widely cultivated by the local community and has become an attraction in Lake Ranau is tilapia. The specific tilapia (*Oreochromis niloticus*) cultivated in Lake Ranau is Ranau tilapia.

Ranau tilapia has become a typical fishery commodity in the region. Ranau tilapia is also considered superior to other types of tilapia. This is supported by research from Wibowo *et al.* (2021), which states that tilapia from Lake Ranau is larger in size, has thicker, denser meat, and does not smell like mud. Ranau tilapia also has a higher organoleptic value compared to tilapia from community ponds. Therefore, further processing of Ranau tilapia can add value to this commodity. Further processing of Ranau tilapia, which has advantages in terms of organoleptic properties, nutrition, and size, has the potential to be made into shredded fish with added spices. Shredded spiced fish can be defined as a food product in the form of dry fibers. Shredded spiced fish processing is one of the innovative preservation technologies because fish are prone to spoilage. Generally, shredded fish can be stored for 5-8 months (Wangsa *et al.*, 2021).

Based on information from [Sartika et al. \(2024\)](#), regarding innovations in the process of making shredded spiced fish and after conducting sensory tests, it was found that the panelists liked the product because it had a smooth texture, a very distinctive shredded spiced fish aroma, a yellowish-brown color, and a very distinctive shredded spiced fish taste. In the production of shredded spiced fish, there are still obstacles, especially in the roasting process, which is done traditionally and without certainty in determining the roasting time. Roasting process needs to be considered because it is the final stage in the production of shredded spiced fish and plays a role in determining the product characteristics.

Problems in the process of roasting shredded spiced fish are feared to produce suboptimal products, especially when done on a large scale, where workers are more prone to fatigue, thus increasing the possibility of contamination during the stirring process. In addition, the duration of roasting is also important in determining the optimal time to produce shredded spiced fish with the desired characteristics. Based on this information, the production process of shredded spiced fish, especially the roasting process, must be carefully considered, such as considering the use of a stirring machine or a conventional stirrer by determining variations in roasting time.

Therefore, this study aims to determine the interaction and the best results of shredded spiced fish between the use of a stirring machine and conventional stirring combined with five different roasting times (60, 75, 90, 105, and 120 min) based on chemical, microbiological, and sensory tests. This research is also expected to provide a scientific basis for the development of an efficient shredded spiced fish stirring machine that meets industry needs. The development of a stirring machine (Figure 1) is a strategic step to support the food industry, especially micro, small, and medium enterprises (MSMEs), in improving product efficiency and quality consistency. This innovation is expected to help businesses face the challenges of large-scale production in a more controlled, hygienic, and labor-saving manner. Thus, the results of this study can be a practical reference for MSMEs in adopting appropriate technology to produce high-quality, competitive, and marketable shredded spiced fish products in the national market.

2. RESEARCH MATERIALS AND METHODS

2.1. Materials and Equipments

The main ingredient used in this study was fresh Ranau tilapia (*Oreochromis niloticus*) sized of $\pm 300\text{g}$ and $\pm 30\text{cm}$ each. Additional ingredients included lemongrass, galangal, ginger, coriander, pepper, lime leaves, bay leaves, turmeric, chili peppers, shallots, garlic, salt, sugar, mushroom broth, and coconut milk. The main and additional ingredients were obtained from Way Halim Market, Bandar Lampung. The materials used for analysis were HgO , K_2SO_4 , H_2SO_4 , NaOH , $\text{Na}_2\text{S}_2\text{O}_3 \cdot \text{H}_2\text{O}$, H_3BO_3 , pp indicator, 0.02 N HCl, 96% ethanol, NaOH, sterile NaCl, distilled water, and PCA media.

Shredded spiced fish was produced using a LPG-fueled rose burner completed with vertical-type stirring machine (Figure 1). The machine was equipped with single curved blade rotated using a vertical shaft to mix the material along the vessel contour, yielding consistent and controllable mixing. A curved impeller was selected because it promotes bulk recirculation throughout the frying pan, improving mixture homogeneity and shortening mixing time ([Taufikurahman, 2020](#); [Amru et al., 2015](#)).

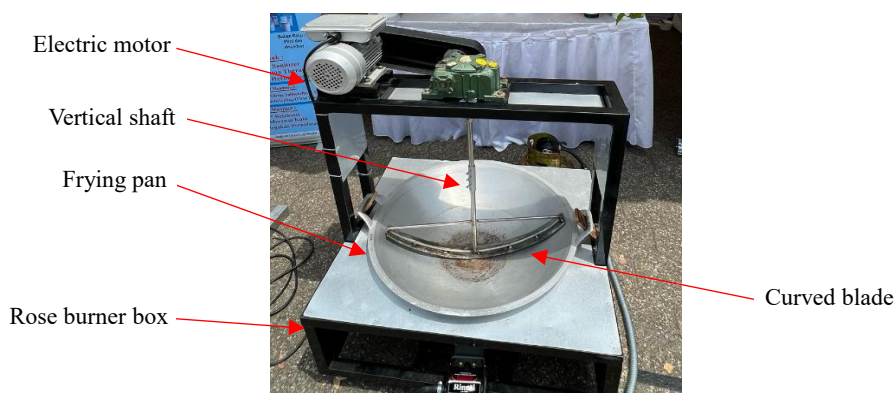


Figure 1. Stirring machine used to produce shredded spiced fish

The research was conducted across several laboratories at the Faculty of Agriculture, University of Lampung, and was supported by external veterinary testing facilities in Bandar Lampung. The production, packaging, and storage of shredded spiced fish samples were carried out in the Agricultural Product Processing Laboratory, Department of Agricultural Product Technology. Chemical analyses of the shredded spiced fish were performed in the Agricultural Product Analysis Laboratory, Department of Agricultural Product Technology, and were also supported by the Animal Nutrition and Feed Laboratory, Department of Animal Husbandry, University of Lampung. Sensory evaluation of the samples was conducted in the Sensory Laboratory, Department of Agricultural Product Technology. Microbiological analyses to assess product safety and hygiene were conducted at the Veterinary Public Health Laboratory, Regional III Veterinary Investigation and Testing Center (BPPV) in Bandar Lampung.

2.2. Shredded Spiced Fish Preparation

Shredded spiced fish was prepared using the best formulation reported by [Sartika *et al.* \(2024\)](#). Before processing, gutted and washed tilapia were marinated in a 10% salt solution with 5% lime juice for 15 min. All spices were peeled and rinsed with clean water. Processing comprised three stages. Stage 1, marinated tilapia was steamed for 15 min at ± 100 °C. Cooked flesh was separated from bones and spines, weighed, and hand-shredded. Stage 2, spices (galangal, ginger, chili, shallots, garlic, turmeric, coriander seed, and black pepper) were blended to a paste, and blending was facilitated by the addition of fish stock. Stage 3, shredded tilapia was combined with the spice paste and dry-roasted while gradually adding coconut milk, salt, sugar, lime juice, mushroom stock powder, lemongrass, bay leaves, and kaffir lime leaves. Roasting was carried out at 80–100 °C for 60, 75, 90, 105, or 120 min according to the assigned treatment. The finished shredded spiced fish was then subjected to analysis.

2.3. Experimental Design and Analysis Methods

The research design used a completely randomized factorial design with two factors and three replicates. The first factor was the type of stirrer (M), which consisted of two levels, a conventional stirrer (M1) and a stirring machine (M2). The second factor was the roasting time (S), which consisted of 5 levels, namely 60 min (S1), 75 min (S2), 90 min (S3), 105 min (S4), and 120 min (S5). In this study, ten (10) treatment combinations were tested, namely (M1S1), (M1S2), (M1S3), (M1S4), (M1S5), (M1S6), (M1S7), (M2S1), (M2S2), (M2S3), (M2S4), and (M2S5). The characteristics of shredded spiced fish were determined through several tests, including AOAC methods for moisture content, ash content, protein content ([Latimer Jr., 2019](#)), total plate count microbiology test ([SNI, 2015](#)), and sensory tests including color, aroma, taste, texture, and overall acceptance. As many as 25 panelists were voluntarily selected from semi-trained students from the Department of Agricultural Product Technology who had taken sensory testing courses who have no sensory impairments.

The data obtained were tested for homogeneity using the Bartlett test and for data additivity using the Tukey test. The data were then analyzed using analysis of variance (ANOVA) to obtain an estimate of the error range and determine the effect of treatments. The data were then further tested for Honestly Significant Difference (HSD) at the 5% level using Minitab Statistical Software 22. Furthermore, the best treatment was determined using the method of [DeGarmo *et al.* \(1994\)](#). The best treatment was determined by comparing the product value of each treatment using an effectiveness index determined by experts. The treatment with the highest product value (NP) was selected as the best treatment because this value was obtained by considering all variables that play a role in determining product quality, both chemically, microbiologically, and sensorily.

3. RESULTS AND DISCUSSION

3.1. Moisture Content

Analysis of variance (ANOVA) results showed that variations in stirring technique (M), roasting time (S), and the interaction between these factors significantly affected the moisture content of shredded spiced fish ($p < 0.05$). The observed moisture contents ranged from 5.4944% to 25.5009%. HSD test (Table 1) indicated that all treatments were significantly different from each other. The interaction between the type of device used for stirring and cooking time was particularly relevant to the moisture content of shredded spiced fish, particularly in relation to compliance with the

Indonesian National Standard (SNI) for shredded fish 7690:2019, which sets a maximum moisture content of 15%. The type of stirrer and cooking time play an important role in determining the moisture content of shredded spiced fish.

The highest moisture content above the SNI limit was recorded for treatments M1S1, M2S1, and M2S2, with 25.5009%, 18.8012%, and 16.8892%. In contrast, the M1S5 treatment showed the lowest moisture content of 5.4944%. These results indicate that the type of stirring and roasting time play an important role in the effective moisture reduction in shredded spiced fish. The type of stirring used in the production of shredded spiced fish can affect the heat distribution during the process. Furthermore, the variation of roasting time is very important, as the ability of products to retain moisture due to direct contact with pan heat accelerates moisture loss (Deni *et al.*, 2024).

This study observed significant differences in the total moisture content of marinated raw fish due to differences in heat dissipation capacity between different stirrer types. While stirrer machines offer advantages in maneuverability and efficiency, their operating system, which frequently changes ingredients without completely replacing them, can prevent some ingredients from coming into direct contact with the pan surface. This results in better stability and less water loss compared to conventional stirrer methods. This is consistent with the results of research by Sudarsono *et al.* (2021), which showed that mixing improves material adhesion and heat transfer efficiency. Conventional stirrer processes require frequent mixing. Consequently, greater contact between the ingredients and the pan surface results in a more rapid and drastic reduction in moisture content as the roasting time increases. Furthermore, differences in the surface area and volume of ingredients can also affect heat transfer efficiency during the drying process. This observation is supported by research by Hakim (2016), which states that surface area significantly affects the rate of heat transfer.

Table 1. Chemical characteristics of shredded spiced fish

Sample	Moisture Content (%)	Ash Content (%)	Protein Content (%)
	$\alpha_{(0,05)} = 0.515$	$\alpha_{(0,05)} = 1.1342$	$\alpha_{(0,05)} = 6.662$
M1S1	25.50±0.10 ^a	2.24±1.33 ^d	28.57±2.59 ^d
M1S2	16.89±0.11 ^c	3.42±0.66 ^{bc}	30.65±1.50 ^{bcd}
M1S3	10.27±0.08 ^{ef}	3.94±0.95 ^{abc}	37.04±5.49 ^{ab}
M1S4	7.53±0.16 ^h	4.51±0.59 ^{ab}	32.13±3.91 ^{abcd}
M1S5	5.49±0.29 ⁱ	4.91±0.88 ^a	29.72±6.50 ^{cd}
M2S1	18.80±0.13 ^b	3.23±0.82 ^{cd}	30.26±5.21 ^{cd}
M2S2	11.08±0.06 ^d	3.73±0.93 ^{bc}	34.60±1.41 ^{abcd}
M2S3	10.74±0.18 ^{de}	3.89±0.97 ^{abc}	35.90±3.05 ^{abc}
M2S4	9.79±0.23 ^f	4.07±0.85 ^{abc}	38.57±2.20 ^a
M2S5	8.27±0.21 ^g	4.26±0.72 ^{abc}	37.16±1.07 ^{ab}

Note: values followed by different superscript letters (a, b, c, d, e) within the same column indicate significant differences at 0.05 significance level.

3.2. Ash Content

Analysis of variance (ANOVA) results showed that the variation in stirring technique (M) has no significant effect (p -value > 0.05) on the ash content of shredded spiced fish. However, the roasting time (S) and the interaction between the type of stirring machine and roasting time have a significant effect (p -value < 0.05). The HSD test (Table 1) shows that the differences between treatments resulted in ash content ranging from 2.2445% to 4.9073%. All treatments met the requirements of the Indonesian National Standard (SNI) for shredded products 01-3707-1995, which is still below the maximum limit of 7%. Ash content testing is very important for evaluating processing quality, material type, and nutritional parameters, and for verifying the authenticity of the product. The ash content value reflects the proportion of minerals in the dry matter, but does not always indicate the addition of minerals during processing. Changes in ash content observed during the roasting process are usually caused by water evaporation.

The interaction between stirrer type and roasting time significantly affected the ash content of shredded spiced fish. The use of a conventional stirrer with a roasting time of 120 min (M1S5) resulted in the highest ash content of 4.9073%. It is clearly seen that as the roasting time increases, the percentage of ash content increases due to water evaporation, with values recorded as 3.9407% at 90 min (M1S3) and 4.5104% at 105 min (M1S4). Meanwhile, the stirrer machine also showed an increase in ash content with longer roasting time, but this increase was more stable compared to the

conventional stirrer. The highest ash content in the stirring machine was recorded as 4.2575% at 120 min (M2S5), followed by 4.0667% at 105 min (M2S4) and 3.8948% at 90 min (M2S3). This suggests that the use of conventional stirrers for longer roasting times led to water evaporation and increased the proportion of ash content in the dry matter. In summary, the ash content tended to increase with longer annealing times in both types of stirrers. This observation is in line with [Ghaisani *et al.* \(2023\)](#) that food processing significantly affects mineral availability. Longer cooking durations and higher temperatures increase water evaporation and ash content.

The lowest ash content occurred at the roasting time of 60 min, with the conventional stirrer (M1S1) producing an ash content of 2.2445% and the stirrer machine (M2S1) showing an ash content of 3.2330%. This suggests that shorter annealing durations in conventional stirrers or stirrer machines result in lower ash content. The low ash content indicates the presence of higher water content in the material. This finding is in line with the study by [Safarianti *et al.* \(2022\)](#), who stated that ash content is inversely proportional to water content products with high water content tend to have low ash content. Moreover, low ash content can arise from the bond decomposition of water molecules (H₂O) and imperfect water evaporation ([Lisianti *et al.*, 2022](#)).

3.3. Protein Content

Analysis of variance (ANOVA) results showed that the changes in stirring technique (M), roasting time (S), and their interaction had a significant effect (p -value < 0.05) on the protein content of shredded spiced fish. Based on HSD test (Table 1), the differences between treatments showed that the protein content ranged from 28.57% to 39.69%. The type of stirring technique and roasting time also significantly affected the protein content of shredded spiced fish. A change of 60 min (M1S1) using the conventional stirrer resulted in a significant decrease of protein content (28.56%). The protein content percentage was highest at 37.04% at a roasting time of 90 min, but decreased to 29.72% at a longer time (120 min). This indicates that excessive cooking in food processing can significantly reduce protein content.

Meanwhile, in the stirrer machines, the 60-minute treatment (M2S1) produced the lowest protein content of 30.25%. The highest protein content was recorded at a roasting time of 105 min (M2S4) at 38.57%, and decreased again at 120 min (M2S5) to 37.15%. Based on this data, shredded spiced fish processed with a stirrer machine tends to have a more stable protein content compared to conventional stirrer, especially at longer roasting durations. The stability in maintaining the protein content in shredded spiced fish occurs because the stirrer has an automatic stirring system that always mixes consistently. This finding aligns with the research by [Feng *et al.* \(2024\)](#), that an automatic stirrer can consistently stir and heat ingredients during the cooking process, thereby optimizing cooking results.

The change in protein content during the roasting process is primarily due to a decrease in moisture content, not the addition of new proteins. This phenomenon is consistent with the research of [Aisah *et al.* \(2021\)](#), which explains that the evaporation of moisture from food makes protein-containing solids more concentrated. Meanwhile, the application of heat during food processing can cause protein denaturation (in myofibrils, sarcoplasm, and interstitium), which can change the amino acid structure and hydrophobic interactions within proteins and reduce the moisture content of muscle fibers. As a result, some proteins may coagulate and lose solubility, resulting in a decrease in the total protein content of the product. This finding is consistent with those of [Ajima *et al.* \(2024\)](#) and [Nguju *et al.* \(2018\)](#), who also found that prolonged heating can reduce protein content and trigger the Maillard reaction. This is evident from the results of processing shredded spiced fish using different stirrers and roasting for 120 min. Continuous heating can damage the protein's integrity, resulting in a decrease in protein content.

The decrease in protein content is closely related to the protein denaturation process, which primarily alters the secondary, tertiary, and quaternary structure of proteins upon exposure to heat. The heating process disrupts the hydrogen bonds that support the secondary and tertiary structures of proteins, causing the hydrophobic sides of the polypeptide side chains to open up. High temperatures increase kinetic energy, causing the molecules that make up proteins to move quickly and disrupting the bonds between these molecules. As a result, the ability of proteins to bind water is reduced due to the disruption of non-covalent interactions in the natural structure of proteins without breaking their covalent bonds, peptide bonds. In addition, protein solubility also decreases, causing protein precipitation and coagulation ([Hanum, 2018](#); [Wahyudiati, 2017](#)). According to the Indonesian National Standard (SNI) 7690:2019 on shredded spiced fish ([BSN, 2019](#)), shredded spiced fish must have a minimum protein content of 30% to meet quality standards. The treatment used in this study generally exceeded these requirements, mainly because tilapia contains about 43.76%

protein (Saputra *et al.*, 2020). The protein content in the shredded spiced fish produced is also comparable to the findings of other studies, such as a study that recorded 33.60% protein in fried tilapia shredded spiced fish (Alik *et al.*, 2014). Overall, this research confirms that shredded spiced fish has high protein quality.

3.4. Total Plate Count (TPC)

Analysis of variance (ANOVA) results showed that the variation in stirring technique (M) has no significant effect (p -value > 0.05) on the total plate count value of shredded spiced fish. Conversely, roasting time (S) and the interaction between the type of stirring machine and roasting time had a significant effect (p -value < 0.05) on the total plate count value of shredded spiced fish. Based on Tukey's HSD test (Table 2), the differences between treatments resulted in total plate counts ranging from 1.058 to 2.8056 log CFU/g.

Table 2. Microbiological characteristics (Total Plate Count) of shredded spiced fish

Sample	TPC (Log CFU /g) $\alpha_{(0,05)} = 0.454$
M1S1	2.81±0.42 ^a
M1S2	2.37±0.49 ^{abc}
M1S3	1.76±0.07 ^{de}
M1S4	1.06±0.10 ^f
M1S5	1.06±0.10 ^f
M2S1	2.50±0.45 ^{ab}
M2S2	2.18±0.48 ^{bcd}
M2S3	2.01±0.47 ^{cd}
M2S4	1.53±0.13 ^e
M2S5	1.56±0.21 ^e

Note: values followed by different superscript letters (a, b, c, d, e) within the same column indicate significant differences at 0.05 significance level.

Based on SNI 7690:2019 for shredded spiced fish (BSN, 2019), the total plate count value of shredded spiced fish that meets the quality standard is a maximum of 5×10^4 CFU/g. All treatments in this study met the SNI requirements because the values were below the maximum limit set. The results of the study show that the treatment with highest TPC value was M1S1 (conventional stirrer, 60 min) with a value of 2.8056 log CFU/g, which indicates the highest number of microbes compared to other treatments. This indicates that conventional stirrers and machine stirrers with shorter roasting times, especially 60 and 75 min, produce high TPC values. This is in line with Kasmianti *et al.* (2020) that processed fish products, such as shredded fish that have undergone high-temperature heating, are relatively sterile from bacteria but still have the potential to be contaminated with bacteria through cross-contact, especially during the cooling process before packaging. Additionally, water activity as a secondary factor can also influence the deterioration of fish products and their derivatives. Bacteria grow more rapidly in products with high water content because bacterial metabolic activity is directly proportional to the amount of water available in the food (Maulana *et al.*, 2022).

Meanwhile, M1S5 (conventional stirrer with a roasting time of 120 min), M1S4 (conventional stirrer with a roasting time of 105 min), and M2S4 (stirrer machine with a roasting time of 105 min) had the lowest TPC values and microbial counts, at 1.0587 log CFU/g and 1.5349 log CFU/g. These results indicate that longer roasting times using a conventional stirrer and stirrer machine tend to lower TPC values and reduce microbial counts, thereby improving the safety and shelf life of shredded spiced fish. This is supported by Kustyawati (2020), who noted that longer heating times result in a higher microbial death rate. Furthermore, continuous roasting at a constant temperature accelerates bacterial death by directly exposing the bacteria present in the product to heat, resulting in an exponential decrease in bacterial counts (Wibisono *et al.*, 2016).

3.5. Color

Color is the first attribute that consumers see when purchasing or consuming a product. Attractive color encourages reviewers or consumers to taste the product. The expected color of minced fish is golden brown (Sinambela *et al.*, 2020). The results of the sensory color evaluation were analyzed using analysis of variance. The results of the analysis of variance (ANOVA) showed that the changes in stirring technique (M), roasting time (S), and the interaction between

stirrer type and roasting time had a significant effect (p -value < 0.05) on the color value of shredded spiced fish. Based on Tukey's HSD test (Table 3), the differences between treatments resulted in color score ranging from 2.59 to 4.68.

Table 3. Sensory characteristics of shredded spiced fish

Sample	Color	Taste	Aroma	Texture	Overall Acceptance
	$\alpha_{(0,05)} = 0.717$	$\alpha_{(0,05)} = 0.465$	$\alpha_{(0,05)} = 0.288$	$\alpha_{(0,05)} = 0.633$	$\alpha_{(0,05)} = 0.418$
M1S1	4.48±0.24 ^a	2.92±0.08 ^d	3.19±0.20 ^g	2.57±0.36 ^c	2.72±0.24 ^e
M1S2	3.75±0.12 ^{bc}	3.11±0.16 ^{cd}	3.64±0.18 ^{ef}	2.64±0.34 ^c	3.17±0.18 ^d
M1S3	3.37±0.46 ^{cd}	3.76±0.18 ^{ab}	4.00±0.28 ^{cd}	3.41±0.37 ^{ab}	3.89±0.16 ^a
M1S4	2.99±0.12 ^{de}	3.35±0.15 ^{bcd}	4.19±0.24 ^{bc}	3.67±0.28 ^{ab}	3.64±0.21 ^{abc}
M1S5	2.59±0.40 ^e	3.31±0.14 ^{bcd}	4.12±0.22 ^{bc}	3.80±0.28 ^a	3.84±0.11 ^{ab}
M2S1	4.56±0.18 ^a	3.19±0.14 ^{cd}	3.48±0.11 ^f	3.09±0.23 ^{bc}	3.32±0.18 ^{cd}
M2S2	4.64±0.25 ^a	3.27±0.14 ^{cd}	3.81±0.26 ^{de}	3.47±0.14 ^{ab}	3.51±0.14 ^{abcd}
M2S3	4.68±0.14 ^a	3.55±0.14 ^{abc}	3.91±0.32 ^{cde}	3.55±0.21 ^{ab}	3.67±0.09 ^{abc}
M2S4	4.39±0.10 ^{ab}	3.91±0.23 ^a	4.31±0.28 ^{ab}	3.72±0.16 ^{ab}	3.92±0.12 ^a
M2S5	4.23±0.08 ^{ab}	3.41±0.12 ^{bc}	4.51±0.22 ^a	4.00±0.04 ^a	3.45±0.17 ^{bcd}

Note: values followed by different superscript letters (a, b, c, d, e) within the same column indicate significant differences at 0.05 significance level.

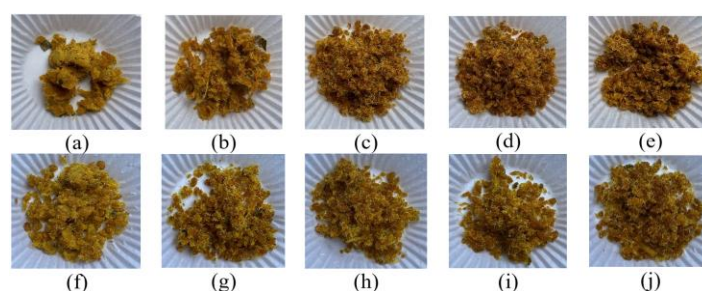


Figure 2. Color of spiced fish floss according to applied treatments. Top row is from conventional mixing: (a) 60 min, (b) 75 min, (c) 90 min, (d) 105 min, (e) 120 min. Bottom row is machine mixing: (f) 60 min, (g) 75 min, (h) 90 min, (i) 105 min, (j) 120 min.

The results, shown in Figure 2, demonstrated a significant interaction between stirrer type and roasting time on the color value of spiced fish. Generally, product color changes with cooking time, but this effect varies depending on the type of stirrer used. With the stirring machine, the highest color value was measured at 4.68 after 90 min of roasting (M2S3), while the lowest was measured at 4.23 after 120 min of roasting (M2S5). These data indicate that while color value decreases with increasing roasting time, the stirring machine maintains a higher level compared to the conventional stirrers. This is because the constant mixing process results in a more controlled water exchange rate. This condition prevents excessive heat generation, which can cause browning and discoloration of the shredded fish. During conventional stirrers, the color value reached a maximum value of 4.48 after 60 min (M1S1). After 120 min of roasting, a significant decrease in color value (M1S5) was observed, reaching a very low value of 2.59. These results indicate that with conventional stirrers, the heat is not distributed evenly as the roasting time increases, increasing the risk of overheating in some areas and accelerating browning.

Overall, the interaction between stirring method and roasting time significantly affected the color quality of shredded spiced fish. The stirring machine resulted in brighter and more stable colors at shorter cooking times, conventional stirrers generally resulted in darker colors due to unstable mixing, especially at longer cooking times. This observation is consistent with the research by [Rahkadima & A'yuni \(2017\)](#), which states that conventional heating methods are characterized by unevenness due to unstable mixing, resulting in high surface temperatures and uneven heat transfer from the outer surface of the sample to the interior. Furthermore, the interaction between the stirring method and roasting time is consistent with results of [Leonita *et al.* \(2022\)](#), who found that increasing roasting time at constant temperature, semi-mechanical stirrer is more effective in enhancing the color of roasted nuts than conventional methods.

The color of shredded spiced fish is also largely determined by the combination of ingredients such as turmeric, chili, and white tilapia meat. Long roasting times, whether with a stirrer machine or a conventional stirrer, consistently

produce colors ranging from golden brown to dark brown. The roasting process changes the color of the food surface to yellow due to the Maillard reaction (Nafsiyah *et al.*, 2023). The intensity of this color not only increases with longer cooking times but also increases with higher temperatures, the longer and hotter the roasting, the darker brown color produced, all due to the Maillard reaction. In addition, the significant presence of proteins and carbohydrates in food ingredients plays an important role in supporting the Maillard reaction during roasting (Dalimunthe *et al.*, 2024).

The Maillard reaction is a browning process between reducing sugars and compounds containing NH_2 amino groups, such as proteins, amino acids, and peptides. This reaction produces melanoidin compounds, which are responsible for deepening the color of shredded spiced fish (Safitri *et al.*, 2023). The process begins with aldose reacting back and forth with amino acids or amino groups from proteins, producing Schiff bases. These reversible Schiff bases then transform into glycosylamines. Glycosylamine undergoes Amadori rearrangement to form aminoketose. When dehydration of the Amadori product occurs, it produces furfuraldehyde derivatives and methyl α -dicarbonyl intermediates, which ultimately lead to the formation of reductants and α -dicarboxyls, such as methylglyoxal, acetol, and diacetyl. These aldehyde compounds polymerize with amino acid groups to produce brown melanoidin compounds (Winarno, 2008).

3.6. Taste

The results of sensory taste assessment were then analyzed using analysis of variance. Analysis of variance (ANOVA) shows that variations in stirring technique (M), roasting time (S), and the interaction between the type of stirrer and roasting time had a significant effect (p -value < 0.05) on the taste value of shredded spiced fish. HSD test (Table 3), the differences between treatments produced taste values ranging from 2.92 to 3.91. Based on the data, a combination of conventional stirrer for 105 min of roasting time (M2S4) produced the highest taste value of 3.91, indicating a distinctive taste. The use of a conventional stirrer for 90 min (M1S3) also had a similar taste value of 3.76, indicating a distinctive taste. This is in line with the information from Pramudya *et al.* (2022) that the heating process in food processing can produce a better taste.

However, for a very long roasting time (120 min), neither the stirring machine nor the conventional stirrer showed a significant increase in taste value compared to the roasting time of 105 min. Furthermore, there was a slight decrease in taste value in M2S5 treatment (stirring machine, 120 min), with a value of 3.41 compared to M2S4 (105 min), which showed the highest value. A similar decrease occurred in the M1S5 treatment (conventional stirrers, 120 min) with a value of 3.31 compared to M1S3 (90 min). This indicates that too long a roasting time can reduce taste quality due to the possibility of overcooking. This is in accordance with information from Margaretha *et al.* (2023) that excessive or too long heating time can produce an undesirable overcooked taste.

Meanwhile, over a shorter time (60 min), treatment with a stirrer machine (M2S1) produced a better taste value of 3.19 compared to a conventional stirrer (M1S1) with a value of 2.92 over the same duration. This shows that the stirrer machine is more effective in mixing and balancing tastes, even with a relatively short roasting time. The automatic stirring system and larger pan diameter allow the stirrer machine to be more effective because the larger surface area supports rapid heat transfer (Hakim, 2016). However, at this short duration, the shredded spiced fish still has a high moisture content, which affects the taste quality because it tastes less like floss and is slightly wet. This high moisture content also prevents the distinctive taste of shredded spiced fish from coming out to the fullest (Yuliani *et al.*, 2021).

The taste of shredded spiced fish is also influenced by the amino acids contained in the food ingredients. Tilapia, which is the basic ingredient for making shredded spiced fish, is known to contain 76.12 mg/g of glutamic acid as the highest amino acid component (Rieuwpassa *et al.*, 2020). The savory taste caused by the presence of glutamic acid is formed due to the hydrolysis of protein into amino acids. Protein is composed of various amino acids, so the higher the protein content of an ingredient, the more amino acids it contains, including glutamic acid (Pramudya *et al.*, 2022).

In addition, heterocyclic compounds containing sulfur from the Maillard reaction can provide savory, meaty, and roasted tastes. Heterocyclic and carbonyl compounds from the Maillard reaction provide various important taste compounds through the Strecker reaction. The Strecker reaction cannot occur without amino acids. Taste formation during the Maillard reaction is greatly influenced by temperature and time. Tilapia shredded fish contains 20 types of amino acids (Rieuwpassa *et al.*, 2020), enabling the Strecker reaction and the formation of various important taste compounds that can affect the taste of shredded spiced fish (Agustini *et al.*, 2015).

3.7. Aroma

The results of sensory aroma assessment were then analyzed using analysis of variance. Analysis of variance (ANOVA) shows that the variation in stirring technique (M) had no significant effect (p -value > 0.05) on the aroma value of shredded spiced fish. Conversely, roasting time (S) and the interaction between the type of stirring machine and roasting time had a significant effect (p -value < 0.05) on the aroma value of the resulting shredded spiced fish. HSD test (Table 3), the differences between treatments produced aroma values ranging from 3.19 to 4.51. The interaction between the type of stirrer machine and the roasting time had a significant effect on the aroma value of the shredded spiced fish. The aroma value of the product varied according to the type of stirrer machine used and the roasting time. Based on the data, the M2S5 treatment (stirrer machine with a roasting time of 120 min) produced the highest aroma value of 4.51, indicating the most distinctive and preferred aroma. In general, there was an increase in aroma value as the roasting time increased. In the stirrer machine, the aroma value increased from 3.4800 at 60 min to 4.51 at 120 min. Meanwhile, in the conventional stirrer, the highest aroma value was found at 105 min (4.19), but decreased at 120 min (4.12). This decrease is likely due to inconsistent stirring in the conventional stirrer. This condition can cause some parts of the shredded spiced fish to overheat or even decrease in aroma quality due to the degradation of dominant volatile compounds (Gaga *et al.*, 2022).

This indicates that a longer roasting time supports the formation of a stronger and more distinctive aroma of shredded spiced fish. This is in line with research by Sulistiyati *et al.* (2022) that cooking methods affect food aroma, where longer heating can produce a stronger aroma and eliminate fishy odors. In addition, the distinctive roasted aroma of shredded spiced fish can also be caused by the Maillard reaction. The distinctive aroma of grilled or roasted meat, along with the length of the cooking process, can occur because Amadori products resulting from the Maillard reaction through Strecker degradation can form several groups of heterocyclic compounds and amino acid degradation products, including pyrazine, oxazole, and thiazole, which play a role in giving meat a grilled or roasted aroma (Rosida, 2011).

Meanwhile, the M1S1 treatment (conventional stirrer with roasting for 60 min) had the lowest aroma value of 3.19, indicating a less distinctive or less desirable aroma. Conventional stirring or stirring machines with shorter roasting times, especially 60 min, produced lower aroma values. This was due to the suboptimal evaporation of volatile substances during the short cooking process, considering that the spices and water, including coconut milk, were still absorbed in the ingredients, thus not providing a distinctive aroma to the shredded meat (Yuliani *et al.*, 2021).

3.8. Texture

The results of sensory texture assessment were further analyzed using analysis of variance. Analysis of variance (ANOVA) shows that variations in stirring technique (M), roasting time (S), and the interaction between the type of stirrer and roasting time had a significant effect (p -value < 0.05) on the texture value of the resulting shredded spiced fish. HSD test (Table 3), the differences between treatments produced texture values ranging from 2.57 to 4.00. The highest texture value was achieved in treatment M2S5 (stirrer machine with 120 min of roasting) with a value of 4.00, indicating that the texture was very desirable. Meanwhile, the use of a conventional stirrer for the same duration (120 min) produced a slightly lower texture value of 3.80, but it was still in the very desirable category. Thus, the use of a stirrer machine for a longer roasting time (120 min) produced the desired shredded spiced fish texture.

The combination of a stirrer machine with an optimal roasting time tends to produce a homogeneous texture of shredded spiced fish, while a conventional stirrer for the same duration can produce a coarser or less homogeneous texture. This is in line with research conducted by Anam *et al.* (2021) that a spice cooking machine equipped with an automatic stirrer can mix ingredients and distribute heat optimally, resulting in more homogeneous dispersion. In addition, the interaction between the variation of the stirring machine and the roasting time is also in line with the research by Sulisty & Yudo (2018), which shows that stirring machines are more optimal than manual stirrers in producing homogeneous chili paste with the same heating temperature and short processing time.

At shorter roasting times, specifically with a conventional stirrer for 60 min (M1S1), the lowest texture value was 2.57, indicating that the texture was not good. At a roasting time of 105 min, the stirring machine (M2S4) and the conventional stirrer (M1S4) showed quite good results, with texture values of 3.72 and 3.67, which are considered acceptable. These results are in line with research by Puspita *et al.* (2019), which showed that the longer the roasting

time, the better texture of the shredded fish produced. By increasing the roasting time, both stirring machine and conventional stirrer can produce shredded spiced fish with the desired texture. This is because the mixing and heating processes, which involve drying and evaporation, release more water from the food ingredients. The outer shell of the material also shrinks due to dehydration during drying, and the evaporation of the remaining water causes pores to form inside the food material, giving the product a dry texture (Sinambela *et al.*, 2020).

3.9. Overall Acceptance

The overall sensory evaluation results were then analyzed using analysis of variance. Analysis of variance (ANOVA) shows that variations in stirring technique (M), roasting time (S), and the interaction between the type of stirring machine and roasting time had a significant effect (p -value < 0.05) on the overall acceptance value of shredded spiced fish. HSD test (Table 3), the differences between treatments resulted in overall acceptance values ranging from 2.72 to 3.92. In terms of overall acceptance, the panelists preferred the shredded spiced fish made with the M2S4 treatment (stirrer machine with a roasting time of 105 min) compared to the other treatments. This indicates that the use of a stirrer machine with a longer roasting time produces a better overall acceptance value compared to a conventional stirrer. In addition to the type of stirrer, the roasting time also plays an important role in increasing the overall acceptance of the product. The panelists assessment of overall acceptance is the result of an assessment of all organoleptic parameters, such as texture, color, taste, and aroma. Overall, the M2S4 treatment (stirrer machine with a roasting time of 105 min) had a dry and soft texture that was very much liked by the panelists, a light brown color, a very distinctive fish spice taste, and a very distinctive fish spice aroma.

3.10. Optimal Treatment

The optimal processing method for shredded spiced fish was determined using the De Garmo method, a multi-criteria decision-making approach that evaluates multiple parameters simultaneously. The parameters considered included chemical properties (moisture, protein, and ash), microbiological quality (total plate count), and sensory properties, including color, taste, and aroma scoring tests, as well as hedonic tests for texture and overall acceptability. Based on the De Garmo, confirmed that the 105-min with stirring machine (M2S4) was the optimal condition for producing high-quality shredded spiced fish with desirable physicochemical properties, microbiological safety, and high consumer acceptance. The optimal processing method, M2S4, met the upper 15%, lower 30%, and upper 10^4 CFU/g limits of the [SNI Shredded Fish 7690:2019](#) standard for moisture content (9.79%), protein content (38.57%), and total plate count (1.5349 log CFU/g). Furthermore, the ash content of the spicy shredded fish obtained by this process was 4.0667%, which meets the requirements of the [SNI Shredded Fish Product 01-3707-1995](#), which specifies an upper limit of 7%. The sensory evaluation results ultimately showed a taste score of 3.9067 (very characteristic of shredded spiced fish), aroma 4.31 (very distinctive aroma of shredded spiced fish), texture 3.72 (very liked), color 4.39 (light brown), and acceptability 3.84 (very liked).

4. CONCLUSION

The conclusion of this study shows that the interaction between the stirring method and roasting time significantly affects the chemical, microbiological, and sensory properties of shredded spiced fish. The results of the study show that the optimal treatment was achieved by using a stirrer machine for 105 min (M2S4), resulting in a moisture content (9.79%), protein content (38.57%), ash content (4.0667%), and total plate count (1.5349 log CFU/g) that meet the Indonesian National Standard (SNI). Further sensory evaluation results show a high level of acceptance, with an aroma value of 4.31 (very distinctive aroma of shredded spiced fish), a taste score of 3.91 (very characteristic of shredded spiced fish), a texture score of 3.72 (very liked), a color score of 4.39 (light brown), and an overall acceptance score of 3.84 (very liked). Compared with conventional processing, the stirrer machine improved efficiency and produced a more stable quality, indicating potential for application in larger-scale production. These findings may serve as a practical reference for MSMEs to enhance production efficiency and maintain consistent, SNI-compliant product quality. Further research is recommended to evaluate the effect of different mixing speeds (rpm) on the chemical, microbiological, and sensory characteristics of shredded spiced fish.

AUTHOR CONTRIBUTION STATEMENT

Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
PMA	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
DS	✓	✓		✓			✓			✓		✓	✓	✓
GA	✓	✓		✓			✓			✓		✓		
SH				✓						✓				
SA				✓						✓				
C: Conceptualization			Fo: Formal Analysis			O: Writing - Original Draft			Fu: Funding Acquisition					
M: Methodology			I: Investigation			E: Writing - Review & Editing			P: Project Administration					
So: Software			D: Data Curation			Vi: Visualization								
Va: Validation			R: Resources			Su: Supervision								

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