

International Journal Research Publication Analysis

Page: 01-16

CHARACTERIZATION OF OVEN-DRIED COCONUT RESIDUE FLOUR AT DIFFERENT TEMPERATURES AS A HIGH-FIBER FOOD INGREDIENT

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Article Received: 09 April 2026

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Article Revised: 29 April 2026

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Published on: 19 May 2026

DOI: <https://doi-doi.org/101555/ijrpa.5026>

ABSTRACT

Coconut residue from household coconut milk production is an abundant by-product that still contains nutritionally valuable components, particularly dietary fiber. This study evaluated the effect of oven-drying temperature on the chemical and functional characteristics of coconut residue flour intended for use as a high-fiber food ingredient. Fresh residue from mature coconuts was sorted, washed, pressed, steamed for 10 min, dried at 50°C, 60°C, or 70°C to constant weight, milled, and sieved through an 80-mesh screen. A one-factor completely randomized design with three replications was applied. Moisture, ash, protein, fat, carbohydrate by difference, total dietary fiber, yield, water absorption capacity, and oil absorption capacity were analyzed using one-way analysis of variance at a 5% significance level. Drying temperature significantly affected all observed parameters. The 60°C treatment produced the highest total dietary fiber (49.15%), yield (22.35%), and water absorption capacity (3.28 g/g), whereas 70°C produced the lowest moisture content (5.42%) and the highest oil absorption capacity (2.32 g/g). Although pairwise treatment differences could not be statistically confirmed because no post hoc test was conducted, the mean values indicated that 60°C provided the most balanced drying condition. These findings support the valorization of household coconut residue into a functional, high-fiber flour for bakery, noodle, cookie, and snack formulations.

KEYWORDS: Coconut residue, high-fiber flour, oven drying, total dietary fiber, functional food.

1. INTRODUCTION

Coconut residue is produced in large quantities during household and small-scale coconut milk processing. In many local food systems, this residue is still treated primarily as organic waste, although it remains rich in plant cell wall materials and residual nutrients. Converting this residue into flour provides a practical route to increase the value of a low-cost by-product while reducing avoidable food waste. This approach is consistent with the wider emphasis on valorizing agro-food by-products as secondary raw materials rather than disposing of them as processing residues [1-3]. The development of coconut residue flour is also relevant for local functional food innovation because the raw material is widely available in coconut-producing regions and can be processed using relatively simple technologies.

The nutritional potential of coconut residue is closely related to its dietary fiber and residual protein contents. Spent coconut meal has been described as a promising food ingredient containing approximately 45-55% dietary fiber and 14-25% protein, supporting its classification as a nutrient-rich coconut-processing by-product [4]. Defatted coconut meal has also been reported to contain about 25% protein and 52% dietary fiber and to show hydration and interfacial properties that may support food structuring [5]. Partially defatted coconut flour containing 5.21% moisture, 14.03% fat, 21.34% protein, 46.39% fiber, and 3.27% ash confirms that coconut-derived flour can contribute both nutritional and technological value to food systems [6].

Dietary fiber is not only nutritionally important but also technologically relevant in food formulation. In high-fiber ingredients, the capacity to bind water, retain oil, and influence viscosity can modify texture, mouthfeel, stability, and product acceptability. Coconut residue is particularly interesting because its hydration properties depend on fat content, particle size, and processing treatment. Earlier coconut-residue studies showed that reducing fat content from 10% to 2% improved hydration behavior and that a particle size of 550 μm produced the highest hydration properties [7]. Grinding and sieving are therefore critical steps because particle-size reduction can alter water-holding capacity, water-retention capacity, swelling capacity, and fat absorption capacity [8].

The use of coconut-derived flour has been explored in several food systems. Defatted coconut flour improved bioactive compounds, dietary fiber, antioxidant properties, functional properties, and sensory quality of nixtamalized maize blends, indicating that coconut by-products can contribute beyond simple fiber enrichment [9]. In rice noodle formulations, defatted coconut flour increased water absorption capacity, oil absorption capacity, mineral content, antioxidant activity, total phenolics, and total flavonoids, although 10%

incorporation was selected as the optimum level because higher concentrations negatively affected product quality [10]. Defatted, dehydrated coconut flour has also been evaluated for use in sandwich bread, where 5-10% incorporation produced acceptable bread texture and volume while increasing fiber and reducing gluten content [11].

Despite this potential, transforming household coconut residue into stable flour requires careful drying. Drying reduces moisture content, improves handling, facilitates grinding, and increases potential storage stability. However, temperature is not only a water-removal variable; it can also affect chemical composition, structural characteristics, particle behavior, and functional properties. Studies on plant-based flours show that drying and pretreatment conditions can affect yield, color, particle-size distribution, microstructure, flow behavior, and functional properties [12]. Hot-air drying temperature has also been shown to influence quality parameters in green banana flour, while jackfruit seed flour dried at 50-80°C showed changes in moisture, protein, fat, carbohydrate, and starch contents [13,14].

For coconut residue flour, oven-drying temperature may be especially influential because the matrix contains water, residual fat, protein, carbohydrate, and fiber fractions that may respond differently to thermal treatment. A relatively low temperature may leave more residual moisture and reduce milling efficiency, whereas a higher temperature may accelerate water removal but potentially alter matrix structure, yield, and functional properties. These changes are important for practical application because moisture content affects storage stability, residual fat affects flavor and potential rancidity, total dietary fiber determines high-fiber potential, and water and oil absorption capacities influence food formulation behavior.

Previous studies provide evidence on coconut flour applications, coconut residue hydration, and by-product valorization, but fewer studies have focused specifically on household coconut residue from coconut milk preparation and its conversion into flour by oven drying at simple temperature levels. This research gap is relevant because household residue is less standardized than industrial defatted coconut meal and may contain more variable moisture and residual fat. Food-upcycling studies also emphasize that inconsistent raw material quality, non-homogeneous inputs, certification requirements, and consumer skepticism remain challenges for upcycled ingredients [15].

This study aimed to evaluate the effect of oven-drying temperature on the characteristics of coconut residue flour as a high-fiber food ingredient. The drying temperatures investigated were 50°C, 60°C, and 70°C. The measured properties included proximate composition, total dietary fiber, flour yield, water absorption capacity, and oil absorption capacity. The working hypothesis was that drying temperature would significantly influence both chemical and

functional properties of coconut residue flour. The novelty of this study lies in its focus on household coconut residue and its systematic comparison of simple oven-drying temperatures to identify a condition that gives a balanced combination of low moisture, high dietary fiber, good yield, and favorable absorption properties.

2. MATERIAL AND METHOD

2.1 Research Design

The study used an experimental method arranged in a one-factor completely randomized design. The factor investigated was the oven-drying temperature during the preparation of coconut residue flour. Three temperature levels were applied, namely 50°C, 60°C, and 70°C. Each treatment was replicated three times, resulting in nine experimental units. The treatment codes were T1 for 50°C, T2 for 60°C, and T3 for 70°C. This design was selected because the main objective was to isolate the effect of drying temperature on flour characteristics while maintaining the same raw material preparation and analytical procedures across treatments.

The observed responses consisted of chemical and physical-functional parameters. Chemical parameters included moisture, ash, protein, fat, carbohydrate by difference, and total dietary fiber. Physical-functional parameters included flour yield, water absorption capacity, and oil absorption capacity. The use of multiple quality parameters was necessary because the optimal drying condition for high-fiber flour cannot be determined solely by moisture reduction. Instead, a balanced assessment must include nutrient composition, fiber retention, flour recovery, and interaction with water and oil.

Table 1: Treatment structure for oven drying of coconut residue flour.

Treatment code	Oven-drying temperature	Number of replications
T1	50°C	3
T2	60°C	3
T3	70°C	3

2.2 Materials and Apparatus

The main material was fresh coconut residue obtained from household production of coconut milk using mature coconuts. The residue was collected from ordinary household processing without specific control of the grated coconut-to-water ratio. This raw material source was selected to represent realistic household waste streams, although it may exhibit greater natural variation than industrial defatted coconut meal. The use of household residue is consistent with recent interest in valorizing food-processing and household by-products into functional food ingredients [1,3].

The coconut residue used in the experiment had to meet specific quality criteria before processing. The material was selected in fresh condition, without sour odor, slime, mold growth, or visible physical impurities. All residue was processed on the same day that it was obtained to minimize spontaneous fermentation, aroma changes, and quality loss before drying. Each experimental unit used 500 g of wet coconut residue. With three drying treatments and three replications, the minimum total requirement was 4.5 kg of wet residue; approximately 5-6 kg was prepared to anticipate losses during sorting, washing, draining, drying, milling, and sieving.

The apparatus included a drying oven, an analytical balance, a steamer, a dedicated flour grinder, an 80-mesh sieve, stainless-steel containers, drying trays, a spatula, a desiccator, and laboratory equipment for proximate analysis, total dietary fiber analysis, water absorption analysis, and oil absorption analysis. The use of grinding and sieving was important because the particle size of coconut residue is known to affect hydration and fat absorption behavior [8].

2.3 Preparation of Coconut Residue Flour

Fresh coconut residue was first sorted manually to remove foreign materials and visible impurities. The selected residue was washed with clean water, drained, and pressed to remove free water. The pressed residue was then steamed for 10 min as a preliminary treatment. Steaming was used to reduce initial contamination, limit enzymatic activity, and standardize material condition before thermal drying. Similar coconut dregs powder preparation has used blanching or heat pretreatment before drying and product application, supporting the relevance of thermal pretreatment in coconut-residue processing [16].

After steaming, the material was cooled at room temperature and drained again. The residue was divided into 500 g portions according to the experimental units. Each portion was dried in an oven at the assigned treatment temperature of 50°C, 60°C, or 70°C until constant weight. Constant weight was defined as the condition in which two consecutive weighing steps showed no meaningful change in sample mass. This endpoint was used to ensure that drying was sufficiently completed before milling and to reduce the influence of variable residual moisture on subsequent flour preparation.

The dried coconut residue was ground using a dedicated flouring device until it became a powder. The powder was then sieved through an 80-mesh sieve, and the fraction passing through the sieve was collected as coconut residue flour for analysis. The production sequence consisted of fresh coconut residue, sorting, washing, draining and pressing,

steaming for 10 min, cooling, oven drying according to treatment, milling, 80-mesh sieving, and collection of the flour fraction. Figure 1 summarizes the flour preparation process.

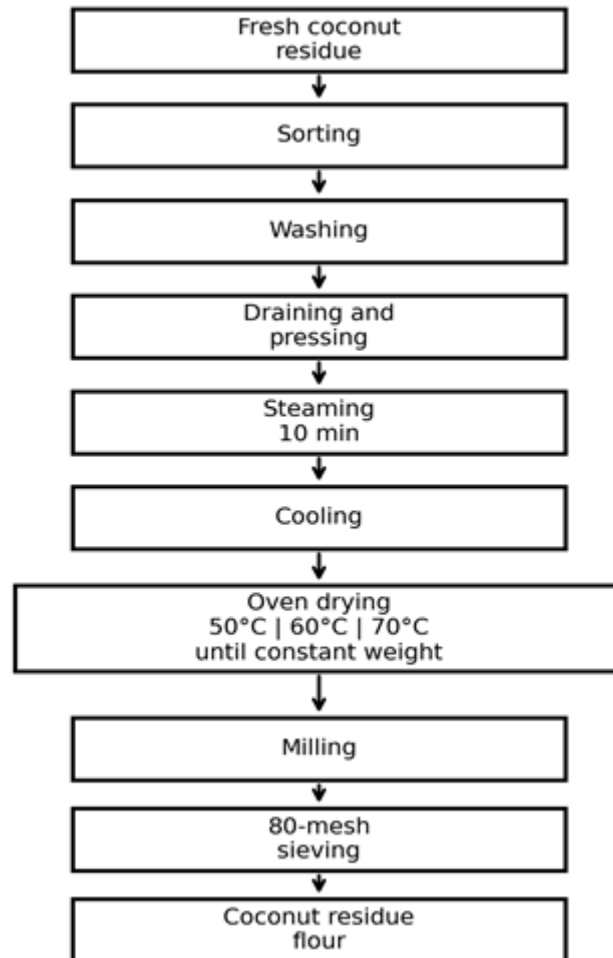


Figure 1. Flow diagram of the production process of coconut residue flour under different oven-drying temperatures.

2.4 Analytical Measurements

Moisture, ash, protein, fat, and total dietary fiber were analyzed using standard laboratory procedures based on AOAC methods. Total dietary fiber determination was supported by the general principles of validated AOAC enzymatic-gravimetric procedures. AOAC Method 2017.16 was validated across 13 laboratories and 16 test portions, with dietary fiber values ranging from 6.90 to 60.37 g/100 g, showing the applicability of validated fiber methods to diverse food matrices [17]. AOAC Method 2022.01 further supports the measurement of insoluble, soluble, and total dietary fiber in food matrices with acceptable repeatability and reproducibility [18].

Carbohydrate content was calculated by difference using the following equation: carbohydrate (%) = 100 - [moisture (%) + ash (%) + protein (%) + fat (%)]. Because this value was obtained indirectly, it was interpreted as a calculated proximate fraction rather than a direct measurement of individual carbohydrate components. Flour yield was calculated by comparing the weight of sieved coconut residue flour obtained after drying, milling, and sieving with the initial wet coconut residue weight, then multiplying the ratio by 100.

Water absorption capacity was measured to assess the flour's ability to bind water. This parameter is important for high-fiber food formulation because it relates to dough hydration, viscosity, texture, and moisture retention. Oil absorption capacity was measured to assess the flour's ability to bind oil, which is associated with flavor retention, mouthfeel, and interactions with lipid components. Similar integrated analyses of coconut flour functionality have been used in maize and rice noodle studies, where water and oil absorption capacities were evaluated alongside dietary fiber and other quality attributes [9,10].

2.5 Data Analysis

All test data were expressed as mean \pm standard deviation from three replications. The influence of oven-drying temperature on moisture, ash, protein, fat, carbohydrate, total dietary fiber, yield, water absorption capacity, and oil absorption capacity was evaluated using one-way analysis of variance at a 5% significance level. The analysis was performed using Microsoft Excel.

The statistical decision was based on the p-value. When $p < 0.05$, drying temperature was considered to have a significant effect on the parameter tested. When $p \geq 0.05$, drying temperature was considered to have no significant effect. Because the analysis was not followed by a post hoc comparison test, the statistical interpretation was limited to whether drying temperature had a general effect. Specific pairwise differences among 50°C, 60°C, and 70°C were therefore not claimed statistically.

3. RESULT AND DISCUSSION

3.1 Production Process and Treatment Overview

The production of coconut residue flour was carried out through a sequential process designed to transform fresh household coconut residue into a stable, fine, and analyzable flour fraction. The process began with fresh coconut residue obtained from household coconut milk preparation. The material was sorted to remove physical impurities, washed with clean water, drained, pressed, steamed for 10 min, cooled, and then divided into

experimental units. The residue was dried at 50°C, 60°C, and 70°C until constant weight was achieved, then ground and sieved through an 80-mesh sieve. This standardized sequence ensured that drying temperature was the main treatment variable while the other processing stages remained uniform.

The use of steaming, controlled oven drying, grinding, and sieving produced a flour matrix suitable for proximate analysis, determination of total dietary fiber, yield calculation, and evaluation of water and oil absorption capacities. Figure 1 indicates that the oven-drying stage was the key processing intervention expected to modify water removal, particle behavior, and functional characteristics. Therefore, the following subsections discuss both the quantitative results and the processing implications of each quality attribute.

3.2 Proximate Composition of Coconut Residue Flour

The proximate composition of coconut residue flour varied according to oven-drying temperature. As shown in Table 2 and Figure 2, moisture content decreased consistently as the drying temperature increased. The highest moisture content was recorded at 50°C ($7.82 \pm 0.11\%$), whereas the lowest was recorded at 70°C ($5.42 \pm 0.11\%$). This pattern indicates that higher drying temperature enhanced water removal from the coconut residue matrix. The reduction is technologically important because low moisture content generally supports better flour stability during storage, reduces microbial risk, and improves handling characteristics.

Table 2: Proximate composition of coconut residue flour produced under different oven-drying temperatures.

Drying temperature	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Carbohydrate (%)
50°C	7.82 ± 0.11	2.51 ± 0.03	15.87 ± 0.11	21.06 ± 0.15	52.73 ± 0.17
60°C	6.28 ± 0.11	2.58 ± 0.03	16.27 ± 0.11	20.11 ± 0.15	54.75 ± 0.17
70°C	5.42 ± 0.11	2.65 ± 0.03	16.10 ± 0.11	19.36 ± 0.15	56.46 ± 0.17

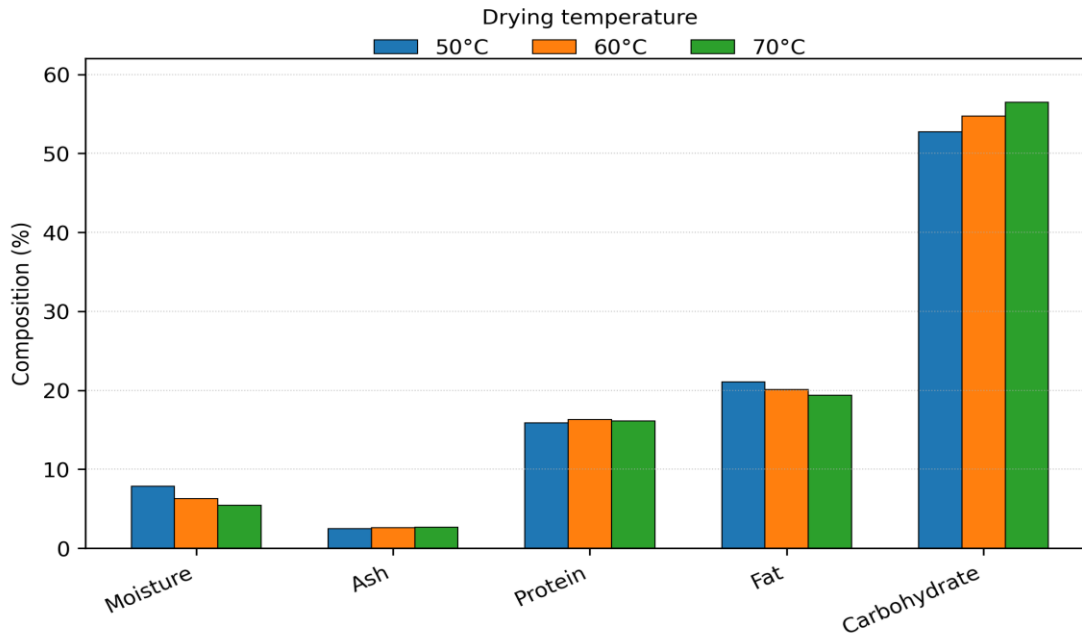


Figure 2. Proximate composition of coconut residue flour produced under different oven-drying temperatures.

Figure 2 shows a clear temperature-dependent change in the major proximate components of coconut residue flour. Moisture and fat contents declined as oven temperature increased, whereas ash and carbohydrate contents increased. Protein content showed a slightly different pattern, increasing from $15.87 \pm 0.11\%$ at 50°C to $16.27 \pm 0.11\%$ at 60°C , before decreasing slightly to $16.10 \pm 0.11\%$ at 70°C . These values are within the reported protein range of spent coconut meal, approximately 14-25% [4], although they are lower than the 21.34% protein reported for partially defatted coconut flour [6].

The ash content increased from 2.51% at 50°C to 2.65% at 70°C , probably due to a concentration effect as water content decreased. Fat content decreased from 21.06% at 50°C to 19.36% at 70°C , confirming that household coconut residue flour still retained substantial residual lipid. This fat level was higher than the 14.03% reported for partially defatted coconut flour [6], which is reasonable because the present material was not subjected to a defatting step. Carbohydrate content, calculated by difference, increased from 52.73% to 56.46%.

3.3 Total Dietary Fiber and Flour Yield

Total dietary fiber was one of the primary indicators used to evaluate the suitability of coconut residue flour as a high-fiber food ingredient. As shown in Table 3 and Figure 3, the total dietary fiber content ranged from $46.20 \pm 0.20\%$ to $49.15 \pm 0.20\%$. The highest value was obtained from flour dried at 60°C , while the lowest value was observed at 70°C . This

result indicates that the most intensive drying condition did not produce the most favorable fiber profile, even though it produced the lowest moisture content.

Table 3: Total dietary fiber content and yield of coconut residue flour produced under different oven-drying temperatures.

Drying temperature	Total dietary fiber (%)	Yield (%)
50°C	47.35 ± 0.20	21.70 ± 0.16
60°C	49.15 ± 0.20	22.35 ± 0.16
70°C	46.20 ± 0.20	21.55 ± 0.16

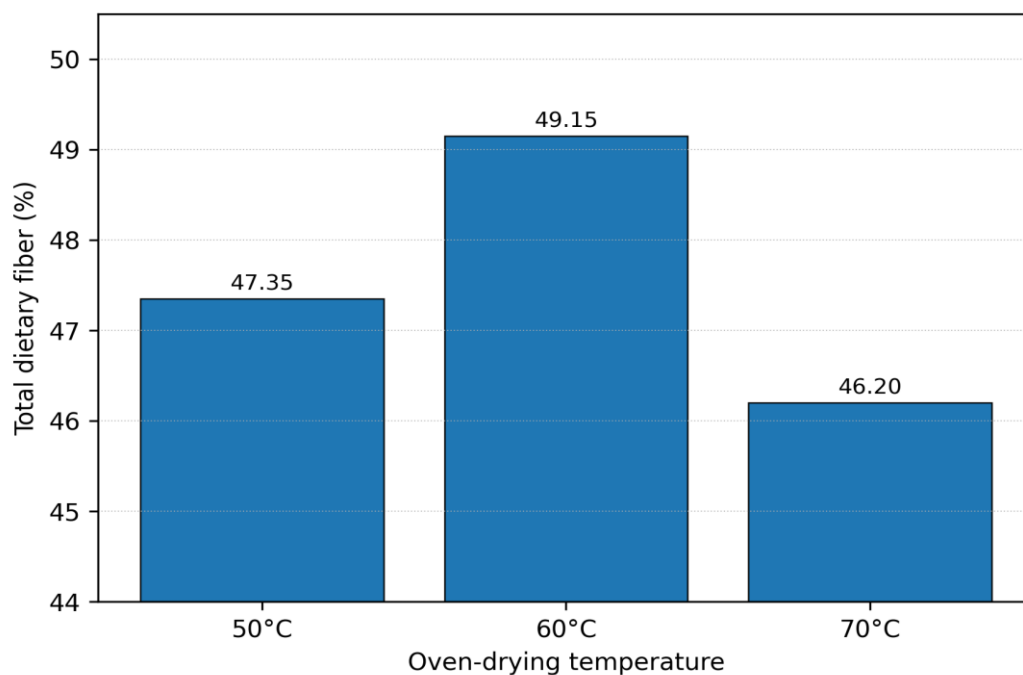


Figure 3. Total dietary fiber content of coconut residue flour produced under different oven-drying temperatures.

The total dietary fiber value of 49.15% at 60°C is consistent with the reported dietary fiber range of spent coconut meal, approximately 45-55% [4], and is also comparable with partially defatted coconut flour containing 46.39% fiber [6]. These similarities confirm that coconut residue flour can be considered a meaningful dietary fiber source, even when prepared from household coconut milk by-products. The decline in total dietary fiber at 70°C may be due to thermal effects on matrix structure, accessibility, or the fraction of particles recovered by sieving, though this mechanism requires further study.

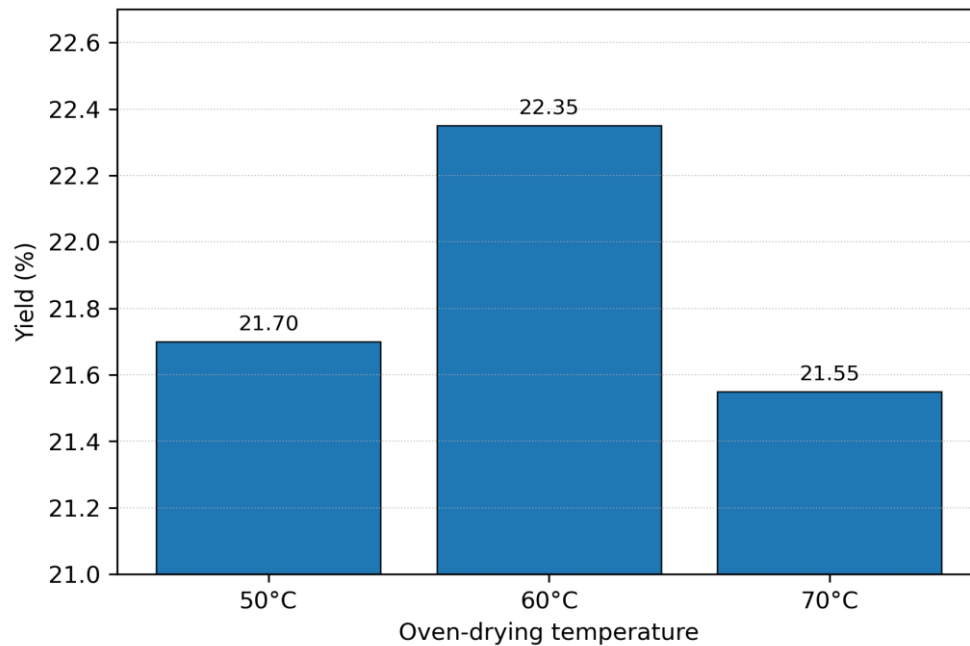


Figure 4. Yield of coconut residue flour produced under different oven-drying temperatures.

Flour yield followed a pattern similar to total dietary fiber. As shown in Table 3 and Figure 4, yield increased from $21.70 \pm 0.16\%$ at 50°C to $22.35 \pm 0.16\%$ at 60°C , but decreased to $21.55 \pm 0.16\%$ at 70°C . The lower yield at 50°C may be due to higher residual moisture, which could reduce the efficiency of grinding and sieving. Conversely, the lower yield at 70°C may indicate greater mass loss during drying or formation of particles that did not pass efficiently through the 80-mesh sieve. These findings suggest that 60°C provided a better balance between sufficient drying and flour recovery. Similar emphasis on flour yield and processing efficiency has been reported in plant-based flour studies, where drying and pretreatment conditions affected yield, particle structure, and functional properties [12,14].

3.4 Water Absorption Capacity and Oil Absorption Capacity

The functional properties of coconut residue flour were evaluated by measuring its water and oil absorption capacities. As presented in Table 4 and Figure 5, water absorption capacity ranged from 3.05 ± 0.04 to 3.28 ± 0.04 g/g, whereas oil absorption capacity ranged from 2.08 ± 0.04 to 2.32 ± 0.04 g/g. These properties are important because high-fiber flours can modify hydration behavior, dough viscosity, moisture retention, mouthfeel, and fat interaction in food systems.

Table 4: Water absorption capacity and oil absorption capacity of coconut residue flour produced under different oven-drying temperatures.

Drying temperature	Water absorption capacity (g/g)	Oil absorption capacity (g/g)
50°C	3.05 ± 0.04	2.08 ± 0.04
60°C	3.28 ± 0.04	2.18 ± 0.04
70°C	3.12 ± 0.04	2.32 ± 0.04

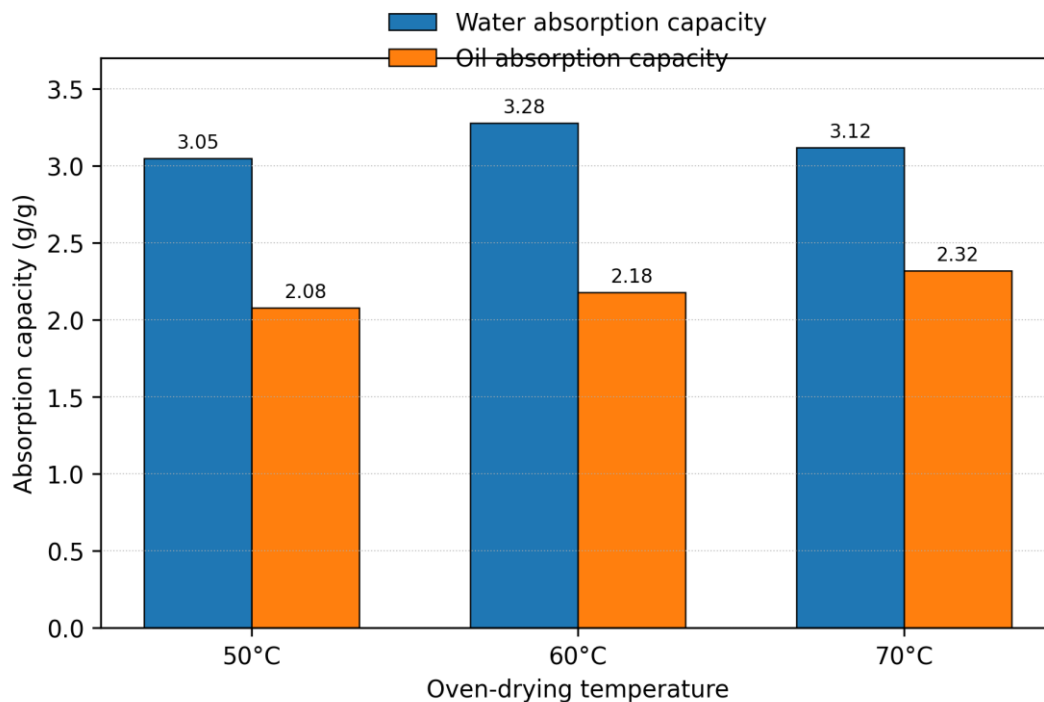


Figure 5. Water absorption capacity and oil absorption capacity of coconut residue flour produced under different oven-drying temperatures.

Water absorption capacity reached its highest value at 60°C (3.28 ± 0.04 g/g), compared with 3.05 ± 0.04 g/g at 50°C and 3.12 ± 0.04 g/g at 70°C. This suggests that flour dried at 60°C had a matrix structure more favorable for water binding. Coconut residue fiber has been reported to show hydration properties that are affected by treatment, fat content, and particle size [7,8]. The stronger water absorption at 60°C may therefore indicate a favorable balance among residual fat, particle structure, and exposed hydrophilic fiber components.

Oil absorption capacity showed a different response. As shown in Figure 5, oil absorption increased continuously from 2.08 g/g at 50°C to 2.32 g/g at 70°C. This suggests that higher drying temperature may have modified the surface properties of the flour particles and enhanced their interaction with oil. The contrasting patterns of water and oil absorption show that no single drying temperature optimized all functional properties simultaneously. The 60°C treatment was superior for hydration capacity, whereas 70°C was superior for oil-

binding capacity. Therefore, the choice of drying temperature should depend on the intended application of the flour. Nevertheless, because 60°C also produced the highest dietary fiber and yield, it remains the most balanced treatment in this study.

These functional properties have practical implications for food product development. Flour with high water-binding ability can influence dough hydration, viscosity, softness, and moisture retention, making coconut residue flour potentially useful in bakery products, cookies, noodles, snacks, and other high-fiber formulations. However, high water absorption may also alter processing behavior and final product texture. Previous studies using defatted coconut flour in rice noodles and bakery products indicate that coconut-derived flour can improve nutritional properties but must be optimized carefully, because excessive incorporation may affect texture, cooking behavior, and sensory acceptability [10,11,16].

3.5 Statistical Analysis

One-way analysis of variance showed that oven-drying temperature significantly affected all measured parameters at the 5% significance level. The affected parameters included moisture, ash, protein, fat, carbohydrate, total dietary fiber, yield, water absorption capacity, and oil absorption capacity. The highest F value was observed for carbohydrate content ($F = 377.12$, $p < 0.001$), followed by moisture content ($F = 351.10$, $p < 0.001$). Total dietary fiber was also strongly affected by drying temperature, with $F = 159.31$ and $p < 0.001$.

Table 5: ANOVA results for the effect of oven-drying temperature on coconut residue flour characteristics.

Parameter	F value	p-value	Decision
Moisture	351.10	<0.001	Significant
Ash	21.00	0.002	Significant
Protein	9.57	0.014	Significant
Fat	95.09	<0.001	Significant
Carbohydrate	377.12	<0.001	Significant
Total dietary fiber	159.31	<0.001	Significant
Yield	22.23	0.002	Significant
Water absorption capacity	21.95	0.002	Significant
Oil absorption capacity	30.42	<0.001	Significant

The ANOVA results confirm that drying temperature was an important processing variable in the production of coconut residue flour. However, because no post hoc tests were conducted, the statistical interpretation was limited to the overall effect of temperature. Specific pairwise differences among 50°C, 60°C, and 70°C cannot be claimed statistically. Therefore, the identification of 60°C as the most balanced treatment should be interpreted descriptively

based on the mean values of total dietary fiber, yield, and water absorption capacity. Similar studies on plant-based flours have also shown that hot-air drying conditions influence moisture, proximate composition, microstructure, and functional performance [13,14].

4. CONCLUSION

Oven-drying temperature significantly influenced the chemical and functional characteristics of coconut residue flour. Increasing the temperature from 50°C to 70°C reduced moisture content from 7.82% to 5.42% and increased oil absorption capacity from 2.08 to 2.32 g/g, indicating that higher drying intensity improved water removal and oil-binding ability. However, the most balanced flour characteristics were obtained at 60°C, which produced the highest total dietary fiber (49.15%), yield (22.35%), and water absorption capacity (3.28 g/g). These results indicate that the optimum processing condition for coconut residue flour should not be selected solely on the basis of the lowest moisture content, but should also consider fiber content, process recovery, and functional performance. The findings support the conversion of household coconut residue into a high-fiber flour that may be used as a local functional food ingredient. This study contributes to the valorization of coconut-processing by-products by providing evidence that a simple oven-drying temperature can shape flour quality. Further studies should include post hoc statistical testing, standardized coconut milk extraction, soluble and insoluble fiber profiling, microbiological assessment, storage evaluation, particle-size analysis, and application trials in bakery, noodle, cookie, snack, or composite food formulations.

5. ACKNOWLEDGEMENTS

The authors would like to acknowledge the administrative and technical support provided by the Department of Chemistry, Faculty of Mathematics and Natural Sciences, Tadulako University. The authors also appreciate the material contributions and equipment support provided by the laboratory facilities.

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