DOI: https://doi.org/10.37833/cord.v41i.484
Coconut Research & Development, 2025, 41, 7-15

Physical, nutritional and functional quality of defatted coconut residue from four coconut (*Cocos nucifera* L.) varieties; as a dietary supplement for the food industry

H. P. D. T. Hewa Pathirana[1]*, W. M. K. Lakdusinghe[1], L. L. W. C. Yalegama[2], C. A. T. D. Chandrapeli[3], J. M. Nazrim Marikkar[4]

[1] Research Officer, Coconut Processing Research Division, Coconut Research Institute, Lunuwila, 61150, Sri Lanka
[2] Head/Senior Research Officer, Coconut Processing Research Division, Coconut Research Institute, Lunuwila, 61150, Sri Lanka
[3] Technical Officer, Coconut Processing Research Division, Coconut Research Institute, Lunuwila, 61150, Sri Lanka
[4] Associate Research Professor, National Institute of Fundamental Studies, Hanthana Road, Kandy, Sri Lanka

* Corresponding author. Email: dilthihewa@gmail.com

ABSTRACT

The value addition to the by-products enhances the profitability of the industry with a zero-waste concept. Defatted desiccated coconut flour (DCF) is a residue after the extraction of virgin coconut oil (VCO). This research aims to identify the effect of a variety of coconuts on the physical, nutritional and functional quality of DCF compared to whole wheat flour (WWF). Mature coconuts of four different varieties: Tall×Tall (TT), Ran Thambili (RT), San Ramon (SR), and Gon Thambili (GT) were used for the VCO extraction process by the cold press extraction followed by conversion of residue into flour (DCF). The average residue recovery is 15.33 ± 0.41% ($p>0.05$). The particle size of DCF is significantly higher than WWF, and only 23.16% of DCF is at the 250 µm level. The highest wettability (27.46±0.00 s) and swelling capacity (49.00±0.00 ml) have been identified in GT with a significantly ($p<0.05$) lower bulk and tapped density. The oil content (13.74 ±1.84%) and protein content (15.63±0.54) of GT were significantly low. SR and TT showed the highest protein and ash contents, 22.07±0.63 %, and 6.81±0.67% respectively. DCF is a valuable fiber supplement (18%). The best physical properties were identified in GT varietal flour, while the best nutritional values were observed in SR and TT varietal flours. The best functional properties, including phenolic content, were exhibited by GT, RT and ST (1.04 ±0.09 mg GAE /g). Therefore, the results conclude that DCF is a nutrient-rich dietary supplement, high fiber and minerals with functional qualities suitable for food products fortification. Further, the quality characteristics are varied due to the inter-varietal effects of the coconut palm.

Keywords: Coconut, defatted coconut residue, functional properties, approximate nutrition, variety

---

INTRODUCTION

The coconut palm (*Cocos nucifera* L.) is a versatile plant that is grown in the tropical and subtropical regions of the world. It has remarkable commercial benefits for mankind. Based on the morphological characteristics and breeding behavior of the coconut palm, Sri Lankan coconuts were categorized into three distinct varieties: typica (tall palm), nana (dwarf palm) and aurantiaca (intermediate - king coconut) (Liyanage, 1958). Coconut fruit is an edible portion of the coconut palm, which consists of fibrous mesocarp, shell, coconut meat (kernel) and coconut water. An average mature fresh coconut meat has 31.20% moisture, 8.13% protein, 34.47% fat, 0.77% ash, 5.44% crude fiber and 10.57% carbohydrates (Chuku & Onikio, 2021). Khaykal & Pulukadang (2021) identified the concentration of Fe (44,075 mg/kg) and Zn (24.2 mg/kg) in coconut flour after the milk extraction process.

A variety of products have been made from coconut, such as coconut milk, desiccated coconut, coconut milk cream, coconut chips and coconut oil. Moreover, the production of coconut oil can be further diversified into different types, including white coconut oil, virgin coconut oil (VCO), refined, bleached, and deodorized coconut oil, coconut pairing oil, and industrial coconut oil, by passing through a range of processing practices. VCO is produced primarily through dry processing (cold-press method), which generates defatted desiccated coconut residue (DCR) or oil cake (Poonac) as a by-product (Thaiphanit & Anprung, 2016). Apart from the dry processing method, VCO is extracted through wet processing methods without giving heat treatments such as enzymatic separation, centrifugation, freezing and cooling method and fermentation (Prasanna et al., 2024).

Previous studies identified that the nutritional composition of partially defatted coconut flour contains 21% of protein, 46.39% total dietary fiber and 14.75% of fat content (Adsare & Annapure, 2024). This by-product of DCR is exported to the bakery industry to create flour blends that enhance the dietary fiber and mineral content of supporting products (Adeloye et al., 2020). Moreover, the crude fiber content of biscuits blended with defatted coconut flour (4.7%) has increased significantly compared to wheat flour-based biscuits (1.46%) (Pathirana et al., 2020). Therefore, consumer awareness of the functional benefits of food extends to a novel trend beyond basic nutrition.

If the food product provides more dietary ingredients, such as minerals, vitamins, dietary fibers, and protein concentrates which can be considered as dietary supplements (USDA Food Data Central, 2023) and defatted coconut flour also can be categorized as a dietary supplement specially for bowel health, glycemic control due to its higher dietary fiber content (Trinidad et al., 2003). Functional properties of food, including antioxidant and phenolic content, provide additional health benefits to consumers by helping prevent non-communicable diseases.

However, the main ingredient of bakery products is wheat flour because it provides structure for the dough of bakery products through the gluten protein. Moreover, what flour contains 8-13% of protein, 2% of crude fiber, and 1.5% of fat (Verem et al., 2021). In contrast, the partially defatted coconut flour contains 21% of proteins, 46.39% total dietary fiber and 14.75% of fat content (Adsare & Annapure, 2024).

Morphological variations in fruits can have interrelations with specific internal variations in physical or nutritional properties. Moreover, Marasinghe et al. (2019) reported on the nutritional variation of coconut testa flour with inter-varietal effect and physiochemical properties of defatted coconut testa flour with the inter-varietal effect (Marasinghe et al., 2021). Similarly, there can be a significant variation in the nutritional profiles of DCR within the variety of coconuts. Furthermore, there may be specific nutrients and functional qualities of defatted coconut flour compared to whole wheat flour. Therefore, this research aimed to evaluate the physical, nutritional and functional properties of defatted desiccated coconut flour (DCF) of three types of indigenous coconut varieties, namely Tall x Tall (TT), Gon Thambili (GT), Ran Thambili (RT), and an exotic breed of San Ramon (SR). The physical, nutritional and functional properties of DCF of each variety were compared with whole wheat flour (WWF) as a reference flour for general use.

METHODOLOGY

Sample Collection

Fifty fully mature coconuts of each variety, Tall (TT), Gon Thambili (GT), Ran Thambili (RT) and San Ramon (SR), were collected from the Bandirippuwa Estate of Coconut Research Institute, Lunuwila, Sri Lanka during the three picks. They were separately seasoned for three weeks under shade and used for DCF preparation.

Preparation of the DCF

Along with maturity, the moisture content of the coconut kernel is reduced, which improves the ease of deshelling. The reduction of the moisture of the coconut kernel positively affects the drying time. Then, mature, seasoned coconuts were dehusked and deshelled according to the recommendation of the Coconut Research Institute of Sri Lanka.

After removing the outer brown skin (Testa) of the coconut fruit, the white kernel was washed. Then the white kernel was fed to a disintegrator (Unitex Engineers, Sri Lanka), followed by dehydration at 60°C (4 to 6 hours until 3% moisture) using a cabinet-type dehydratore (Wessberg, Martin, Germany). The dry kernel was fed into a cold press oil expeller (Udaya Industries, Sri Lanka) and the defatted desiccated coconut/ residue (DCR) was collected. Then it was converted to flour (DCF) using a pulverizer (FRITSCHPUL-14 Sri Lanka) (Figure 1). The samples were prepared from three different varieties and stored in a refrigerator (4 ± 2°C). Whole wheat flour (Prima brand) was purchased from the Cargills supermarket in Dankotuwa, Sri Lanka.

Data collection

Physical properties of DCF and WWF

Yield of defatted desiccated coconut pellet (DCP). The DCP yield of each variety was recorded after extraction of VCO to the fresh kernel weight as in Equation (Eq.1).

$$Yield\ of\ DCP\ (\%) = \frac{Amount\ of\ DCP\ (Kg)}{Fresh\ coconut\ kernel\ weight\ (Kg)} \quad \text{(Eq. 1)}$$

Particle size distribution of the DCF. The particle size distribution of each flour type was identified using a sieve shaker (AS 200 digit CA RetschGmbH - Germany) with four different sizes of sieves (1 mm, 710 µm, 500 µm, 355 µm and 250 µm) according to AOAC 920.36 in the 1995. The weight of the samples retained on each sieve was measured and represented as a cumulative percentage.

Moisture content. The moisture content of the samples was determined according to the AOAC method 990.20 (1999).

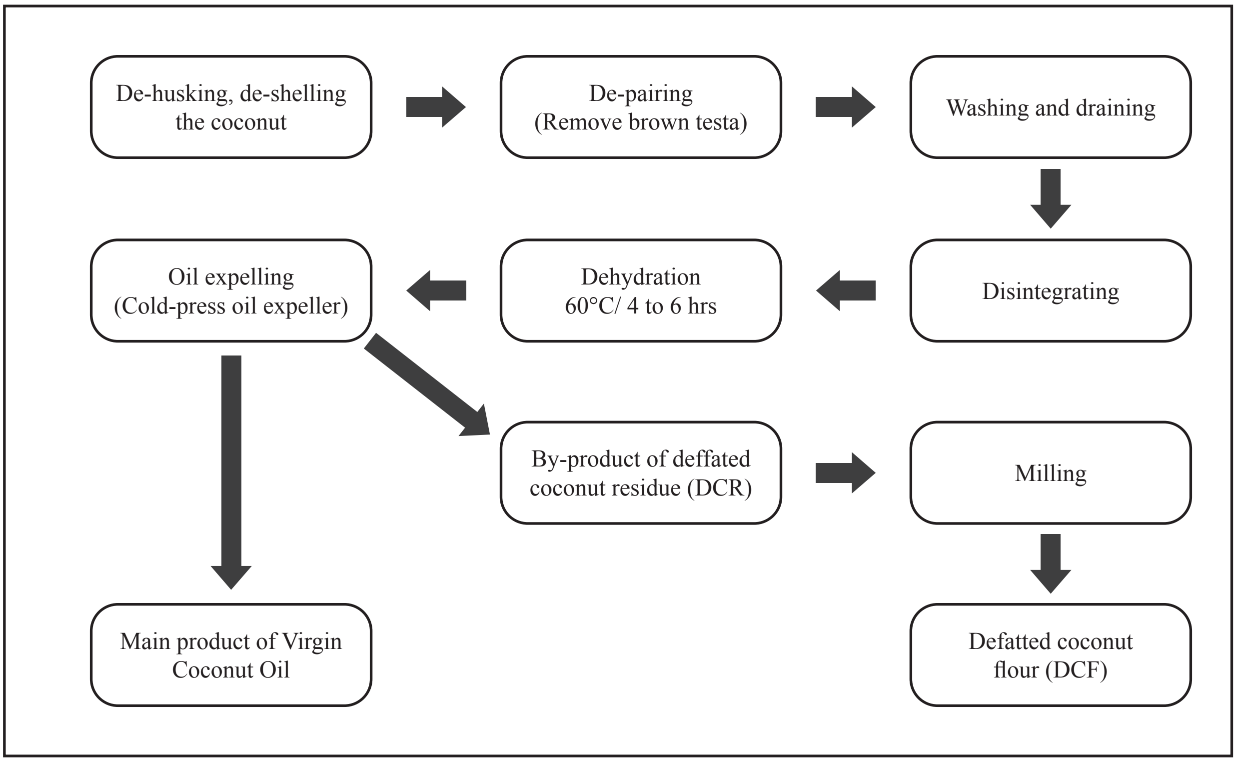

Figure 1. Production process of defatted coconut flour

Swelling capacity. Swell capacity measures the ability to absorb water followed by the swelling properties of flour, which is an important quality parameter for bakery products related to profitability (Awuchi et al., 2019). The swelling capacity of the flour samples was determined using the method (Marikkar et al., 2020). Separately for each variety, the flour sample was added to the 10 ml mark in a 100 ml stoppered graduated cylinder and volume up to the 50 ml mark by distilled water. Then, the cylinder was closed and inverted to facilitate the suspensions to mix thoroughly. The suspension was reverted after 2 min and allowed to stand for another 30 min. The volume (ml) occupied by the sample was taken after 30 min.

Bulk density and Tapped density. The bulk density and the tapped density measure the geometry of the flour related to the starch content, particle size, and surface properties. It reflects the idea for the packaging material that can be used for storage. A sample of flour (10 g) was measured in a 50 ml measuring cylinder and mixed with a vortex vibrator (TX4) at 1,500 rpm for 1 min. The mass-to-volume ratio occupied in the cylinder was determined as the bulk density of the sample. The same sample weight was taken in a 50 ml measuring cylinder and tapped by hand on a bench 100 times from a height of 10 cm to obtain the tapped density (Cynthia et al., 2015). The Hausner ratio (burn volume / tapped volume) of each flour was calculated (Abdullah & Geldart, 1999).

Wettability. The wettability of flour is also an important parameter in the flour industry and bakery industry which reflects the wetting time for the dough-dough making process. The wettability of a flour sample was measured as the time required for 1 g of flour deposition on a liquid surface to completely submerged in 100 ml of distilled water in a 250 ml beaker at 28°C (Vissotto et al., 2010).

Water absorption and oil absorption capacity. The absorption capacity is directly related to the dough making process in the flour-based industry. It also affects the final appearance of bakery food. The oil absorption capacity of the flour has a direct positive relationship with the protein content of the flour (Awuchi et al., 2019).

Water and oil absorption capacities were examined as percent water or oil bound per gramme of flour sample, respectively (Sosulski et al., 1976). First, 1 gramme of flour was mixed with 10 ml of distilled water in a graduated centrifuge tube. The contents were kept for 30 min at room temperature and centrifuged at 3,000 rpm for 30 min. The water absorption capacity was determined by taking the volume of free water directly from the centrifuged tube. The procedure was repeated with soya oil instead of water to determine the oil absorption capacity.

Hygroscopicity. The hygroscopicity of the flour is directly associated with the hygroscopicity of the final product. The hygroscopicity of a flour sample was evaluated using the method described by Goula & Adamopoulos (2008) with modifications to relative humidity (76%) and temperature (23°C). Two grammes of flour was kept in a desiccator at 74% relative humidity (RH) created by saturated sodium chloride at 28°C. The moisture absorbance of the flour samples after seven days of storage under the above conditions was measured as a percentage value.

Solubility. Solubility is linked with different parameters such as oil content, particle size, etc. However, it is an important measurement in the food industry to analyze the digestibility of bakery foods. A gramme of flour was measured in a 50 ml beaker and mixed with 10 ml of distilled water. The mixture was stirred intermittently for 30 min. The sample was centrifuged at 9,000 rpm for 10 min and the supernatant was transferred to an evaporating plate. The supernatant was evaporated at 103 ± 2°C for 4 h until it reached a constant weight. The final weight of the sample was used to calculate the solubility of the sample as a percentage (Zhang et al., 2013).

Nutritional composition of flour varieties

Total phenolic compounds. Total phenolic compounds of different types of flour were extracted in 80% methanol containing a 1% HCl solution as described by Moore et al. (2006). The extracted solution was used to measure the total phenolic content using the Folin-Ceocaltous regent method as Gallic acid equivalent, as described by Javanmardi et al. (2003).

DPPH radical scavenging activity. DPPH radical scavenging activity is an important nutritional analysis to assess the radical scavenging ability of flour against the free radicals having DPPH solution. The free radical scavenging activity of all extracts was evaluated using the 1, 1-diphenyl-2-picryl-hydrazyl (DPPH) method (Marina et al., 2009). The absorbance was measured at 517 nm using a UV-VIS spectrophotometer. The capacity to scavenge the DPPH radical was calculated using the following formula (Eq 2).

$$DPPH\ Scavenging\ Activity\ (\%) = \frac{(A0 - A1)}{A0} \times 100 \quad \text{(Eq. 2)}$$

Where Ao is the absorbance of the 5 mM DPPH solution and A1 is the absorbance in the sample regarding the blank methanol.

Statistical analysis

The experiment was arranged as a complete randomized design (CRD) with three replicates. Each parameter was analyzed using one-way ANOVA after checking for normality. Significant differences between varieties were evaluated using the Tukey test. Data were analyzed using MINITAB 17 software.

RESULTS AND DISCUSSION

Physical properties of DCF and WWF

Yield of DCP

The recovery of copra poonac (copra press cake) from the milling of coconut oil is approximately 40%, which is higher than the recovery of DCP, the immediate by-product of the dry processing of virgin coconut oil. In general, copra poonac is recommended for animal consumption because of the low-quality drying method and high heat treatment during the oil extraction. However, DCP is safer and accepted for human consumption. Figure 2 shows the yield of DCP in selected

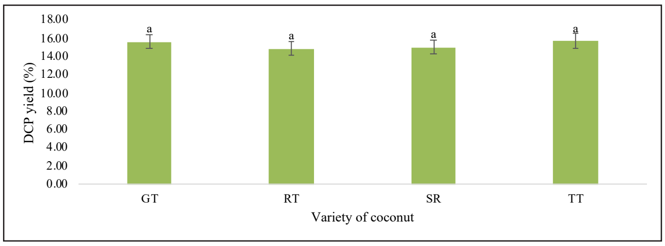

Figure 2. Yield of DCP with respect to the different coconut varieties

The same letters in the standard deviation stated that there was no significant difference between each treatment at P < 0.05.

varieties. Analysis confirmed that there was no significant (p > 0.05) varietal effect (p > 0.05) on the amount of recovery of DCP. The average yield of the DCP regardless of varieties was 15.33 ± 0.41%, which is a considerable output with high quality. Therefore, selected varieties (GT, RT, SR, and TT) can be recommended for commercial production without restricting to the TT variety if any of them shows superior nutritional quality.

Particle size distribution of DCF

The particle size distribution is an important quality parameter that affects the processing technique and product quality (Sullivan et al., 1960). Sadullayev et al. (2024) identified that lower particle size has enhanced the baking properties; loaf volume and softness of the crumb. The particle size of different types of flour is shown in Figure 3 as a cumulative weight distribution. The results revealed that 98.37 ± 0.46% of the WWF sample contained particles smaller than 250 µm diameter, which is the lowest of the five different pore sizes considered in the study. In contrast, approximately 23.16% of DCF have particles of less than 250 µm size, and there were no significant differences between varieties. It was revealed that the size of 710 µm is the ideal pore size for all varietal DCF, as more than 99.72% of each flour is lower than the value of 710 µm. On the contrary, the ideal filtration pore size for WWF was 250 µm. Therefore, the higher particle size of DCF can be a disadvantage when using it as a whole flour for bakery industry.

Moisture content

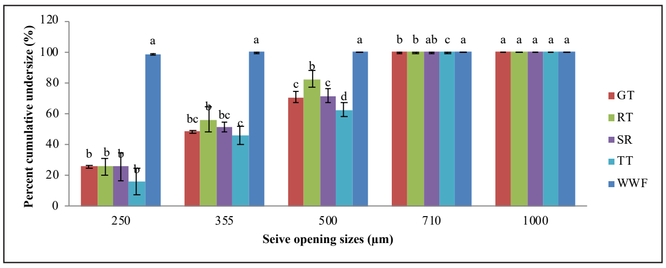

Figure 3. Cumulative distribution of the mean particle size of DCF and WWF

The different letters (from a-d) show the difference between each treatment at P < 0.05.

Table 1. Comparation of the physical properties of DCF of different types of varietals

Parameters	Types of flours				
	GT	RT	SR	TT	WWF
MOI (%)	3.19 ± 0.79[b]	2.94 ± 1.12[b]	2.06 ± 0.01[b]	3.37 ± 0.09[b]	9.59 ± 0.26[a]
SC (ml)	49.0 ± 0.00[a]	47.7 ± 0.58[bc]	48.0 ± 0.00[b]	47.0 ± 0.00[cd]	46.7 ± 0.58[d]
BD(g/ml)	0.48 ± 0.00[c]	0.50 ± 0.00[b]	0.50 ± 0.00[b]	0.63 ± 0.00[a]	0.50 ± 0.00[b]
TD (g/ml)	0.56 ± 0.00[d]	0.67 ± 0.00[b]	0.66 ± 0.00[c]	0.77 ± 0.00[a]	0.67 ± 0.00[b]
WE (Sec)	27.46 ± 0.00[b]	12.28 ± 0.00[e]	18.22 ± 0.00[c]	12.38 ± 0.00[d]	29.23 ± 0.00[a]
OAC (%)	160.00 ± 0.00[a]	120.00 ± 0.00[b]	133.33 ± 11.55[ab]	126.70 ± 23[ab]	126.67 ± 11.55[ab]
WAC (%)	300.00 ± 0.00[a]	300.00 ± 0.00[a]	300.00 ± 0.00[a]	260.00 ± 0.00[b]	100.00 ± 0.00[c]
HYG (%)	11.52 ± 0.20[c]	13.03 ± 0.16[b]	14.21 ± 0.24[a]	11.79 ± 0.26[c]	7.65 ± 0.25[d]
SLU (%)	19.92 ± 1.61[a]	20.07 ± 1.91[a]	18.74 ± 0.89[b]	22.20 ± 2.90[a]	8.20 ± 0.04[c]

Each value in the table represents the mean of three replications. Means with different superscripts are significantly ($p < 0.05$) different from each other along each raw.

MOI – moisture content; SC – swelling capacity; BD – bulk density; TD – tapped density; WE – wettability; LGC – least gelation concentration; OAC – oil absorption capacity; WAC – water absorption capacity; HYG – hygroscopicity; SLU – solubility; GT – Gonthambili; RT – Ran thambili; SR – San Ramon; TT – Tall × Tall; WWF – Whole wheat flour

The moisture content is crucial for the extended shelf life of the flour if it has a high-fat content, due to the low chance of fat oxidation with the help of water molecules. The low moisture content limits the available free water for microbial growth while facilitating the long shelf life. Nasir et al. (2003) reported that moisture and fat content significantly and negatively affected the quality of wheat flour. The DCF of the GT, RT, SR, and TT varieties showed significantly lower moisture content, ranging from 2 - 4% than WWF (9.59 ± 0.26%) (Table 1). The difference in the varieties of fresh coconut kernels did not affect the rate of water removal from the fresh kernel during the dehydration process.

Swelling capacity

The swelling capacity reflects the forces with starch granules and the relationship between αamylose and amylopectin. Higher swelling capacity provides a negative influence on the bakery industry, as it changes the properties of the dough with the higher water absorption rate. The swelling capacity of the flour changes according to the processing method and particle size, and the variety of flour (Chandra & Samsher, 2013). The swelling capacity of the DCF of different varieties showed a significant variation between varieties (Table 1). The swelling capacity of GT (49.00 ± 0.00 ml) was significantly ($p < 0.05$) higher than the coconut flour of other varieties, while the swelling capacity of SR (48.00 ± 0.00 ml) and RT (47.67 ± 0.00 ml) was significantly ($p < 0.05$) higher than the swelling capacity of WWF (46.67 ± 0.00 ml). Therefore, flour formulations mixed with GT and WWF can potentially enhance the swelling capacity of composite flour, thereby enhancing the unique characteristics of bakery products.

Bulk density

The bulk density of a powder depends on the volume of the interparticle void due to the spatial arrangement, size, and density of particles. The bulk density of the variety TT (0.63 g/ml) was the highest among all other coconut varieties used in this study and was also higher than the bulk density of WWF (Table 1). The bulk density of the GT (0.48 ± 0.00 g/ml) was significantly lower than that of the WWF and DCF of other varieties. Furthermore, flour with different rates of bulk density was recommended for different food formulations; higher bulk density flour (e.g., processed fluted pumpkin seed flour (0.50 g/ml)) for the complementary food formulations (Giami & Bekebain, 1992), low bulk density flour (orange seed flour) for baby food items (Akpata & Akubor, 1999). Therefore, the incorporation of the DCF from the TT varietal with WWF (0.50 ± 0.00 g/ml) can be recommended to make a dense food formula for adults, and the incorporation of the DCF of GT variety with wheat flour can be recommended to make a breakfast and infant food formula.

Tapped density

The tapped density is the maximum density attained by tapping to compact the particles with no spaces between the particles. A comparison of bulk and tapped densities can give a measure of the relative importance of interparticle interactions influencing bulking properties that interfere with the flow ability of flour. Significantly higher tapped density was observed in TT (0.77 ± 0.00 g/ml) varietal flour, while similar tapped density could be observed in RT and WWF (0.67 ± 0.00 g/ml). The lowest tapped density was in GT (0.56 ± 0.00 mg/ml).

Wettability

Wetting time is an important parameter in the food industry because it is directly related to the dough mixing rate. It also affects the water absorption rate, as well as the swelling index of the flour. According to the results of this study (Table 1), the flour obtained from RT (12.28 ± 0.0 s), TT (12.38 ± 0.00

Table 2. Proximate composition of DCF of different coconut varieties

Parameters	Types of flours				
	GT	RT	SR	TT	WWF
Fat (%)	13.74 ± 1.84^{b}	18.50 ± 0.40^{a}	16.09 ± 2.99^{ab}	16.56 ± 1.24^{ab}	1.56 ± 0.05^{c}
Ash%	5.68 ± 0.04^{ab}	5.47 ± 0.53^{b}	6.81 ± 0.67^{a}	6.77 ± 0.64^{a}	1.30 ± 0.07^{c}
Protein (%)	15.63 ± 0.54^{b}	16.25 ± 0.39^{b}	20.04 ± 1.98^{a}	22.07 ± 0.63^{a}	16.74 ± 0.24^{b}
Fiber (%)	17.21 ± 0.02^{a}	17.43 ± 0.53^{a}	16.72 ± 0.94^{a}	18.70 ± 0.17^{a}	0.96 ± 0.006^{b}
CHO (%)	44.55 ± 1.72^{b}	39.40 ± 0.68^{c}	38.28 ± 1.58^{c}	32.53 ± 1.60^{d}	69.84 ± 0.30^{a}

Each value in the table represents the mean of three replications. Means with different superscripts are significantly (p < 0.05) different from each other along each raw.

CHO – Carbohydrates; GT – Gonthambili; RT – Ran thambili; SR – San Ramon; TT – Tall × Tall; WWF – Whole wheat flour

s) and SR (18.22 ± 0.00 s) has significantly ($p < 0.05$) lower wetting times compared to the wetting times of wheat flour (29.23 ± 0.00 s) and the flour obtained from GT (27.46 ± 0.00 s). The WWF composite flour mixed with the DCF of RT (12.28 ± 0.00 s) or TT (12.38 ± 0.00 s) can further reduce the WWF wettability than the composite flour and GT and SR composite flour.

Water Absorption Capacity (WAC) and Oil Absorption Capacity (OAC)

The volume of flour increases with the oil or water absorption capacity. The absorption of oil and water is beneficial in the bakery industry, as it increases the volume and weight of the products, with the profitability. In this study, the DCF of the GT, RT, and SR varieties resulted in similar WAC (300%), while TT had a significantly lower WAC value (260%). The WACs of DCF are significantly higher (260 - 300%) than the WAC of WWF (100%), which could be due to the fewer amounts of hydrophilic constituents in WWF (Badifu & Akubor, 2001). Comparatively, it is beneficial to use DCF from the GT, RT or SR variety to make composite flour to improve the dough properties and profitability of the bakery product.

Hygroscopicity

The results in Table 1 showed that the hygroscopic measures of different varieties of DCF ranged from 11.52 ± 0.20 to 14.21 ± 0.24% and were lower than those of milk powder. The hygroscopicity of WWF (7.65±0.25%) was significantly lower than the DCF of the coconut varieties, indicating a comparatively lower caking effect. The hygroscopicity increased with the particle size of the powder as a result of the wider contact surfaces and active sites. Accordingly, larger particle sizes of DCF accelerate the hygroscopicity as a result of extensive contact sides in comparison to those of WWF.

Solubility

The solubility of flour measures the ability to interact with water molecules to make a mixture. The solubility of DCF ranged from 18.74% to 22.20%. The DCF of TT (22.20 ± 2.90%), RT (20.07 ± 1.91%) and GT (19.92 ± 1.61%) showed the highest solubility values, which were not significantly different. In contrast, the solubility of WWF with water was significantly low (8.20 ± 0.04%) compared to the DCF types, which indicates a higher content of soluble molecules in DCF than WWF.

Nutritional composition of the DCF of different coconut varieties and WWF

The approximate composition of DCFs from different coconut varieties is shown in Table 2.

Fat content

The fat component of flour can be used as an internal fat source rather than an external addition. High-fat foods undergo a rapid rancid process reacting with water, which reduces the shelf life of the produce. Coconut fat comprises more than 85% saturated fatty acids and 15% unsaturated fatty acids. According to Table 2, there was an inter-varietal difference in fat content between different DCF. The GT variety has significantly ($p < 0.05$) lower fat content (13.74 ±1.84%) than RT, with the highest fat content present (18.50 ± 0.40%), but was not different with SR and TT.

Therefore, the addition of the DCF of RT variety for food preparation could improve the energy value of food in comparison to the addition of DCF of GT. The fat content in the partially defatted coconut testa flour of the coconut varieties SR, GT, RT, and TT was compared by (Marasinghe et al., 2019). The observed fat contents were 23.49%, 13.41%, 13.28%, and 7.93% for SR, GT, RT, and TT, respectively, which is not comparable with the results of the current study. Han et al. (2011) revealed that the fat content of rice varieties was changed due to environmental factors, varietal differences, and processing methods.

Ash Content

The ash content of the DCF was directly correlated with the mineral content of the flour. The percentage of DCF ranged from 5.47 ± 0.53% to 6.77 ± 0.64%, which was significantly higher than the WWF ash content of WWF (1.30 ± 0.07%). A previous study identified that a variation in the ash content of partially defatted testa flour was also observed from four different coconut varieties and RT has shown a significantly

Table 3. Mineral content of DCF of different coconut varieties

Parameters	Types of flours				
	GT	RT	SR	TT	WWF
Ca (mg/100 g)	0.57 ± 0.02^{d}	52.48 ± 7.35^{a}	20.54 ± 2.45^{b}	15.13 ± 3.10^{bc}	6.33 ± 0.67^{cd}
Na (mg/100 g)	7.56 ± 0.14^{b}	8.27 ± 3.53^{b}	9.07 ± 0.81^{ab}	9.19 ± 1.42^{ab}	14.80 ± 3.61^{a}
K (mg/100 g)	77.46 ± 1.56^{ab}	72.33 ± 4.49^{b}	96.84 ± 6.87^{a}	96.69 ± 6.86^{a}	14.12 ± 1.57^{c}
Mg (mg/100 g)	10.12 ± 14.68^{a}	9.55 ± 0.48^{a}	9.88 ± 0.53^{a}	10.43 ± 1.03^{a}	0.31 ± 0.09^{b}

Each value in the table represents the mean of three replications. Means with different superscripts are significantly (p < 0.05) different from each other along each raw.

CHO – Carbohydrates; GT – Gonthambili; RT – Ran thambili; SR – San Ramon; TT – Tall × Tall; WWF – Whole wheat flour

higher ash content of 5.30 ± 0.14% (Marasinghe et al., 2019). Therefore, it is observed that the ash content of flour can be changed due to various factors, such as genetic variation, processing, and extraction methods.

Mineral content

Minerals are very essential inorganic substances present in all human tissues and fluids to maintain normal body functions and improve body immunity. The results of the mineral content of defatted coconut flour and whole wheat flour are shown in Table 3.

As shown in Table 3, the Ca content of the DCF fluctuated between coconut varieties from 0.57 ± 0.23 mg/100 g to 52.48 ± 7.35 mg/100 g. The DCF of RT resulted in a significantly ($p < 0.05$) higher Ca content (52.48 ± 7.35 mg/100 g) ($p < 0.05$) compared to the DCF of other varieties. The Ca quantity of WWF was 6.33 ± 0.67 mg/100 g. The DCF of SR also resulted in a significantly higher Ca content than WWF. Therefore, the DCF of RT and SR was identified as a good source of Ca in comparison to WWF to meet the daily requirement of Ca. Consequently, the preparation of composite flour with DCF of RT and SR can be suggested as a good alternative to using WWF alone.

Sodium is the main mineral in human extracellular fluid. Regulates the osmotic pressure of body fluid while maintaining plasma volume. Therefore, the external addition of sodium as a table salt is recommended. The sodium content of DCF was not significantly different among the varieties. The DCF of the TT variety showed a significantly high Na content (9.19 ± 1.42 mg/100 g). However, defatted coconut flour is not a sodium rich source compared to WWF (14.80 ± 3.61 mg/100 g) which contains a higher sodium amount compared to four types of DCF of different coconut varieties.

DCF contains more than 10 times more K than the Na content. Coconut variety also has a significant effect on the K content of DCF ranging from 72.3 ± 4.49 mg/100 g to 96.8 ± 6.87 mg/100 g. The K content of WWF showed a significantly ($p < 0.05$) lower value (14.12 ± 1.57 mg/100 g) than DCF. The DCFs, SR and TT showed significantly higher K than RT. Therefore, incorporation of SR (96.8 ± 6.87 mg / 100 g) or TT (96.69 ± 6.86 mg / 100 g) defatted coconut flour into wheat flour can be used as a potassium supplement for wheat flour.

The magnesium content of DCF is thirty times higher than the Mg content of WWF (0.31 ± 0.09 mg/100 g). There was no significant difference between the Mg content of DCF of different varieties. On average, DCF contained 9.99 mg/100 g of Mg. The results clearly showed that DCF is a good magnesium alternative to improve healthy foods, in addition to the addition of leafy vegetables.

Protein Content

According to the results of this study, the protein content of defatted coconut flour ranged from 15.63% to 22.07% between varieties. The flour extracted from the varieties TT (22.07 ± 0.63%) and SR varieties (20.04 ± 1.98%) have shown a significantly ($p < 0.05$) higher ($p < 0.05$) protein quantity. Whole wheat flour resulted in significantly ($p < 0.05$) lower protein content compared to TT and SR but similar to DCF of the GT and RT varieties. The predominant proteins in the coconut kernel are globulin and albumin, which represent 40% and 21% of total protein, respectively (Patil & Benjakul, 2018). Gunathilake et al. (2009) revealed that the substitution of wheat flour from non-wheat flour sources can increase the protein content of bakery products. However, a minimum concentration of 11.0% protein should be presented in wheat flour to maintain the quality of baked foods such as gluten. The zero concentration of gluten protein in coconut flour restricts the higher percentage of substitution with wheat flour, as gluten is essential to build the frame to trap gases during food baking.

Crude fiber content

Fiber acts as a therapeutic agent to prevent constipation, hemorrhoids, diverticulosis, coronary heart disease, and some cancers, and maintaining body mass index. WWF, the main matrix of most fast food, contains 0.96 ± 0.06% fiber. The results revealed that there were no significant differences between varietals in the crude fiber content of DCF of four coconut varieties, TT (18.70 ± 0.17%), RT (17.43 ± 0.53%), GT (17.21 ± 0.02%) and SR (16.72 ± 0.94%). Therefore, any of four varieties can serve as the best fiber supplement source in the food industry.

Carbohydrate Content

Carbohydrates (CHO) mainly contain sugars, oligosaccharides, and polysaccharides. According to Table 2, the amounts of DCF ranged from 32.53% to 44.55%. The

Table 4. Total polyphenol and radical scavenging capacity of different coconut varieties

Parameters	Types of flours				
	GT	RT	SR	TT	WWF
Total phenolic content (mg GAE /g of flour)	1.04 ± 0.09[a]	1.02 ± 0.08[a]	1.01 ± 0.09[a]	0.76 ± 0.08[b]	1.07 ± 0.00[a]
Radical Scavenging ability % (5 Mm DPPH equivalent)	22.28 ± 0.99[a]	21.23 ± 3.38[a]	20.81 ± 0.61[a]	19.76 ± 1.16[a]	19.05 ± 0.52[a]

Each value in the table represents the mean of three replications. Means with different superscripts are significantly ($p < 0.05$) different from each other along each raw.

CHO – Carbohydrates; GT – Gonthambili; RT – Ran thambili; SR – San Ramon; TT – Tall × Tall; WWF – Whole wheat flour

amount of CHO in defatted coconut flour were significantly different between the varieties. Compared to the four coconut varieties, WWF showed the highest and significantly different amount of carbohydrate quantity (69.84 ± 0.30%). The least CHO was observed in the TT variety (32.53 ± 1.60%) and was less than half of the CHO in WWF. Therefore, the substitution of WWF from DCF of TT variety can be recommended for low-glycaemic product development.

Functional properties of the DCF of different coconut varieties and WWF

Total phenol content and radical scavenging activity of flour varieties

Total phenolic content and antioxidant properties of food enhance the functional properties with added advantages such as reducing non-communicable diseases. Recent studies suggested that the consumption of grain-based foods reduced the risk of non-communicable diseases (Okarter et al., 2010). The total phenolic content with respect to the dry weight of the sample of four coconut varieties and WWF is presented in Table 4.

Consequently, the DCF of the TT variety showed a significantly lower total phenolic content (0.76 ± 0.08 mg GAE/ g of flour) compared to the others. Other varieties and WWF were not significantly different, and their total phenolic contents ranged from 1.01 ± 0.09 to 1.04 ± 0.09 mg GAE/g of flour. The removal of the outer layer of the wheat grain with its bran, which contains large amounts of phenolics (Hung & Morita, 2008), in the preparation of wheat flour, may be the reason behind the equality of the phenolic content in DCF and WWF. Radical scavenging ability did not show a significant difference between varieties and WWF.

CONCLUSIONS

DCF was identified as a valuable byproduct of VCO processing that can be utilized as a fiber-rich and mineral-rich supplement. The DCF of GT showed the best functional properties, while SR and TT showed better nutritional benefits. DCF is a valuable substitute for cereal bars, gluten-free protein diet, fiber-rich formulations, and thinking agents for soup or porridge for adults and children. Therefore, the defatted coconut flour of the GT, SR and TT varietal flour can be used effectively in the development of bakery food as a dietary supplement by substituting for a portion (approximately from 10% to 25%) of wheat flour. However, the application rate of DCF as a flour mixture for bakery products or others depends on their structural development and the sensory uniqueness of the product.

REFERENCES

Abdullah, E. C., & Geldart, D. (1999). The use of bulk density measurements as flowability indicators. *Powder Technology, 102*(2), 151–165. https://doi.org/10.1016/S0032-5910(98)00208-3

Adeloye, J. B., Osho, H., & Idris, L. O. (2020). Defatted coconut flour improved the bioactive components, dietary fibre, antioxidant and sensory properties of nixtamalized maize flour. *Journal of Agriculture and Food Research, 2*, 100042. https://doi.org/10.1016/j.jafr.2020.100042

Adsare, S. R., & Annapure, U. S. (2024). Partially defatted coconut flour as a functional ingredient in replacement of refined wheat flour for development of fiber rich muffins. *Journal of Food Science and Technology, 61*(3), 491–502. https://doi.org/10.1007/s13197-023-05857-2

Akpata, M. I., & Akubor, P. I. (1999). Chemical composition and selected functional properties of sweet orange (Citrus sinensis) seed flour. *Plant Foods for Human Nutrition, 54*(4), 353–362. https://doi.org/10.1023/A:1008153228280

AOAC. (1999). *Official methods of analysis of AOAC International* (17th ed.). Association of Analytical Communities International.

Awuchi, C. G., Igwe, V. S., & Echeta, C. K. (2019). The Functional Properties of Foods and Flours. *International Journal of Advanced Academic Research | Sciences, Technology and Engineering, 5*(11), 139–160.

Badifu, G. I. O., & Akubor, P. I. (2001). Influence of pH and sodium chloride on selected functional and physical properties of African breadfruit (Treculia africana Decne) kernel flour. *Plant Foods for Human Nutrition, 56*(2), 105–115. https://doi.org/10.1023/A:1011194927947

Chandra, S., & Samsher. (2013). Assessment of functional properties of different flours. *African Journal of Agricultural Research, 8*(38), 4849–4852. https://doi.org/10.5897/ajar2013.6905

Chuku, L. U., & Onikio, M. (2021). Proximate analysis of Coconut (Cocos nucifera) endocarp. *Discovery, 57*(301), 86–89.

Giami, S. Y., & Bekebain, D. A. (1992). Proximate composition and functional properties of raw and processed full-fat fluted pumpkin (Telfairia occidentalis) seed flour. *Journal of the Science of Food and Agriculture, 59*(3), 321–325. https://doi.org/10.1002/jsfa.2740590308

Goula, A. M., & Adamopoulos, K. G. (2008). Effect of Maltodextrin Addition during Spray Drying of Tomato Pulp in Dehumidified Air: II. Powder Properties. *Drying Technology, 26*(6), 726–737. https://doi.org/10.1080/07373930802046377

Gunathilake, K., Yalegama, C., & Kumara, A. (2009). Use of coconut flour as a source of protein and dietary fiber in wheat bread. *Asian Journal of Food and Agro-Industry, 2*(03), 386–395.

Han, H. M., Cho, J. H., & Koh, B. K. (2011). Processing properties of Korean rice varieties in relation to rice noodle quality. *Food Science and Biotechnology, 20*(5), 1277–1282. https://doi.org/10.1007/s10068-011-0176-5

Hung, P. V., & Morita, N. (2008). Distribution of phenolic compounds in the graded flours milled from whole buckwheat grains and their antioxidant capacities. *Food Chemistry, 109*(2), 325–331. https://doi.org/10.1016/j.foodchem.2007.12.060

Javanmardi, J., Stushnoff, C., Locke, E., & Vivanco, J. M. (2003). Antioxidant activity and total phenolic content of Iranian Ocimum accessions. *Food Chemistry, 83*(4), 547–550. https://doi.org/10.1016/S0308-8146(03)00151-1

Khaykal, Muh. F., & Pulukadang, S. H. V. (2021). Determination of Iron (Fe), Zinc (Zn) Levels and Organoleptic Tests in Coconut Pulp Flour. *Jurnal Akademika Kimia, 10*(4), 269–276. https://doi.org/10.2248/j24775185.2021.v10.i4

Liyanage, D. D. V. (1958). *Varieties And Forms of the Coconut Palm Grown in Ceylon*.

Marasinghe, S. S. K., Marikkar, J. M. N., Yalegama, C., Wimalasiri, S., Seneviratne, G., Weerasooriya, R., & Liyanage, R. (2019). Comparison of inter-varietal differences in chemical composition and nutritional properties of coconut testa flour. *Journal of the National Science Foundation of Sri Lanka, 47*(3), 349–356. https://doi.org/10.4038/jnsfsr.v47i3.8699

Marasinghe, S. S. K., Yalegama, C., Pathirana, D. T. H., & Marikkar, J. M. N. (2021). The Physical and Functional Properties of Partially Defatted Coconut Testa Flour. *CORD, 37*, 11–22. https://doi.org/10.37833/cord.v37i.424

Marikkar, N., Nagaraja, R., Somawathie, K. M. S., Hewapathirana, H. P. T. D., Yalegama, C., Littardi, P., & Chiavaro, E. (2020). Effect of Coconut Testa Flour on Cookie Characteristics. *Italian Journal of Food Science, 32*(1). https://doi.org/10.14674/IJFS-1694

Marina, A. M., Che Man, Y. B., Nazimah, S. A. H., & Amin, I. (2009). Chemical Properties of Virgin Coconut Oil. *Journal of the American Oil Chemists' Society, 86*(4), 301–307. https://doi.org/10.1007/s11746-009-1351-1

Moore, J., Liu, J.-G., Zhou, K., & Yu, L. (Lucy). (2006). Effects of Genotype and Environment on the Antioxidant Properties of Hard Winter Wheat Bran. *Journal of Agricultural and Food Chemistry, 54*(15), 5313–5322. https://doi.org/10.1021/jf060381l

Nasir, M., Butt, M. S., Anjum, F. M., Kamran, S., & Rashid, M. (2003). Effect of moisture on the shelf life of wheat flour. *International Journal of Agriculture and Biology, 5*(4), 458–459.

Okarter, N., Liu, C.-S., Sorrells, M. E., & Liu, R. H. (2010). Phytochemical content and antioxidant activity of six diverse varieties of whole wheat. *Food Chemistry, 119*(1), 249–257. https://doi.org/10.1016/j.foodchem.2009.06.021

Pathirana, H. P. D. T. H., Lakdusinghe, W. M. K., Yalegama, L. L. W. C., Chandrapeli, C. A. T. D., & Madusanka, J. A. . D. (2020). Evaluation of Nutritional Composition of Defatted Coconut Flour Incorporated Biscuits. *CORD, 36*, 33–39. https://doi.org/10.37833/cord.v36i.427

Patil, U., & Benjakul, S. (2018). Coconut Milk and Coconut Oil: Their Manufacture Associated with Protein Functionality. *Journal of Food Science, 83*(8), 2019–2027. https://doi.org/10.1111/1750-3841.14223

Prasanna, N. S., Selvakumar, M., Choudhary, N., & Raghavarao, K. S. M. S. (2024). Virgin coconut oil: Wet production methods and food applications – a review. *Sustainable Food Technology, 2*(5), 1391–1408. https://doi.org/10.1039/D4FB00093E

Sadullayev, S., Ravshanov, S., Mirzayev, J., Ibragimov, A., Baxromova, L., & Yuldashova, R. (2024). Impact of Flour Particle Size and Starch Damage on Baking Properties of Wheat Flour Grown in Dry Climates: A Uzbekistan Case Study. *The 3rd International Electronic Conference on Processes, 47*. https://doi.org/10.3390/engproc2024067047

Sosulski, F., Garratt, M. D., & Slimkard, A. E. (1976). Functional Properties of Ten Legume Flours. *Canadian Institute of Food Science and Technology Journal, 9*(2), 66–69. https://doi.org/10.1016/S0315-5463(76)73614-9

Sullivan, B., Engebretson, W. E., & Anderson, M. L. (1960). The relation of particle size to certain flour characteristics. *Cereal Chemistry, 37*(4), 436–455.

Thaiphanit, S., & Anprung, P. (2016). Physicochemical and emulsion properties of edible protein concentrate from coconut (Cocos nucifera L.) processing by-products and the influence of heat treatment. *Food Hydrocolloids, 52*, 756–765. https://doi.org/10.1016/j.foodhyd.2015.08.017

Trinidad, T. P., Valdez, D. H., Loyola, A. S., Mallillin, A. C., Askali, F. C., Castillo, J. C., & Masa, D. B. (2003). Glycaemic index of different coconut (Cocos nucifera)-flour products in normal and diabetic subjects. *British Journal of Nutrition, 90*(3), 551–556. https://doi.org/10.1079/BJN2003944

U.S. Department of Agriculture, Agricultural Research Service. (2023). *FoodData Central: Food item 170170, Wheat flour, white, all-purpose, enriched, bleached*. FoodData Central. https://fdc.nal.usda.gov/fdc-app.html#/food-details/170170/nutrients

Verem, T. B., Dooshima, I. B., Ojoutu, E. M., Owolabi, O. O., & Onigbajumo, A. (2021). Proximate, Chemical and Functional Properties of Wheat, Soy and Moringa Leaf Composite Flours. *Agricultural Sciences, 12*(01), 18–38. https://doi.org/10.4236/as.2021.121003

Vissotto, F. Z., Jorge, L. C., Makita, G. T., Rodrigues, M. I., & Menegalli, F. C. (2010). Influence of the process parameters and sugar granulometry on cocoa beverage powder steam agglomeration. *Journal of Food Engineering, 97*(3), 283–291. https://doi.org/10.1016/j.jfoodeng.2009.10.013

Zhang, H., Xia, W., Xu, Y., Jiang, Q., Wang, C., & Wang, W. (2013). Effects of spray-drying operational parameters on the quality of freshwater mussel powder. *Food and Bioproducts Processing, 91*(3), 242–248. https://doi.org/10.1016/j.fbp.2012.10.006