

OPTIMIZATION OF THE DUOKAILI CRISPY PROCESSING ON THE PROXIMATE AND ORGANOLEPTIC CONTENT OF ANCHOR, MORINGA LEAF, AND SWEET POTATO-BASED PRODUCTS

Optimalisasi Proses Pengolahan Duokaili Krispy Terhadap Kandungan Proksimat dan Organoleptik Produk Berbasis Ikan Teri, Daun Kelor, dan Ubi Jalar

Safriyanto S. Maruka^{1*}, Fitriani Basrin², Nurfadilah²

¹ Sea Product Processing Technology Study Program, Palu Polytechnic

² Capture Fisheries Study Program, Faculty of Animal Husbandry and Fisheries, University of West Sulawesi

Jl. Sinar Kemuning 1 No 1A Tondo-Palu, Central Sulawesi

*Corresponding Author: edi.safriyantomaruka@gmail.com,

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ABSTRACT

Duokaili is a traditional food of the Kaili community made from anchovies (Duo), moringa leaves, and sweet potatoes. However, variations in the processing methods, particularly in ingredient proportions, frying temperature, proximate composition, and the resulting organoleptic quality, remain inconsistent. This study aimed to evaluate the effects of ingredient proportions and frying temperatures on the proximate composition and organoleptic characteristics of Duokaili. The research employed a laboratory experimental method, beginning with primary data collection through treatments using anchovies, moringa leaves, and sweet potatoes, namely F0: 50%:0%:50%, F1: 40%:20%:40%, F2: 30%:30%:40%, and F3: 50%:20%:30%, combined with frying temperatures of S1: 150°C, S2: 165°C, and S3: 180°C. The analyses included proximate composition, consisting of moisture, fat, ash, protein, and carbohydrate contents, as well as antioxidant activity and organoleptic characteristics. Data were analyzed through tabulation, statistical analysis, and interpretation of the results. The results showed that ingredient formulation, frying temperature, and their interaction significantly affected ($p < 0.05$) the proximate composition, antioxidant activity, and organoleptic quality of Duokaili Krispy. Increasing the frying temperature decreased moisture and fat contents but increased ash content, while higher proportions of moringa leaves and anchovies increased protein content and antioxidant activity. Conversely, the highest carbohydrate content was obtained in the formulation with a higher proportion of sweet potatoes. F2S2 (30% anchovies: 30% moringa leaves: 40% sweet potatoes at 165°C) was determined as the optimal treatment based on the balance of proximate composition, antioxidant activity, and organoleptic characteristics. F2S2 achieved high panelist acceptance, favorable nutritional quality, and antioxidant activity, making it the best combination of formulation and frying temperature for Duokaili Krispy.

Keywords: ingredient formulation; frying temperature; proximate composition; antioxidant activity; sensory evaluation.

ABSTRAK

Duokaili merupakan pangan tradisional khas masyarakat kaili yang terbuat dari ikan teri (duo), daun kelor, dan ubi jalar. Namun hingga kini, variasi proses pengolahan terutama pada tahap proporsi bahan, suhu penggorengan, mutu proksimat dan organoleptik produk yang dihasilkan tidak seragam. Tujuan penelitian adalah mengevaluasi pengaruh proporsi bahan dan suhu penggorengan terhadap kandungan proksimat dan organoleptik duokaili. Metode mencakup penelitian eksperimen laboratorium yang diawali dengan pengumpulan data primer melalui tahapan perlakuan bahan (teri, kelor, ubi jalar) : F0 : 50%; 0%; 50%, F1: 40% : 20% : 40%, F2: 30% : 30% : 40%, F3: 50% : 20% : 30%, serta perlakuan suhu penggorengan S1: 150°C, S2: 165°C dan S3: 180°C. dilanjutkan pengujian proksimat kadar air, kadar lemak, kadar abu, kadar protein, Kadar karbohidrat, antioksidan. Kedua, analisis data: tabulasi, analisis statistik, dan interpretasi hasil. Berdasarkan hasil menunjukkan bahwa formulasi, suhu penggorengan, dan interaksi keduanya berpengaruh nyata ($p < 0,05$) terhadap karakteristik proksimat, aktivitas antioksidan, dan mutu organoleptik Duokaili Krispy. Peningkatan suhu penggorengan menurunkan kadar air dan lemak, namun meningkatkan kadar abu, sedangkan peningkatan proporsi daun kelor dan ikan teri meningkatkan kadar protein dan aktivitas antioksidan. Sebaliknya, kadar karbohidrat tertinggi diperoleh pada formulasi dengan proporsi ubi jalar yang lebih besar. F2S2 (30% ikan teri : 30% daun kelor : 40% ubi jalar pada suhu 165°C) ditetapkan sebagai perlakuan optimal berdasarkan keseimbangan parameter proksimat, aktivitas antioksidan, dan karakteristik organoleptik. F2S2 menghasilkan penerimaan panelis yang tinggi serta mutu gizi dan aktivitas antioksidan yang baik, sehingga dinilai sebagai kombinasi formulasi dan suhu pengolahan terbaik pada produk Duokaili.

Kata Kunci: Ikan Teri, Formulasi Bahan, Suhu, Proksimat, Organoleptik

INTRODUCTION

Lero Village in Sindue District, Donggala Regency, Central Sulawesi Province, is a major production center for anchovies (*Stolephorus spp.*). Despite possessing significant resource potential, anchovy utilization in Lero Village remains dominated by conventional food products with relatively low added value. These products face various challenges, including fluctuating selling prices, intense market competition, and suboptimal diversification of fishery products. This situation highlights the need for processing technology innovations capable of yielding new products with higher economic value. "Kaili Krispy" is a traditional snack of the Kaili people in Palu City, made from anchovies (*duo*), moringa leaves (*keloku*), and sweet potatoes, with the addition of a binding agent such as rice flour. The product features a savory taste, a distinctive fish aroma, and high nutritional value. Anchovies are a source of protein, calcium, and essential minerals, while moringa leaves are known to be rich in antioxidants, vitamins A and C, and other bioactive compounds (Devi *et al.*, 2023). The combination of these three local ingredients makes it a promising product for development as a functional food characteristic of the Kaili people of Palu. However, the quality of "Duokaili" produced by home industries and MSMEs remains inconsistent. Crispness levels often vary, particularly after several days of storage. Furthermore, the product tends to suffer quality degradation such as becoming soggy, oily, or rancid due to non-standardized production processes (Zalfa, 2025). Factors such as ingredient proportions, frying duration and temperature, the type of binding agent, oil draining methods, and packaging techniques significantly influence final quality and shelf life (Syarif *et al.*, 2024). This study aims to optimize the processing of anchovy and moringa-based Kaili Krispy, focusing on enhancing crispness, stability, and shelf life. Optimization was achieved by adjusting ingredient

proportions, varying frying temperatures and durations, and refining draining and packaging techniques (Maruka & Novitasari, 2023). The study's findings are expected to establish production process standards that enhance product quality and support the commercialization of this traditional snack, thereby contributing to local food security for the Kaili community.

This research is crucial for establishing processing standards and generating chemical and organoleptik quality data; it also plays a strategic role in strengthening food security and ensuring the sustainable management of fishery resources. These objectives align with the national development policy outlined in the National Research Master Plan (RIRN) 2017–2045 (Ministry of Research, 2017), which prioritizes food and health. Furthermore, this research supports the "Golden Indonesia 2045" vision and the President of the Republic of Indonesia's *Asta Cita* (Eight Missions), which emphasize strengthening a natural resource-based economy, developing research-based industries, and empowering local potential (DPPM, 2026).

RESEARCH METHODS

Time and Place

This research was conducted from April to August 2026 at the Agricultural Product Processing Technology Laboratory of Palu Polytechnic and the Chemistry Laboratory of the Faculty of Mathematics and Natural Sciences at Tadulako University, Palu.

Tools and Materials

The equipment used in this study included: writing instruments, label paper, markers, a basin, a stirring rod, an analytical balance, test tubes and a rack, sterile Petri dishes, an autoclave, a drying oven, a hotplate, a Kjeldahl flask, an atomic absorption spectrophotometer (AAS), an organoleptic assessment form, a desiccator, sterile gloves, a lab coat, and a face mask. The materials used were anchovies, moringa leaves, sweet potatoes, and tapioca flour.

Research Stages

Penelitian This research was conducted in three main stages data collection, data analysis, and the reporting of research results which consisted in detail of the following:

Phase 1. Data Collection

The study employed a 4×3 factorial Completely Randomized Design (CRD) with three replications, featuring the following main factors (Muttaqin, A., *et al.* 2016):

1. Proportion of ingredients (anchovies : moringa : sweet potato):
 - a) F0 : 50% : 0% : 50%
 - b) F1: 40% : 20% : 40%
 - c) F2: 30% : 30% : 40%
 - d) F3: 50% : 20% : 30%
2. Frying temperature
 - a) S1: 150°C
 - b) S2: 165°C
 - c) S3: 180°C
3. Factorial Design
 - A = Formulation (4 levels)
 - B = Temperature B Factor (3 levels)
 - Repetition = 3

Each treatment was performed in three replicates, yielding $4 \times 3 \times 3 = 36$ experimental unit data points.

Activity details:

4. Preparation of materials

The production of Duokaili begins with the preparation of raw materials: anchovies (washed and drained), moringa leaves (stripped from their stems, washed, and drained), and sweet potatoes (peeled, washed, steamed until soft, and mashed). Garlic, salt, and

pepper are ground into a seasoning paste and then thoroughly mixed with the anchovies, mashed sweet potatoes, and moringa leaves. Tapioca flour is added according to the formulation to achieve a dough texture that is easy to shape. Portions of the homogeneous mixture are taken and flattened to ensure a crispy texture after frying and arranged on a baking tray or flat surface prior to the next processing stage. The ingredients are mixed and homogenized according to the specific formulation treatment. The product is packaged in airtight PP/nylon plastic for temporary storage pending proximate and organoleptic analysis.

Stage 2. Data Analysis

The results of each treatment were tested for content:

1. Analysis Parameters

A. Chemical Analysis

1. Moisture content (105°C oven method)
2. Fat content (Soxhlet)
3. Ash content
4. Protein content (Kjeldahl)
5. Carbohydrate content (by difference)
6. Antioxidant analysis (IC₅₀ method using UV-Vis spectrophotometry)

B. Organoleptic Analysis

Organoleptic testing (1–9 scale) and hedonic testing were conducted by 30 semi-trained panelists to evaluate color, aroma, texture, taste, and overall acceptance. Data were analyzed using ANOVA, followed by Duncan's Multiple Range Test (DMRT) at a 5% significance level in the event of significant differences, using SPSS 22.0. (Muchtar *et al.*, 2023).

C. Data Analysis

The research data were analyzed using:

1. Analysis of Variance (ANOVA) at a 95% confidence level ($\alpha = 0.05$).
2. If significant differences are found, a post-hoc test (Duncan's Multiple Range Test/DMRT) is conducted to determine differences between treatments.
3. Organoleptic and proximate data are presented in tables and graphs to facilitate the interpretation of research results.

RESULTS

Proximate Analysis

Moisture Content Analysis

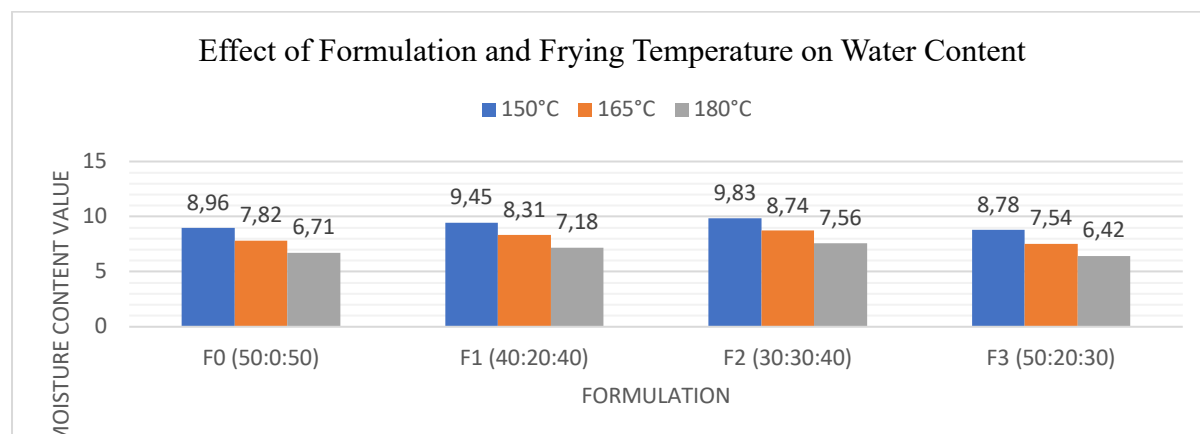


Figure 1. Average moisture content test results for Duokaili products.

Based on Figure 1, the average moisture content values ranged from 6.42% to 9.83%. The highest moisture content (9.83%) was observed in the F2S1 treatment (30% anchovies : 30% moringa leaves : 40% sweet potato at 150°C), while the lowest (6.42%) was observed in the F3S3 treatment (50% anchovies : 20% moringa leaves : 30% sweet potato at 180°C). Analysis of variance results indicated that the formulation, frying temperature, and the interaction between the two had a highly significant effect ($P < 0.01$) on moisture content. DMRT post-hoc test results showed that the F2S1 treatment combination differed significantly from the other combinations and yielded the highest moisture content, whereas the F3S3 combination yielded the lowest.

Protein Content Analysis

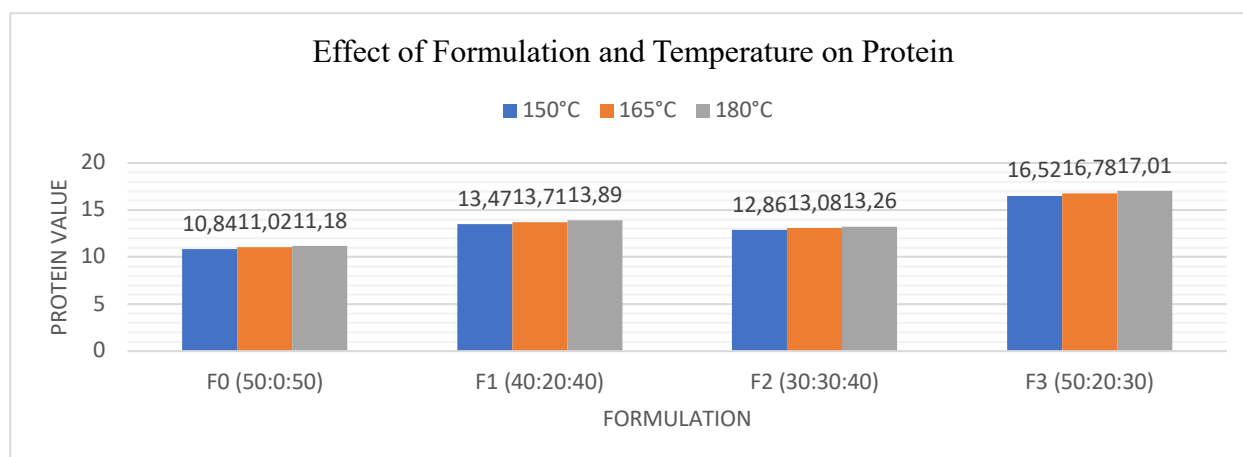


Figure 2. Average protein content test results for Duokaili products.

Berdasarkan Based on Figure 2, the average protein content ranged from 10.84% to 17.01%. The lowest protein content was observed in the F0S1 treatment (50% anchovy : 0% moringa leaves : 50% sweet potato) at 150°C (10.84%), while the highest was found in the F3S3 treatment (50% anchovy : 20% moringa leaves : 30% sweet potato) at 180°C (17.01%). Analysis of variance results indicated that the formulation, frying temperature, and the interaction between the two had a significant effect ($P < 0.05$) on the protein content of Duokaili. This suggests that changes in raw material composition elicit different responses at each frying temperature level. Further testing using DMRT revealed that the F3S3 treatment combination yielded a protein content that was significantly different from most other treatments, whereas the F0S1 combination resulted in the lowest protein content.

Carbohydrate Content Analysis

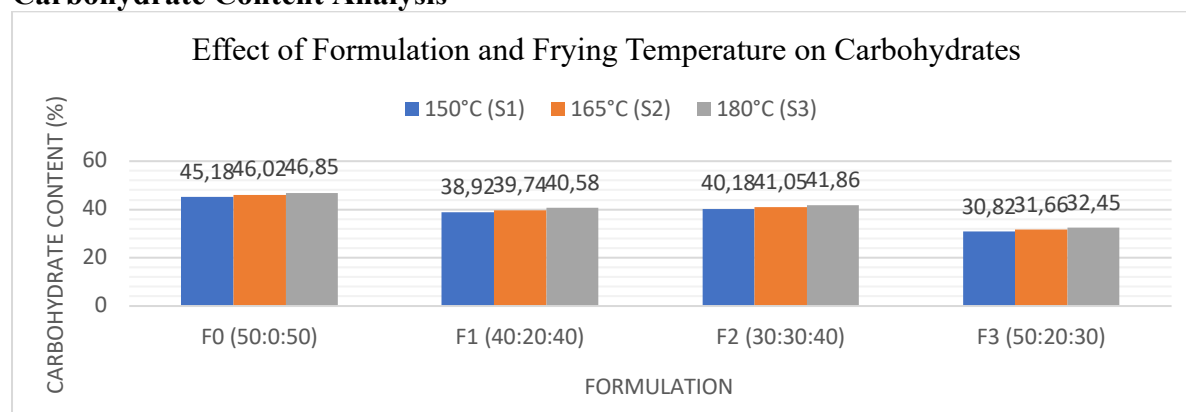


Figure 3. Results of Average Carbohydrate Content in Duokaili Products

Based on Figure 3. Graph of average data results from analysis of carbohydrate content. Duokaili formulated from anchovies, moringa leaves, and sweet potatoes showed carbohydrate content ranging from 30.82% to 46.85%. The highest carbohydrate content was observed in formulation F0 (50% anchovies : 0% moringa leaves : 50% sweet potatoes) fried at 180°C (S3), at 46.85%, while the lowest content was found in formulation F3 (50% anchovies : 20% moringa leaves : 30% sweet potatoes) fried at 150°C (S1), at 30.82%. Analysis of variance results indicated that formulation, frying temperature, and the interaction between formulation and frying temperature had a significant effect ($P < 0.05$) on the carbohydrate content of Duokaili. Duncan's Multiple Range Test (DMRT) at the 5% level showed that the F0S3 treatment combination yielded the highest carbohydrate content, differing significantly from most other treatment combinations. Conversely, the F3S1 combination produced the lowest carbohydrate content, which also differed significantly from treatments with higher sweet potato content.

Fat Content Analysis

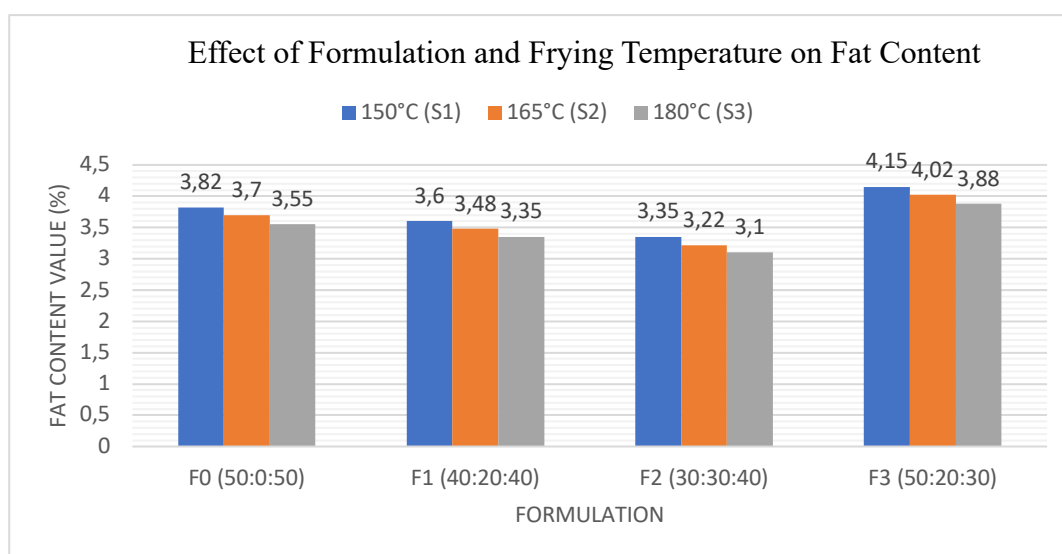


Figure 4. Average fat content of Duokaili products

Figure 4 presents the graph of the mean fat content analysis results for Duokaili, indicating that the raw material formulation and drying temperature influenced the product's fat content. The observed fat content ranged from 3.10% to 4.15%; the highest value (4.15%) was found in formulation F3 (50% anchovies : 20% moringa leaves : 30% sweet potato) at 150°C, while the lowest value (3.10%) was obtained with formulation F2 (30% anchovies : 30% moringa leaves : 40% sweet potato) at 180°C. Analysis of variance results showed that the formulation, drying temperature, and the interaction between the two had a significant effect on the fat content of Duokaili ($P < 0.05$). The effect of the formulation was attributed to the varying proportions of anchovies, which served as the primary source of fat. Based on the DMRT post-hoc test at the 5% level, formulation F3 differed significantly from all other formulations, as it yielded the highest fat content. Formulation F0 also differed significantly from F1 and F2, while F2 was the formulation with the lowest fat content.

Ash Content Analysis

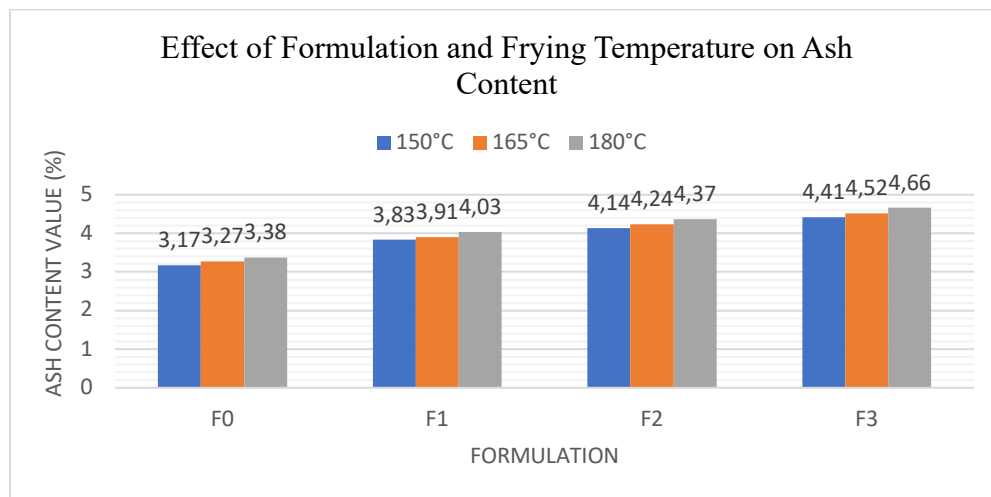


Figure 5. Average ash content of Duokaili products

Based on the graph of average data (Figure 5), the ash content of Duokaili ranged from 3.18% to 4.66%. The lowest ash content was observed in treatment F0 (drying temperature of 150°C), while the highest was found in treatment F3 (drying temperature of 180°C). Analysis of variance (ANOVA) results indicated that the formulation had a significant effect on ash content. The ANOVA also revealed a significant interaction between formulation and frying temperature ($P > 0.05$), indicating that increasing the temperature resulted in relatively different patterns of ash content increase across the various formulations. Results from the DMRT post-hoc test (at the 5% level) showed significant differences in ash content among all formulations.

Antioxidant Analysis

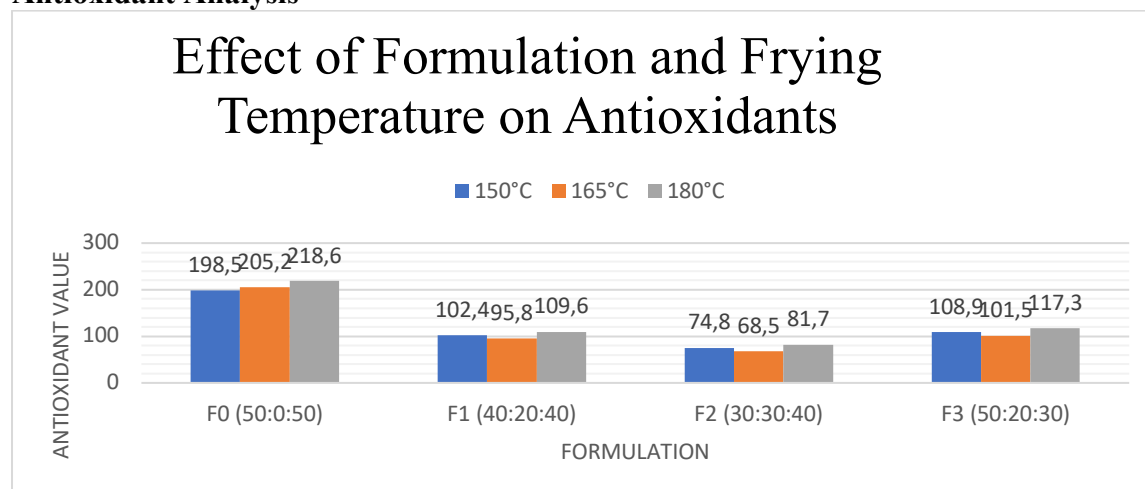


Figure 6. Average antioxidant content in Duokaili products

Based on the graph in Figure 6, the data on the average antioxidant activity of *Duokaili* indicate that the formulation and frying temperature influence the product's free radical scavenging capacity. Antioxidant activity values ranged from 68.5 to 218.6. The highest antioxidant activity was observed in formulation F2 (30% anchovies : 30% moringa leaves : 40% sweet potato) under treatment S2 (frying temperature of 165°C), with a value of 68.5, whereas the lowest activity was found in formulation F0 (50% anchovies : 0% moringa leaves : 50% sweet potato) at 150°C, with a value of 198.5. Analysis of variance (ANOVA) revealed that the formulation had a highly significant effect ($P < 0.01$) on antioxidant activity. Frying temperature also had a highly significant effect ($P < 0.01$). The interaction between formulation and temperature was significant ($P < 0.05$), indicating that the effect of frying temperature on antioxidant activity depends on the *Duokaili* formulation composition. Results from Duncan's

Multiple Range Test (DMRT) at the 5% level showed significant differences in antioxidant activity among the *Duokaili* formulations.

Organoleptic Quality

Table 1. Organoleptic Quality Test Results for Duokaili

Formulation	Temperature (°C)	Color	Aroma	Flavor	Texture	Total Revenue
F0	150	6,70 ± 0,47 ^a	6,80 ± 0,48 ^a	6,90 ± 0,48 ^a	6,80 ± 0,48 ^a	6,80 ± 0,48 ^a
	165	7,20 ± 0,41 ^c	7,30 ± 0,47 ^b	7,50 ± 0,51 ^c	7,40 ± 0,50 ^c	7,30 ± 0,47 ^b
	180	6,80 ± 0,41 ^a	6,90 ± 0,48 ^a	7,00 ± 0,45 ^b	7,10 ± 0,48 ^b	6,90 ± 0,48 ^a
F1	150	7,10 ± 0,40 ^b	7,20 ± 0,41 ^b	7,30 ± 0,46 ^c	7,30 ± 0,46 ^c	7,30 ± 0,46 ^b
	165	7,80 ± 0,41 ^e	7,90 ± 0,40 ^d	8,00 ± 0,37 ^e	8,00 ± 0,37 ^e	8,00 ± 0,37 ^d
	180	7,30 ± 0,47 ^c	7,40 ± 0,49 ^c	7,50 ± 0,51 ^c	7,60 ± 0,49 ^d	7,50 ± 0,51 ^c
F2	150	7,50 ± 0,51 ^d	7,60 ± 0,49 ^c	7,80 ± 0,41 ^d	7,70 ± 0,46 ^d	7,80 ± 0,41 ^c
	165	8,30 ± 0,47^f	8,40 ± 0,50^e	8,60 ± 0,50^f	8,50 ± 0,51^f	8,60 ± 0,50^e
	180	7,70 ± 0,46 ^e	7,80 ± 0,41 ^d	8,00 ± 0,37 ^e	8,00 ± 0,37 ^e	8,00 ± 0,37 ^d
F3	150	6,90 ± 0,55 ^a	7,00 ± 0,53 ^a	7,20 ± 0,48 ^b	7,00 ± 0,53 ^b	7,10 ± 0,48 ^b
	165	7,40 ± 0,50 ^{cd}	7,60 ± 0,49 ^c	7,70 ± 0,46 ^d	7,70 ± 0,46 ^d	7,70 ± 0,46 ^c
	180	7,00 ± 0,45 ^b	7,20 ± 0,48 ^b	7,40 ± 0,50 ^c	7,40 ± 0,50 ^c	7,30 ± 0,47 ^b

Note: Primary data, 2026

DISCUSSION

Proximate Analysis

Moisture Content Analysis

The highest moisture content was observed in formulation F2 (30% anchovies : 30% moringa leaves : 40% sweet potato), whereas the lowest was found in F3 (50% anchovies : 20% moringa leaves : 30% sweet potato). The high moisture content in F2 is thought to be influenced by the dietary fiber in moringa leaves, as well as the starch and pectin in sweet potatoes components that possess water-holding capacity, thereby enabling moisture retention during the frying process. This indicates that the raw material composition affects the product's ability to retain moisture during processing. Moringa leaves are known for their high dietary fiber content, while sweet potatoes contain hydrophilic starch and pectin. Furthermore, increasing the frying temperature from 150°C to 180°C consistently reduced moisture content across all formulations due to the increased rate of heat transfer and water evaporation from the material. Consequently, the F3 formulation fried at 180°C yielded the lowest moisture content, potentially offering superior storage stability. (Zalfa, 2025) explains that dietary fiber exhibits functional properties specifically water-holding capacity, swelling capacity, and oil-

holding capacity which contribute to enhanced moisture retention in various food products. It is also noted that higher drying or frying temperatures increase the temperature and water vapor pressure gradients between the material and the environment, thereby accelerating the rate of moisture mass transfer and resulting in a lower final moisture content (Manggabarani *et al.*, 2023).

Protein Content Analysis

The protein content of Duokaili increased in tandem with changes in formulation and rising frying temperatures. Formulation F3 (50% anchovies : 20% moringa leaves : 30% sweet potato) yielded the highest protein content (17.01%), whereas F0 (50% anchovies : 0% moringa leaves : 50% sweet potato) yielded the lowest (10.84%). This increase indicates that adding moringa leaves a source of plant-based protein and reducing the proportion of sweet potato effectively boosted the product's protein content. Moringa leaves are known for their high protein content and are frequently used to fortify foods and enhance their nutritional value. Beyond formulation, raising the frying temperature from 150°C to 180°C resulted in a measured increase in protein content, albeit a relatively small one. This phenomenon is attributed to the reduction of moisture during frying, which increased the concentration of protein within the product. However, higher heat can also cause protein denaturation and trigger the Maillard reaction, preventing the rise in protein content from being strictly proportional; the rate of increase slowed as proteins underwent heat-induced denaturation. While denaturation does not directly reduce the total amount of protein, it alters protein structure, thereby affecting functional properties. Furthermore, high temperatures accelerate the Maillard reaction between protein amino groups and reducing sugars from the sweet potato, rendering some amino groups less available. These findings align with research by Devi *et al.* (2023), which reported that moringa leaf powder has high protein content and the potential to enhance the nutritional value of food products. Additionally, Velayati *et al.* (2023) demonstrated that the rise in protein content was not due to the synthesis of new protein but rather to water evaporation during frying, which lowered the product's moisture content. This reduction in moisture led to a higher concentration of solid components including protein when expressed as a percentage of wet weight (wet basis). (Putri *et al.*, 2026) state that the roasting process causes a reduction in moisture content, thereby increasing protein concentration, although excessive heating can trigger protein denaturation and the Maillard reaction.

Carbohydrate Content Analysis

The carbohydrate content of Duokaili is influenced by formulation composition and processing temperature. Formulation F0 yielded the highest carbohydrate content due to its 50% sweet potato content, whereas F3 exhibited the lowest carbohydrate content resulting from a smaller proportion of sweet potato (30%) and a larger proportion of anchovies (50%). Sweet potato serves as the primary source of starch; thus, increasing its proportion raises the product's carbohydrate content, whereas anchovies contain negligible carbohydrates, being composed predominantly of protein and minerals. Moringa leaves also contain carbohydrates, but in much lower quantities than sweet potatoes, so their contribution to the product's total carbohydrate content is less significant. Among formulations F1 and F2, which share the same sweet potato proportion (40%), F2 showed a slightly higher carbohydrate content because it contained a lower proportion of anchovies than F1. In addition to formulation, increasing the frying temperature also raised carbohydrate levels across all treatments. This increase was not due to the formation of new carbohydrates but rather a reduction in moisture content during heating, which increased the concentration of dry matter, including carbohydrates. This phenomenon aligns with the principles of proximate analysis using the "carbohydrate by difference" method, where a decrease in moisture content leads to a higher measured percentage of carbohydrates.

(International, 2023). These findings are consistent with Rizki & Wulandari (2026), who reported that increasing the proportion of sweet potato in food formulations contributes to higher carbohydrate levels due to its high starch content. Furthermore, Manggabarani *et al.* (2023) stated that drying or heating processes reduce moisture content, thereby increasing the concentration of solid components, including carbohydrates. Starchy materials possess the ability to retain their solid structure during drying, meaning that moisture loss results in a higher concentration of starch (Fitria *et al.*, 2025).

Fat Content Analysis

Increasing the drying temperature from 150°C to 180°C caused the fat content of Duokaili to show a downward trend. This phenomenon is attributed to intensified lipid oxidation and degradation at high temperatures, which damages some fatty acids and results in a lower measured fat content. Nevertheless, the formulation with the highest proportion of anchovies (F3) still yielded the highest fat content compared to the other formulations, as anchovies serve as the primary source of lipids in the product. Moringa leaves are a food ingredient rich in protein and minerals but relatively low in fat, meaning they do not contribute significantly to increasing the product's fat content. Small fish (small pelagic fish), including anchovies, are good sources of protein and lipids; thus, increasing the proportion of fish in the formulation raises the product's fat content. These results indicate an interaction between raw material formulation and drying temperature in determining the final fat content of Duokaili. These findings align with Ramadhania *et al.* (2025), who reported that higher drying temperatures accelerate lipid oxidation, thereby reducing fat content in fishery products. Furthermore, Devi *et al.* (2023) stated that high temperatures accelerate lipid oxidation, particularly affecting the unsaturated fatty acids abundant in fish. Lipid oxidation leads to the formation of hydroperoxides, which subsequently decompose into aldehydes, ketones, and other volatile compounds, causing a loss of fat fractions during the heating process. Similar results have been reported indicating that higher drying temperatures increase the degradation of lipid components due to thermal oxidation, causing the fat content of food products to decrease (Belkacemi, 2021).

Ash Content Analysis

The ash content of Duokaili showed an upward trend corresponding to the increased proportion of mineral-rich ingredients specifically anchovies and moringa leaves. Formulation F0 yielded the lowest ash content because it lacked moringa leaves and contained a higher proportion of sweet potato, resulting in a relatively lower total mineral content. Conversely, formulations F1 and F2 exhibited increased ash content due to the addition of moringa leaves, which are known to be rich in calcium, iron, potassium, magnesium, phosphorus, and zinc. Formulation F3 produced the highest ash content (4.52%) due to a larger proportion of anchovies (50%) and a lower proportion of sweet potato, thereby increasing the product's overall mineral content. In addition to the formulation, raising the drying temperature from 150°C to 180°C also increased the ash content. This increase was not caused by a rise in actual mineral content but rather by the reduction of moisture during the drying process, which concentrated the minerals within the product's final weight. Thus, the drying temperature played a more significant role in increasing mineral concentration than the absolute amount of minerals present. These findings align with Abano (2020), who reported that fortifying fish-based products with moringa leaves increases ash content due to the leaves' high mineral levels. Similarly, Ibrahim and Safriyanto Maruka (2019) demonstrated that moisture loss during drying leads to a higher concentration of minerals in the final product weight. Furthermore, Ariani *et al.* (2023) stated in their review article that moringa leaves are a source of essential minerals capable of enhancing the nutritional value and ash content of various food products.

Meanwhile, Yang *et al.* (2023) reported that increasing the proportion of moringa leaf powder in functional noodles resulted in higher ash content due to the increased mineral content of the raw materials.

Antioxidant Analysis

The antioxidant activity of *Duokaili* increased with the rising proportion of moringa leaves in the formulation. Formulation F2 (30% moringa leaves) yielded the highest antioxidant activity, whereas F0 showed the lowest value due to the absence of moringa leaves. This increase is attributed to the high content of bioactive compounds in moringa leaves such as flavonoids (quercetin and kaempferol), phenolic acids, vitamin C, and carotenoids which act as free radical scavengers. Sweet potato also contributes to antioxidant activity through its carotenoid and phenolic compound content, although this contribution is lower than that of moringa leaves. Antioxidant activity measured by IC₅₀ (50% Inhibitory Concentration) is a more commonly used parameter than percentage inhibition. A lower IC₅₀ value indicates stronger antioxidant activity, as a lower concentration is required to inhibit 50% of free radicals. Based on IC₅₀ values, the highest antioxidant activity was observed in treatment F2S2 (165°C), while treatment F0S3 (180°C) resulted in the lowest activity. Formulation F2 (30% anchovies : 30% moringa leaves : 40% sweet potato) at 165°C yielded an IC₅₀ of 68.5 ppm, placing it in the strong antioxidant category. F1 and F3 fell into the moderate antioxidant category, while F0 was classified as a very weak antioxidant due to the absence of moringa leaves. These results indicate that excessively high frying temperatures can accelerate the degradation of bioactive compounds through oxidation and thermal damage, thereby reducing the product's free radical scavenging capacity. Conversely, a temperature of 165°C effectively reduces moisture content while preserving the majority of phenolic compounds and flavonoids, ensuring optimal antioxidant activity. These results align with various studies indicating that the stability of phenolic compounds, flavonoids, and carotenoids is significantly influenced by processing temperature, whereby excessive heating can reduce the antioxidant capacity of food products (Ramadhania *et al.*, 2025).

Organoleptic Quality

Organoleptic test results indicate that formulation and frying temperature influence the sensory quality of *Duokaili* specifically its color, aroma, taste, texture, and overall acceptance. Organoleptic scores ranged from 6.70 to 8.60, with the highest scores achieved by formulation F2 (30% anchovies : 30% moringa leaves : 40% sweet potato) fried at 165°C (treatment S2). This treatment yielded scores of 8.30 for color, 8.40 for aroma, 8.60 for taste, 8.50 for texture, and 8.60 for overall acceptance, reflecting the highest level of panelist preference. The high organoleptic scores for formulation F2 are attributed to the balanced composition of anchovies, moringa leaves, and sweet potato, which produced optimal sensory characteristics. Anchovies contributed umami flavor; sweet potato provided natural sweetness and facilitated color development via the Maillard reaction; and moringa leaves, at a 30% proportion, enhanced nutritional value without imparting an unpleasant raw/grassy aroma or an overpowering bitter taste. Furthermore, a frying temperature of 165°C optimized browning, aroma compound formation, and crispiness, whereas 150°C resulted in underdeveloped sensory characteristics, and 180°C caused excessive browning and a decline in sensory quality. These results are supported by Ahmad *et al.* (2022), who stated that overall acceptance is a key indicator of a food product's success, as it reflects the panelists' simultaneous assessment of all sensory attributes. The findings are also consistent with evidence that formulations based on moringa leaves and fish significantly influence the level of overall acceptance among panelists (Enjelita & Salsabila, 2026).

CONCLUSION

Based on the research findings, F2S2 (30% anchovies : 30% moringa leaves : 40% sweet potato at 165°C) was determined to be the optimal treatment, balancing proximate parameters, antioxidant activity, and organoleptic characteristics. F2S2 yielded high panelist acceptance as well as favorable nutritional quality and antioxidant activity, making it the best combination of formulation and processing temperature for the Duokaili product.

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