*Research Article*

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# Leftover Coconut Pulp: An Alternative for Dietary Fibre Gluten-Free Products

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## Abstract

Gluten, a protein found in various grains, plays a crucial role in providing the elasticity and structure of food products. However, for individuals with gluten intolerance (GIP), adhering to gluten-free diets is necessary, which can lead to a decrease in dietary fibre intake essential for maintaining intestinal health. Moreover, gluten-free products are often more expensive. This study focuses on developing an optimal formulation for a high dietary fibre gluten-free alternative flour using leftover coconut pulp, an agricultural waste product. The study involved physical experiments, including milling yield, water activity, and colour analysis, to determine the ideal drying time and temperature for producing leftover coconut pulp flour (LOCPF). Various drying times (2, 3, and 4 hours) at temperatures of 40, 50, and 60°C were tested. The results of the physical analysis revealed that LOCPF dried at 40°C for 3 hours yielded the most favourable outcomes, with a higher milling yield (51.43 ± 0.15%), maintained acceptable water activity levels (0.53 ± 0.01), and colour properties closely resembling those of wheat flour, the control sample. This study suggests that Leftover Coconut Pulp Flour (LOCPF) is a promising high dietary fibre gluten-free flour alternative for individuals with gluten intolerance. Furthermore, LOCPF has the potential to contribute to waste reduction by utilizing agricultural by-products, reduce the cost of gluten-free products, and simultaneously enhance the dietary fibre content of gluten-free diets.

## Keywords:

Left-over coconut pulp, Wastage, Gluten-free, Physical analysis

## 1 Introduction

Coconut (Cocos Nucifera) is renowned for its nutritional value (USDA, 2018). Today, it is commonly used in the production of water, oil, and milk, primarily extracted from its flesh. The remnants are often discarded or employed as animal feed. Despite coconut residue (left-over coconut pulp) not being a primary focus for producers, it boasts a high dietary fiber content and is gluten-free (Barge & Divekar, 2018). Gluten, a protein found in cereals such as barley, wheat, and rye, poses significant challenges for individuals intolerant to it, particularly those with celiac disease (Biesiekierski, 2017). Gluten consumption has been linked to damage in the small intestine of celiac patients (Wünsche et al., 2018). Consequently, gluten is strongly discouraged for such individuals, and opting for gluten-free foods is the optimal choice.

However, gluten-free foods are often more expensive due to their market size, and more importantly, gluten-free products are mostly made from starch-based ingredients like corn, potato, and rice flour. Hence, even though a gluten-free diet is the only option for celiac patients, a low intake of dietary fiber can lead to secondary health issues such as diarrhea, or if continuous, it can even lead to dietetic or colon cancer. Therefore, this study was conducted to explore the potential of leftover coconut pulp as a cost-effective and high-fiber gluten-free alternative for individuals with gluten intolerance. This research aims to address the need for more affordable gluten-free options while enhancing the dietary fiber content of gluten-free diets.

## 2 Literature Review

Coconut (Cocos Nucifera) has maintained its nutritional importance from the past to the present (USDA, 2018). Coconut has found versatile use in various applications, including food, construction materials, clothing materials, and fuel (Batugal et al., 2005; Gunn et al., 2011). Rich in saturated fats and lauric acid, coconut differs from other food products, such as dairy and processed meats, which contain higher amounts of long chain saturated fatty acids (Eirik, 2018). The coconut serves as a raw material for numerous food products, including coconut oil, raw coconut, coconut cake, coconut water, coconut milk, copra, coconut biscuits, and chips. Processing industries, such as virgin coconut oil processing, flavored coconut milk production, and coconut milk powder manufacturing, generate coconut milk residue as a by-product (left-over coconut pup). Despite being frequently discarded as waste or utilized as animal feed, coconut residue remains a valuable resource due to its high dietary fiber content and status as a gluten-free raw material (Barge & Divekar, 2018).

Gluten is a protein found in cereals, including barley, wheat, and rye, and is composed of gliadin and glutenin (Biesiekierski, 2017). It imparts elasticity and heat resistance, making it a common ingredient in bakery products to enhance texture, quality, and structure. Additionally, due to these functional properties, it is used as an additive in numerous ready-to-eat products (Biesiekierski, 2017; Jnawali et al., 2016). This reliance on gluten presents a challenge in the production of gluten-free products, as gluten plays a crucial role in boosting the texture and taste of food products. Consequently, gluten-free products often require extensive redesign and development, contributing to their higher cost in the market (Stevens & Rashid, 2008).

Despite the importance of cereal-based products in food technology, they have significant adverse effects on individuals with gluten intolerance (Wünsche et al., 2018). Gluten has been shown to damage the small intestine in celiac patients (Wünsche et al., 2018), making it unsuitable for consumption by them, and gluten-free foods become the recommended choice. However, the gluten found in cereals is a valuable nutrient that contributes to people's daily dietary fiber intake (Biesiekierski, 2017). Therefore, eliminating gluten from the diet indirectly reduces dietary fiber intake, a concern raised by researchers such as (Hager et al., 2011; Shepherd & Gibson, 2013), who have noted the insufficient dietary fiber content in gluten-free diets.

Dietary fiber is categorized into two groups: digestible and non-digestible. Digestible dietary fiber contains calories and is found in fruits and vegetables, while non-digestible dietary fiber, devoid of calories, is present in products such as coconuts and potatoes (Biswas et al., 2022). Dietary fiber plays a crucial role in reducing intestinal transit time, preventing constipation, lowering the risk of colorectal cancer, reducing blood cholesterol levels, and promoting the production of short-chain fatty acids and beneficial intestinal microflora (Brennan & Cleary, 2005). Insufficient dietary fiber intake can lead to secondary health issues, including colon cancer and diabetes, if prolonged (Biswas et al., 2022). Therefore, it is imperative to find cost-effective and high-fiber gluten-free alternatives for individuals with celiac disease, and leftover coconut presents itself as a promising option due to its gluten-free nature, underutilized potential, and high dietary fiber content.

# 3 Methodology

This section presents the materials and methods employed in this study, including left-over coconut pulp, preparation of Left-over coconut pulp flour, physical analysis (milling yileds, water activity and colour analysis), and statistical analysis.

## 3.1 Materials

The Leftover Coconut Pup (LOCP) was obtained from a local market in Shah Alam. The identified supplier was contacted a day before the collection of LOCP. Approximately 2 kg of LOCP with minimal impurities were collected early in the morning, around 6:30 am. This sample was immediately placed into an air-tight icebox with a temperature ranging from 2 to 4 degrees Celsius and transported directly to the laboratory. Upon arrival at the laboratory, the collected sample was prepared for the drying process. In addition, about 2 kg of commercial wheat flour was purchased from a hypermarket in Shah Alam to be used as the control sample.

## 3.2 Preparation of Left-Over Coconut pulp Flour

The LOCP sample underwent a drying process using a dehydrator (Excalibur, 3926TBX, USA) at varying temperatures and durations. Initially, around 100 g of LOCP was dried at temperatures of 40, 50, and 60°C for 2, 3, and 4 hours, respectively. The tested drying temperature and time are based on the fact that the temperature between 40 to 60°C for not more than 4 hours can preserve the nutrient content, biologically active compounds and antioxidants (Danso-Boateng, 2013). It should be conducted carefully to ensure the preservation of the valuable compounds in watermelon rinds as a poor drying process may lead to the loss of volatile compounds or to the formation of new ones following the completion of the drying process, all samples were removed from their respective dehydrators and placed on trays, preparing them for the next step, which is the grinding process. In the grinding phase, the dried LOCP samples were ground using a conventional grinder (Panasonic, MX-800, Japan). This grinding process lasted for 1 minute, with the grinder set to medium speed. Subsequently, the ground LOCP was sieved to obtain particles with a size range of 0.18-0.20 mm. The resulting LOCP flour samples were then stored in an airtight container at a temperature of 4 °C until they were ready for analysis.

## 3.3 Physical Analysis

Following all the steps involved in preparing the flour from Leftover Coconut Pulp (LOCP), the resulting samples, now known as Leftover Coconut Pulp Flour (LOCPF), underwent the physical analysis. These analyses included milling yields, water activity and colour analysis.

### *3.3.1 Milling Yield Analysis*

The milling yield analysis played a vital role in ascertaining the percentage of LOCPF obtained following the drying process. This calculation hinges on two pivotal factors: the initial weight of the LOCPF before drying and its weight after the drying process. The formula specified by Victoria (2015) was employed for this calculation. It's noteworthy that this analysis was carried out in triplicate to ensure precision and uniformity in the results.

$$Yield\ \% = \frac{Weight\ before\ roasting\ - Weight\ after\ roasting}{Weight\ before\ roasting}\ x\ 100\%$$

### *3.3.2 Water Activity*

About 5 grams of the LOCPF were transferred into individual plates, and their water activity was measured at a controlled temperature of 25 ± 0.2 °C. This measurement was carried out using a Rotronic HygroLab, HP23-AW-A Set from the USA, as detailed by Rothschild et al. (2015). It's important to note that this analysis was conducted in triplicate for accuracy and consistency.

### *3.3.3 Colour Analysis*

The colour of the LOCPF was determined using a Hunter colorimeter (Hunter Colour-Flex, CFLX 45-2, Hunter Associates Laboratory, Inc., Reston, VA, USA) based on the CIE (Commission Internationale de l'Eclairage) scale, utilizing the L*, a*, and b* colour space. Here's what these values represent:

- L* value represents lightness, with 0 being completely dark and 100 being pure white.

- a* value indicates the degree of greenness (negative values) or redness (positive values).

- b* value indicates the degree of blueness (negative values) or yellowness (positive values).

Before conducting the colour analysis, the Hunter colorimeter was calibrated. This calibration involved the use of standard ceramic tiles in both white and black, which were obtained from the supplier. The assessments were performed under D-65 illuminate conditions and with a 10° observer angle. For each replicate, the colour of the carob powder was measured in three different arbitrary sections to ensure accuracy and reliability in the results.

## 3.4 Statistical Analysis

For all tests, the means and standard deviations were calculated. Significance in mean values was assessed at a significance level of ($p < 0.05$) using one-way analysis of variance (ANOVA) in conjunction with Fisher's post-hoc test. The analysis was conducted using Excel Software version 2016.

## 4 Findings

This section incorporates the diverse results obtained from various physical analyses, including the milling yield analysis, water activity assessment, and color analysis for both the LOCPF samples and the wheat flour (control sample). Additionally, this section provides a thorough discussion, analysis, and comparisons of these results to draw meaningful conclusions and insights.

### 4.1 Milling Yields Analysis

In the milling yield analysis, the Leftover Coconut Pulp (LOCP) underwent a series of processes, including drying for varying durations (2 hours, 3 hours, and 4 hours) at different temperatures (40°C, 50°C, and 60°C), followed by pulverizing and sieving to produce Leftover Coconut Pulp Flour (LOCPF).

Table 1: The milling yield percentage of various treatment of LOCPF dried at different temperature.

| Temperature (°C ) | Drying Time (hrs) | | |
|---|---|---|---|
| | 2 | 3 | 4 |
| 40 | $53.27 \pm 0.14^{cB}$ | $51.43 \pm 0.15^{bC}$ | $48.66 \pm 0.14^{aB}$ |
| 50 | $52.95 \pm 0.21^{bB}$ | $48.74 \pm 0.18^{aB}$ | $48.58 \pm 0.23^{aB}$ |
| 60 | $52.19 \pm 0.08^{cA}$ | $45.91 \pm 0.04^{bA}$ | $45.72 \pm 0.09^{bA}$ |
| Control | $64.7 \pm 0.42^{e}$ | | |

*Note: a-c indicate a significant difference between tested samples and 'A-C' indicate a significant difference within the sample tested at $p < 0.05$. Control sample = Wheat flour*

In the milling yield analysis, the Leftover Coconut Pulp (LOCP) underwent a series of processes, including drying for varying durations (2 hours, 3 hours, and 4 hours) at different temperatures (40°C, 50°C, and 60°C), followed by pulverizing and sieving to produce Leftover Coconut Pulp Flour (LOCPF). Across the different roasting times, the yield percentages for LOCPF samples roasted at 40°C, 50°C, and 60°C for 2 hours ranged from 48.66±0.14% to 53.27±0.14%. For 3 hours, the range was 48.58±0.23% to 52.95±0.21%, and for 4 hours, it was 45.72±0.09% to 52.19±0.08%. Notably, there was only a slight decrease in milling yield for longer roasting times (3 hours and 4 hours) compared to 2 hours. This data suggests that LOCPF samples roasted at 40°C, 50°C, and 60°C for 2 hours exhibited a higher yield percentage, possibly due to their relatively higher moisture content. The limited roasting time at 40°C may not have fully dehydrated the powder, resulting in a higher yield. On the other hand, LOCPF samples roasted at 40°C, 50°C, and 60°C for 4 hours exhibited a lower yield percentage, likely due to their lower moisture content. Research by Qian et al. (2020) on oat flour supports this observation, indicating that higher roasting temperature and time lead to lower milling yields because more moisture evaporates from the flour.

Furthermore, the lower milling yield of LOCPF compared to the control sample (wheat flour) can be attributed to the type of equipment used during the grinding process. Manufacturers typically employ hammer mills to achieve finer flour particles, whereas this study utilized a conventional food grinder (Panasonic MX-800) for grinding LOCPF. Consequently, larger flour particles were present during the sieving process, resulting in fewer powder particles being sieved and a lower milling yield value. Research by Ashok (2019) highlights that the choice of equipment during the grinding process, as well as factors like the quality of the raw material, temperature, and time (roasting and grinding), can significantly influence the yield value of a food product.

### 4.2 Water Activity

The Food and Drug Administration utilizes easily operated instruments to swiftly measure water activity (aw), typically within a span of three to five minutes. This practice proves valuable in the identification of potentially hazardous food items (FDA, 2014). As per the findings of Erkmen & Bozoglu, (2016), microbial organisms cease to exist at water activity levels below 0.60. Hence, to ensure superior product quality and an extended shelf life, the assessment of water activity in powdered substances can be deemed more crucial than assessing their moisture content, given that microorganisms are unable to thrive below the threshold of 0.6 aw (Erkmen & Bozoglu, 2016).

Table 2: The water activity of various treatment of LOCPF dried at different temperature.

| Temperature (°C ) | Drying Time (hrs) | | |
|---|---|---|---|
| | 2 | 3 | 4 |
| 40 | $0.59 \pm 0.01^{cA}$ | $0.53 \pm 0.01^{bA}$ | $0.47 \pm 0.01^{aA}$ |
| 50 | $0.58 \pm 0.01^{cA}$ | $0.52 \pm 0.01^{bAB}$ | $48.58 \pm 0.23^{aB}$ |
| 60 | $0.58 \pm 0.01^{cA}$ | $0.51 \pm 0.01^{bB}$ | $45.72 \pm 0.09^{bA}$ |
| Control | $0.59 \pm 0.01^{c}$ | | |

*Note: a-d' indicate a significant difference between tested samples and 'A-B' indicate a significant difference within sample tested at p < 0.05. Control sample = Wheat flour.*

As shown in Table 2, the water activity (aw) of LOCPF, when dried at temperatures of 40°C, 50°C, and 60°C for durations of 2 hours, exhibited a range of 0.58-0.59 aw. For 3 hours, the range was 0.51-0.53 aw, and for 4 hours, it was 0.46-0.47 aw. These results indicate that while all samples met the standard for water activity (<0.60), the most favourable water activity levels were achieved at 50°C and 60°C when dried for 4 hours. This can be attributed to the higher drying time and temperature. This concept is supported by Carbonell et al. (2021) and Fukui et al. (2022), who conducted studies on almond and rice powder, respectively. They reported that water activity decreases as roasting time and temperature increase in their respective samples.

On the contrary, it's worth noting that the water activity of all LOCPF samples was significantly improved (p<0.05) compared to the control sample, which was wheat flour. This enhanced water activity in the LOCPF samples can be attributed to their substantially higher fiber content, exceeding that of the control sample by 22%. This aligns with findings from a study conducted by Singh et al. (2016), which emphasized that the addition of xanthan gum, a fiber-rich ingredient, to rice muffins led to a reduction in water activity due to the water-absorbing properties of the fibers, resulting in reduced water availability.

### 4.3 Colour Analysis

Table 3: The L* values of various treatments of LOCPF dried at different temperatures.

| Temperature (°C ) | Drying Time (hrs) | | |
|---|---|---|---|
| | 2 | 3 | 4 |
| 40 | 83.79 ± 0.07$^{bC}$ | 66.94 ± 0.04$^{aB}$ | 65.23 ± 0.03$^{aB}$ |
| 50 | 76.63 ± 0.03$^{bB}$ | 65.89 ± 0.04$^{aA}$ | 65.57 ± 0.03$^{aA}$ |
| 60 | 71.01 ± 0.71$^{bA}$ | 65.57 ± 0.01$^{aC}$ | 64.21 ± 0.01$^{aC}$ |
| Control | 95.70 ± 0.61$^{e}$ | | |

*Note: 'a-e' indicates a significant difference between tested samples and 'A-C' indicate a significant difference within the sample tested at p < 0.05. Control sample = Wheat flour*

The L* values for LOCPF samples, which were dried for 2 hours at 40, 50, and 60 °C, were measured as 83.79 ± 0.07, 76.63 ± 0.03, and 71.01 ± 0.71, respectively. When the samples were dried for 3 hours, the L* values at these temperatures were 66.94 ± 0.04, 65.89 ± 0.04, and 65.57 ± 0.01. Finally, after drying for 4 hours, the L* values recorded were 65.23 ± 0.03, 65.57 ± 0.03, and 64.21 ± 0.01 at 40, 50, and 60 °C, respectively. The data presented in Table 3 illustrates a consistent decrease in lightness as both the roasting temperature and time increase. This reduction in lightness can be attributed to various factors, including sugar caramelization, the generation of Maillard reaction products like melanoidins, and the intensification of brown pigments (Mounir et al., 2021). Furthermore, Nadeem et al. (2017) noted that the colour of cultivated carob was inversely related to roasting temperature and duration.

In comparison to the control sample (wheat flour), the LOCPF samples dried under different conditions consistently displayed significantly lower (darker) L* values. This phenomenon can be attributed to the inherent brownish colour of LOCP, arising from the presence of a thin brown layer between the coconut shell and coconut meat (Testa). A study on coconut hausrorium flour conducted by Mudasir & Sundaramoorthy (2018) revealed that unpeeled coconut hausrorium flour had lower L* values than peeled coconut hausrorium flour due to the yellowish hue of the skin. Moreover, as indicated by Link (2019), the chemicals used to expedite the aging process in bleached flour result in a whiter colour, finer grain, and softer texture, whereas unbleached flour exhibits a denser grain and harder texture. The bleaching process employed in the production of conventional wheat flour accounts for the relatively lighter appearance of the control sample in comparison to LOCPF. These factors collectively elucidate the lower L* values observed in the LOCPF samples compared to the control sample.

Table 4: The a* and b* values of various treatments of LOCPF dried at different temperatures.

| Temperature (°C ) | Redness (a) | | |
|---|---|---|---|
| | Drying Time (hrs) | | |
| | 2 | 3 | 4 |
| 40 | 11.52 ± 0.03$^{bC}$ | 9.74 ± 0.02$^{cB}$ | 9.67 ± 0.18$^{cA}$ |
| 50 | 11.44 ± 0.02$^{aB}$ | 9.43 ± 0.03$^{bA}$ | 9.47 ± 0.03$^{bA}$ |
| 60 | 11.29 ± 0.14$^{aB}$ | 9.26 ± 0.03$^{bA}$ | 9.23 ± 0.04$^{bA}$ |
| Control | 14.30 ± 0.36$^{a}$ | | |
| | Yellowness (b) | | |
| 40 | 14.11 ± 0.02$^{bA}$ | 12.25 ± 0.01$^{aB}$ | 12.26 ± 0.05$^{aB}$ |
| 50 | 17.39 ± 0.07$^{bC}$ | 12.28 ± 0.11$^{aB}$ | 12.28 ± 0.9$^{aB}$ |
| 60 | 15.32 ± 0.01$^{bB}$ | 11.87 ± 0.01$^{aA}$ | 11.88 ± 0.01$^{aA}$ |
| Control | 18.45 ± 0.12$^{a}$ | | |

*Note: a-e' indicate a significant difference between tested samples and 'A-C' indicate a significant difference within the sample tested at p < 0.05. Control sample = Wheat flour.*

When examining the a* values, LOCPF samples dried at 40 °C for 2, 3, and 4 hours exhibited a range of a* values from 9.67 ± 0.18 to 11.52 ± 0.03. The a* values for LOCPF samples dried at 50 °C for the same durations (2, 3, and 4 hours) fell within the range of 9.47 ± 0.03 to 11.44 ± 0.02. Lastly, the a* values for LOCPF samples dried at 60 °C for 2, 3, and 4 hours ranged from 9.23 ± 0.04 to 11.29 ± 0.14. Regarding the yellowness (b*) values, LOCPF samples dried at 40 °C for 2, 3, and 4 hours exhibited b* values ranging from 12.26 ± 0.05 to 14.11 ± 0.02. The b* values for LOCPF samples dried at 50 °C for the same time periods (2, 3, and 4 hours) fell within the range of 12.28 ± 0.9 to 17.39 ± 0.07. Finally, the b* values for LOCPF samples dried at 60 °C for 2, 3, and 4 hours ranged from 11.88 ± 0.0 to 15.32 ± 0.01. Comparing these results to the control sample (cocoa powder), it is evident that the control sample exhibited significantly higher a* (14.30 ± 0.05) and b* (18.45 ± 0.12) values than the LOCPF samples. This difference seen in a* and b* values can be attributed to the fact that L* values are directly proportional to the a* and b* values, as indicated in Table 4. This relationship aligns with the findings of Pasukamonset et al. (2018), who explained that a darker color (i.e., lower L* value) in a given sample results in lower redness (a*) and yellowness (b*) values..

## 5 Conclusion

In conclusion, gluten plays a pivotal role in providing the elasticity and malleable structure of food products due to its protein content. Nonetheless, gluten intolerance (GIP) requires strict adherence to gluten-free diets, which can result in reduced dietary fibre intake essential for maintaining intestinal health. Furthermore, gluten-free products tend to be costlier. Hence, this study focused on developing an optimal formulation for a high dietary fibre gluten-free alternative flour using leftover coconut pulp, an agricultural waste product. The primary raw material for producing gluten-free flour in this research was leftover coconut pulp (LOCP). Several processes, including drying, grinding, and sieving, were employed. Various physical analyses, such as milling yields, water activity measurement, and colour analysis, were conducted on LOCPF (Leftover Coconut Pulp Flour) samples, comparing them to a control sample (wheat flour). The aim was to identify the most favourable drying parameters for producing gluten-free flour from leftover coconut pulp.

Based on the findings from the various analyses, it became evident that LOCPF dried at 40°C for a duration of 3 hours yielded the most favourable results. This specific drying condition resulted in higher milling yields, maintained acceptable water activity levels, and exhibited colour properties closely resembling those of the control sample. In summary, the development of gluten-free flour from leftover coconut pulp holds the potential to reduce waste pollution, cut the cost of gluten-free products, and concurrently increase the dietary fibre content of gluten-free diets.

This study only focusing on the effect of drying parameters (time and temperature) on physical properties of flour, therefore further research on their effect on chemical properties as well as sensorial acceptability in food product from left over coconut pulp need to be explored.

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## 7 About the author

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**Yusnita Hamzah**, earned her Ph.D. in Food Science from The University of Nottingham, UK. She currently holds the position of Senior Lecturer at Universiti Malaysia Terengganu, Malaysia. Her research primarily revolves around the identification and characterization of starch, as well as the physical and chemical alteration of starch and its implications on various food products. Additionally, her research extends to the development of new ingredients and the utilization of underutilized materials to enhance the value of food products. Hamzah, Y. ensures that both new and modified food products undergo thorough characterization for their physicochemical properties, acceptability, and storage quality to estimate their shelf life. Previously, she served as the Head of the Food Science Program at UMT, and currently holds the position of Chief Operating Officer (COO) at the Strategic Innovation Centre (SIC) at Universiti Malaysia Terengganu. Hamzah, Y. has received numerous awards, including medals in various research and educational innovation competitions, as well as recognition as an oral and poster presenter at conferences.

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