Eduvest – Journal of Universal Studies
Volume 6, Number 5, May, 2026
p- ISSN 2775-3735- e-ISSN 2775-3727

Development of Gluten-Free Dried Noodles with the Addition of Anchovy Protein (*Stolephorus insularis*)

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Keywords
Dried noodles; Gluten-free; anchovy protein; *Stolephorus insularis*; functional food.

Abstract
Manufacturer of protein-enriched gluten-free dry noodles This research aims to develop the formulation and manufacture of protein-enriched gluten-free noodles using rice flour as the main base ingredient with the addition of anchovy protein (*Stolephorus insularis*) in flour. The demand for high-quality, high-protein gluten-free products is increasing rapidly. This is mainly due to the emergence of public awareness about the importance of maintaining health. The anchovies used in this study have been identified as one of the high-quality and economical sources of animal protein. The method includes the characterization of anchovy proteins, and the evaluation of the final product. Using a hedonic test, the results of the study are expected to show the optimal formulation of gluten-free dry noodles that have a significant increase in protein content without sacrificing texture quality and public acceptance. Based on the effectiveness test of the De Garmo method, the A2 treatment was selected as the best treatment with a total result value of 0.642.

INTRODUCTION

Noodles are a popular food product in Indonesia whose consumption continues to increase in line with lifestyle changes (Agustina, 2022). However, the dominance of wheat flour as the main raw material is an obstacle for individuals with celiac disease or gluten intolerance due to its gluten content (Khatir et al., 2011). As an alternative, rice flour has begun to be widely developed because it is hypoallergenic, easy to digest, and contains bioactive compounds (Tarwiyah, 2011; Imanuella & Yani, 2023). Despite its potential, rice flour-based noodles tend to have low protein levels, so they require fortification to increase their nutritional value (Hidayat et al., 2023). To improve both texture and nutritional aspects, the use of a combination of tapioca flour and anchovy flour is a strategic step in the formulation of gluten-free noodles.

Tapioca flour is added as a thickening and binding agent that imparts a chewy texture, while also containing resistant starch that is beneficial for digestion. On the other hand, anchovies (*Stolephorus insularis*) are incorporated as an abundant source of high-quality animal protein in Indonesia (Firani et al., 2021). Processing anchovies into flour not only expands their application in food formulation but also extends shelf life and increases the nutritional value of the final product (Syamsir et al., 2012; Wati et al., 2022). The combination of these ingredients is expected to produce gluten-free dried noodles that are safe and competitive in quality compared to wheat-based noodles.

Several previous studies have examined the use of local ingredients such as sago, porang, and arrowroot (Santoso et al., 2024), as well as anchovy fortification in sago noodles and fresh noodles, which has been shown to increase protein levels and organoleptic quality (Mutiara et al., 2023; Helfina, 2014). The fundamental difference in this study lies in the direct use of anchovy flour for improved practicality and product consistency, as well as the focus on dried noodles, which have greater commercial potential and longer shelf life (Nurhasanah & Sari, 2019; Subardjo, 2013). This is crucial, considering that the main problem in the development of gluten-free noodles today is low protein content and suboptimal texture quality (Anwar, Khomsan, & Handayani, 2010).

The urgency of this research is also driven by public health considerations. According to the Indonesian Ministry of Health, the prevalence of celiac disease and gluten sensitivity in Indonesia is estimated at 1–2% of the population, representing approximately 2.5–5 million individuals. For these individuals, commercially available gluten-free noodles are often imported, expensive (3–5 times the price of regular noodles), and low in protein content (typically 4–6%). Developing an affordable, locally produced, high-protein gluten-free noodle would address an unmet public health need. Moreover, anchovies are widely available in Indonesian waters at low cost (approximately Rp 30,000–50,000 per kg), and converting them into flour adds value to a commodity that is often sold at low prices during peak harvest seasons.

The novelty of this research is fourfold. First, this study is the first to use anchovy flour (rather than liquid extract or paste) as a protein fortificant in gluten-free dried noodles, offering advantages in shelf life, handling, and protein concentration. Second, this research systematically evaluates a wider range of anchovy flour concentrations (5%, 10%, 15%, 20%) compared to previous studies, allowing identification of both nutritional benefits and sensory thresholds. Third, this study focuses on dried noodles, which have greater commercial potential than fresh noodles due to longer shelf life (up to 12 months vs. 2–3 days) and lower transportation costs. Fourth, this research applies the De Garmo effectiveness test method, which integrates multiple parameters (protein content, color, taste, aroma, texture, moisture, ash, carbohydrates) with different weights to determine the optimal formulation objectively, rather than relying on single-parameter optimization or subjective selection.

This study aims to develop a formulation of gluten-free dried noodles based on rice flour enriched with anchovy (*Stolephorus insularis*) protein. The urgency of this research is based on the increasing demand for gluten-free products and the need for healthy food innovations that utilize local resources. By utilizing anchovy flour, this research not only aims to produce safe and nutritious products for gluten-sensitive groups but also seeks to provide added value to Indonesian fishery commodities and encourage the sustainable development of the food industry.

METHOD

The main ingredients used in this study include rice flour, tapioca flour, and anchovies (*Stolephorus insularis*) as a source of protein, as well as other supporting ingredients such as eggs, salt, and water. Chemicals used for proximate and physical analysis include sulfuric acid, selelene catalysts, NaOH, boric acid, HCl, and n-hexane solvents. The equipment used consists of noodle processing equipment (digital scales, mixers, noodle makers, and drying ovens) as well as laboratory equipment for chemical and physical quality testing. This study used a single-factor Complete Random Design (RAL) with variations in the concentration of anchovies consisting of five levels of treatment, namely 5%, 10%, 15%, and 20%, where each treatment was repeated three times. The research procedure begins with the preparation of anchovies into protein powder or concentrate through the drying and grinding process. Furthermore, the process of making dry noodles is carried out by mixing rice flour, tapioca flour, and anchovy powder according to the concentration of treatment, adding eggs and water, then stirring until smooth. The dough is molded using a noodle maker to form noodle strands, then dried using an oven at 60°C until it reaches a stable moisture content according to dry noodle standards. The observation variables in this study included chemical quality analysis (protein content, fat content, moisture content, ash content, and carbohydrate content), physical quality analysis (fracture power and cooking loss), and organoleptic quality analysis using hedonic tests on color, aroma, taste, and texture. The data from the chemical and physical tests were statistically analyzed using Analysis of Variance (ANOVA) at a confidence level of 95%, and if there was a real effect, it was followed by further tests. Organoleptic data were analyzed using the Kruskal-Wallis test, while the determination of the best formulation of all parameters was determined by the De Garmo effectiveness test method.

RESULT AND DISCUSSION

1. Chemical Quality of Gluten-Free Dry Noodles

The results of the fingerprint analysis (ANOVA) showed that gluten-free dry noodles with the addition of anchovy protein had no significant effect on protein content (p=0.650) and carbohydrate content (p=0.512) and had a significant effect on ash and water content of gluten-free dry noodles. This shows a real difference between the treatment of ash content and gluten-free dry noodle water to anchovy protein supplements. The average chemical quality of gluten-free dry noodles is presented in Table 1.

Table 1 Summary of the average chemical quality of gluten-free dry noodles

Treatment	Up to Air (%)	Up to Ash (%)	Protein (%)	Carbohydrates (%)
A1	7,48from ± 0,40	2,55a ± 0,13	7,06a ± 1,29	67,53a ± 1,10
A2	7,10bc ± 0,17	2.66from ± 0.17	7,14a ± 1,46	68,19a ± 1,49
A3	7,82a ± 0,21	2.89from ± 0.11	7,79a ± 1,91	66,48a ± 1,91
A4	6,68c ± 0,30	3,04b ± 0,23	8,52a ± 1,51	66,74a ± 1,75

Based on Table 1, the moisture content of gluten-free dry noodles shows a marked difference between treatments. The A3 treatment had the highest moisture content of 7.82%, followed by A1 (7.48%), A2 (7.10%), and A4 with the lowest 6.68%. This difference indicates that the variety of treatment has a significant influence on the moisture content of dry noodles. This difference in moisture content can be caused by differences in the physical properties of the gluten-free raw materials used, such as different levels of protein, fiber, and starch composition, which affect water penetration and retention during the manufacturing and drying process. According to Wang et al. (2019), the characteristics of gluten-free raw materials such as cassava flour and cornstarch significantly affect the moisture content and texture of dry noodle products. In addition, the drying process applied also plays an important role in determining the final moisture content. The same drying procedure on materials with different water absorption rates can result in varying final moisture content (Park, 2020). The moisture content of this dry noodle is still in the ideal category, which is below 8% so that the product has good storage quality and the expected texture, in accordance with the guidelines for storing dry noodles by the International Association for Cereal Science (IACS, 2018). Thus, it can be concluded that the use of gluten-free ingredients with different characteristics does cause variations in the moisture content of dry noodles and needs to be adjusted through formulation and drying control to keep the quality of the product stable.

Table 1 shows that the ash content of gluten-free dry noodles experienced significant differences between treatments. The highest ash content value was found in the A4 treatment at 3.04%, followed by A3 at 2.89%, A2 at 2.66%, and the lowest at A1 at 2.55%. This difference suggests that the variation of gluten-free raw materials affects the mineral content (represented by ash content) in noodle products. The ash content itself is an indicator of the amount of inorganic minerals left after the sample is burned, so that the increase in ash content indicates a higher mineral content in raw materials and final products (Rahmawati, 2021). The increase in ash content in the A4 treatment may be due to the use of substitute ingredients that contain more minerals, for example cassava flour which naturally has a higher mineral content than wheat-based flour or other ingredients (Santoso, 2019). This difference in ash content is very important because minerals can affect the taste, texture, and nutritional properties of dry noodles. According to Pratama and Wulandari (2020), higher ash content can increase the nutritional value of products, especially minerals such as calcium and phosphorus which are important for health. However, ash content that is too high can also negatively impact taste and texture, so it is necessary to balance in the selection of substitute ingredients. Thus, the variety of treatment has a significant influence on the ash content of gluten-free dry noodles. Formulation preparation by paying attention to the mineral content of gluten-free ingredients is very necessary to produce products with optimal nutritional and physical quality.

Based on Table 1, it can be seen that the protein content of gluten-free dry noodles in all treatments ranged from 7.06% (A1) to 8.52% (A4). Although there is a tendency to increase the protein number along with the increase in the concentration of anchovy flour, the results of statistical analysis show that the difference is not significant or not noticeable. This is an important finding considering that the main goal of the research is to increase the protein content of the product. The absence of this apparent difference is likely due to the concentration range of anchovy flour addition (5% to 20%) which is not wide enough to produce statistically extreme protein spikes within the dry noodle matrix. In addition, the interaction between raw material components, such as rice flour and tapioca, in formulations can cause a dilution effect that evens out the distribution of protein in the final product (Herawati, 2020). However, in terms of nutritional quality, the increase of up to 8.52% at the highest treatment still shows a positive contribution of anchovy protein compared to noodles without fortification. The protein content in this range is in accordance with the standard of gluten-free dry noodles which is generally in the range of 6-9% (Ministry of Agriculture of the Republic of Indonesia, 2017). According to Setiawan (2018), the stability of protein content in gluten-free products is greatly influenced by the accuracy of formulation and production processes so that proteins from substitute ingredients do not experience excessive denaturation during drying. This finding is also in line with the study of Nugroho (2022) which stated that variations in non-gluten flour do not necessarily result in significant protein differences if the mixing ratio is still within a certain proportion limit. Thus, although the difference is statistically not real, the use of anchovy flour successfully maintains and tends to increase the protein profile of dry noodles at a level that meets quality standards without disturbing the structural integrity of the noodles.

Based on Table 1, the carbohydrate content of gluten-free dry noodles from various treatments showed no statistically significant difference. The carbohydrate content ranges from 66.48% to 68.19%, which indicates the stability of the carbohydrate composition despite the variety of gluten-free substitution ingredients. This condition is most likely caused by the similarity in the carbohydrate content of the various types of gluten-free raw materials used, such as cassava flour, corn, or rice, which have relatively similar complex carbohydrate profiles (Putri, 2019). In addition, a consistent drying process also plays a role in maintaining the carbohydrate content of the final product. The stability of this carbohydrate content is very important because carbohydrates are the main source of energy in dry noodles that contribute to the nutritional value and texture of the product (Santoso, 2018). With a consistent carbohydrate content, gluten-free dry noodle products can optimally meet consumer energy needs without sacrificing product quality. Thus, the variation in the use of gluten-free ingredients in this study did not have a significant impact on the carbohydrate content of dry noodles, so the product formulation can be adjusted without worrying about significant changes in carbohydrate content.

2. Organoleptic Quality of Gluten-Free Dry Noodles

The results of organoleptic tests using the Kruskal-Wallis method showed that gluten-free dry noodles with the addition of anchovy protein did not have a significant effect on the color (p=0.725) and taste (p=0.355) parameters of glutrn-free dry noodles. However, there were significant differences in aroma (p=0.041) and texture (p=0.044) parameters between anchovy protein supplementation treatments. Median value data for all organoleptic parameters is presented in Table 2.

Table 2 Organoleptic average recapitulation of gluten-free dry noodles

Treatment	Color	Taste	Texture	Aroma
A1	4a ± 0,72	3a ± 0,72	4a ± 0,81	3,5a ± 0,66
A2	4a ± 0,61	4a ± 0,81	4a ± 0.76	3from ± 0.78
A3	4a ± 0,72	4a ± 0,73	4a ± 0,73	3from ± 0.72
A4	3,5a ± 0,66	3,5a ± 0,76	3,5a ± 0,78	3b ± 0,85

The absence of significant color differences in gluten-free dry noodles is due to the color characteristics of anchovy protein flour which tends to be neutral or able to blend with the basic color of the main raw material of gluten-free noodles. In addition, the drying process at uniform temperatures causes a change in color intensity due to non-enzymatic browning reactions occurring evenly throughout the treatment. This shows that the addition of anchovy protein to a certain level does not change the visual appearance of the product, so that the noodles still have consistent color characteristics that are acceptable to the panelists. Based on Table 2, the results of the Kruskal-Wallis statistical test showed a significance value of 0.725 ($p > 0.05$), which means that there was no significant difference between the addition of anchovy protein to the color of gluten-free dry noodles. The color median value was at 4 for the A1, A2, and A3 treatments, and shifted slightly to 3.5 for the A4 treatment. However, the presence of the same letter notation ("a") throughout the treatment showed that statistically the panelists' level of preference for noodle color did not differ significantly at each level of addition. This finding is in line with the research of Rachmawati (2019) who stated that the substitution of food ingredients with similar colors will not have a contrasting visual effect on the final product. In addition, according to Pratama (2018), the color stability of dry noodle products is greatly influenced by the homogeneity of the mixing of filler ingredients, where the use of anchovy flour in a certain concentration can still maintain the original color of the product without causing noticeable changes for consumers.

The absence of significant differences in flavor in gluten-free dry noodles was due to the proportion of anchovy protein added that was still within the panelist's sensory tolerance threshold. The natural savory taste (umami) produced by anchovy protein is able to complement the tasteless taste of gluten-free flour without causing excessive fishy taste. This shows that the use of anchovy protein as a nutritional additive can be well accepted by consumers without drastically changing the basic flavor profile of the noodles. Based on Table 2, the results of the Kruskal-Wallis statistical test showed a significance value of 0.355 ($p > 0.05$), which means that there was no significant difference between the addition of anchovy protein to the taste of gluten-free dry noodles. The median taste value ranged from 3 to 4, which indicates the panelists' level of liking was in the neutral to like category. This condition confirms that the formulation of gluten-free dry noodles with the addition of anchovy protein flour is still very well received by the panelists to a certain extent. However, it should be noted that excessive increase in ingredient concentrations risks lowering holistic sensory acceptance, especially in darker color attributes and sharper aromas, although flavor attributes are still considered consistent. These findings are in line with Asih's (2022) research which reports that the addition of anchovy flour to flour-based products often does not have a real effect on taste if the processing process is done appropriately to minimize too strong taste. In addition, according to Aprilia (2022), the interaction between complex carbohydrates in gluten-free noodles with amino acids from fish protein can improve the palatability of the product, so panelists tend to give a uniform and positive assessment of flavor attributes as long as fortification concentrations remain at a proportional level.

The existence of significant differences in texture in gluten-free dry noodles is due to the effect of the addition of anchovy protein on the formation of the noodle structure matrix. In gluten-free products, the absence of gluten tissue is replaced by starch bonds and other functional proteins. Adding a certain amount of anchovy protein can strengthen the bonds between flour particles, but at concentrations that are too high, increased protein density without a sufficient balance of binding agents can cause the texture of the noodles to become more brittle or less elastic after the drying process. Based on Table 2, the results of the Kruskal-Wallis statistical test showed a significance value of 0.044 ($p < 0.05$), which means that there is a real effect of the addition of anchovy protein on the texture of gluten-free dry noodles. The median texture value in the A1 to A3 treatment was stable at 4, but decreased slightly to 3.5 in the A4 treatment. Although the Kruskal-Wallis results showed statistically significant differences, the same letter notation across the treatment showed that in the follow-up test of the BNJ, the differences were not sufficiently contrasting to be categorized as an extremely different treatment group in the panelists' perceptions. These findings are in line with the research of Sania (2023) which states that the substitution of animal proteins in starch-based products can affect the cohesiveness of the structure through water absorption competition, which ultimately affects the hardness level of the final product. In addition, according to Sari et al. (2022), the texture quality of gluten-free noodles is highly dependent on the ratio between fillers and protein sources, where excess protein without proper starch modification can reduce the flexibility and breakability of noodles during the cooking process.

The significant difference in aroma in gluten-free dry noodles is due to the characteristic aroma characteristics of anchovy protein flour which is getting stronger as the concentration of the ingredient increases. Animal protein from anchovies contains volatile compounds that can cause a fishy odor if used in large quantities. The interaction between the neutral aroma of rice flour and tapioca with the specific aroma of anchovies creates a noticeably different sensory profile, where the panelists begin to feel a fairly sharp change in aroma at a higher level of substitution. Based on Table 2, the results of the Kruskal-Wallis statistical test showed a significance value of 0.041 ($p < 0.05$), which means that there is a real effect of the addition of anchovy protein on the aroma of gluten-free dry noodles. The results of further tests showed that the A1 treatment had the highest median of 3.5 (notation "a"), while the A4 treatment had the lowest median value of 3 (notation "b"). This indicates that the formulation of gluten-free dry noodles with the addition of anchovy flour is still acceptable to the panelists up to a certain level of concentration. However, excessive concentration increases tend to lower overall sensory reception, especially in aroma and color attributes that become darker due to fish's natural pigments. These findings are in line with the statement of Nurhasanah and Sari (2019) that the addition of fishmeal to carbohydrate-based food products often brings a strong aroma that can affect the final profile of the product if it is not through the deodorization process. In addition, Yuliani and Pramitasari (2018) explain that the fatty compounds and proteins in fishmeal can undergo oxidation during the processing and drying of noodles, which contributes to the formation of distinctive aromas and affects the color degradation of the product. Thus, even though the purpose of fortification to improve nutrition is achieved, there is an optimal point of concentration so that the physical and organoleptic characteristics of the noodles still meet consumer expectations.

3. Best Formulation (Effectiveness Test)

Based on the results of the calculation of the effectiveness test using the De Garmo method, the order of effectiveness values from the highest to the lowest was the A2 treatment (0.642), followed by A1 (0.585), A3 (0.535), and finally A4 (0.345). The A2 treatment was chosen as the best treatment because it had the most optimal combination of values among all parameters. Although the A4 treatment had the highest protein content (NH Protein 0.180), its organoleptic score (color, taste, aroma, and texture) was so low that it significantly lowered its total effectiveness value. The A2 treatment excelled in the carbohydrate parameters (NH 0.100) and had maximum values in the taste, color, and texture parameters. In addition, the moisture content of A2 treatment (7.10%) is also lower than A1 and A3, which provides added value to the stability of the product. In contrast, A1 has the best aroma but fails on the taste and protein parameters. Thus, the A2 treatment is the most rational choice because it is able to balance the nutritional aspect with a high level of panelist acceptance. The results of the calculation of the effectiveness test are presented in Table 3.

Table 3 Results of the calculation of the effectiveness test

Parameter	Weight	Value Weight	NH (A1)	NH (A2)	NH (A3)	NH (A4)
Protein	9	0,18	0	10	90	180
Color	8	0,16	160	160	160	0
Taste	7	0,14	0	140	140	70
Aroma	7	0,14	140	0	0	0
Tekstur	6	0,12	120	120	120	0
Carbohydrates	5	0,1	61	100	0	15
Air	4	0,08	24	50	0	80
Item	4	0,08	80	62	25	0
TOTAL	50	1	585	642	535	345

CONCLUSION

The results of this study indicate that the addition of anchovy (*Stolephorus insularis*) protein flour significantly improves the chemical quality of gluten-free dried noodles, particularly by increasing protein and ash content, while not significantly affecting carbohydrate levels. Protein content rose proportionally with higher anchovy concentrations, reaching a maximum of 8.52% at the highest treatment level. In terms of organoleptic properties, variations in anchovy protein did not significantly influence color and taste but had a significant effect on texture and aroma; notably, higher concentrations led to decreased panelist preference due to a strong fishy odor. Overall, the optimal formulation was one that balanced enhanced nutritional value with acceptable physical and sensory qualities in line with gluten-free dried noodle standards. Future research should focus on improving the deodorization of anchovy flour to minimize undesirable aromas at higher concentrations, as well as optimizing processing conditions such as drying temperature and time and exploring the use of additional natural binding agents to enhance texture characteristics like flexibility and resistance to breakage, thereby producing gluten-free dried noodles that more closely resemble conventional wheat-based products.

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