Journal of Food and Agriculture
Volume 18, Issue 02, December 2025
Print ISSN: 1800-4288, E. ISSN: 2613-8530
DOI: https://doi.org/10.4038/jfa.v18i2.5348

Physicochemical, Functional, and Nutritional Characterization of Cashew (*Anacardium occidentale* L.) Apple Flour and Its Use in Cookie Formulation

S.G.V.D.H. Gunasekara[1], U.P. Thennakoon[1], M.K.Y Sandaruwani[1], K. Ratnayake[1]*, K.O.H.M.A.G. Herath[1], M.K.S. Malki[1] and H.M.S.P. Herath[2]

ABSTRACT

Postharvest losses of cashew (*Anacardium occidentale* L.) apple, an underutilized fruit in Sri Lanka, could be reduced by processing it into flour. This study evaluated three methods of cashew apple flour (CAF) preparation: oven drying of raw fruit (Method 1), boiled fruit (Method 2), and blanched fruit (Method 3), followed by grinding to fine powder. Flours were analyzed for their physicochemical and functional properties and proximate composition. Method 2 produced the most desirable flour characteristics, with high bulk density (0.67 g/mL), water absorption capacity (274.60%), and swelling power (8.95 g). Proximate composition of CAF from Method 2 included 2.24% ash, 4.54% crude fibre, 72.12% carbohydrate, 4.31% fat, and 9.08% crude protein. It was further tested in cookie formulations by blending with wheat flour (WF) at 0%, 10%, 20%, 30% and 40% substitution levels. Physical parameters were assessed, and products underwent sensory evaluation. Cookies with CAF-WF blends did not differ significantly (*P*>0.05) from the 100% WF control in weight, diameter, height, or spread ratio, though variations were observed in volume and density. The 30% CAF-70% WF blend yielded the best sensory attributes, including overall acceptability, appearance, colour, flavour, texture, and aroma. Compared to the control, this formulation contained lower protein (12.33%), fat (16.25%), and ash (1.57%), but significantly higher fibre (6.33%) levels. Overall, Method 2 produced CAF with favourable functional properties suitable for bakery applications. Incorporation of CAF at 30% substitution improved cookie fibre content without negatively affecting sensory quality. CAF thus has potential for value addition in food systems, though further research is needed on pasting properties, shelf life, and storability of CAF and CAF-based products.

Keywords: *Anacardium occidentale*, Cashew apple, Cookie, Flour properties, Proximate composition

[1]*Department of Horticulture and Landscape Gardening, Faculty of Agriculture and Plantation Management, Wayamba University of Sri Lanka, Gonawila 60170, Sri Lanka*
[2]*Sri Lanka Cashew Corporation, Kamandaluwa, Andigama 61508, Sri Lanka*

**kamani.ratnayake@uqconnect.edu.au*
https://orcid.org/0000-0002-4055-5372

INTRODUCTION

Cashew (*Anacardium occidentale* L.; Family Anacardiaceae) is an economically significant plantation crop. Native to tropical America, it is now widely distributed across Asia, Africa, and Central America (Das and Arora, 2017). Cashew was introduced to Sri Lanka from Brazil during the 16th century and is predominantly grown in the dry zone areas (Perera and Kandiah, 2016). The crop is primarily cultivated for its kernels and cashew nut shell liquid (CNSL), while the cashew apple, a pseudo fruit attached to the nut, is largely underutilized. In 1997, a dedicated cashew research programme was initiated through a collaboration between the Wayamba University of Sri Lanka and the Sri Lanka Cashew Corporation (SLCC). This effort led to the release of 13 improved cashew varieties, contributing significantly to the expansion of cashew cultivation across the island, primarily targeting its key economic product, the cashew nut.

Cashew apples are, however, highly perishable and often discarded, with over 120,000 metric tonnes wasted annually in Sri Lanka (SLCC, 2020). They are rich in nutritional and bioactive compounds, including vitamin C, sugars, minerals, carotenoids, flavonoids, polyphenols, and anacardic acids (Perera and Kandiah, 2016; Gnagne *et al*., 2023). These compounds are associated with various health benefits, such as antioxidant, antimicrobial, antidiabetic, and anticarcinogenic activities. Studies have shown that dried cashew apples contain significant levels of dietary fibre, up to 61.21%, and appreciable amounts of dietary minerals (Akyereko *et al*., 2023).

Despite their nutritional potential, limited awareness, short shelf life, inadequate processing infrastructure, and high equipment costs have hindered the use of cashew apples in value-added product development (Das and Arora, 2017; Akyereko *et al*., 2023). Converting cashew apples into flour or powder offers a promising approach to minimize postharvest losses, extend shelf life, and enhance the nutritional value of food products. Cashew apple flour has been reported to function effectively as a source of dietary fibre and a partial substitute for wheat flour in baked goods, contributing to improved nutritional quality (Ogunjobi and Ogunwolu, 2010; Offia-Olua and Onwubiko, 2015).

In this study, cashew apples were processed into flour using three methods and a product was developed from locally available cashew varieties. Their physical, functional, and nutritional properties were evaluated. The findings aim to support the development of value-added products from cashew apples, thereby contributing to postharvest loss reduction and improved utilization of this underexploited resource.

MATERIALS AND METHODS

Production of Cashew Apple Flour

Cashew apples of the variety WUCC-05 were collected from the Sri Lanka Cashew Corporation's Eluwankulama Plantation (Agro-Ecological Region of DL_3; N-8.27300 and E-79.88000). Ripe cashew apples with full peel colour development were manually harvested and transported to the laboratory under cool conditions.

After removal of the adhering nut, the cashew apples were washed in running water and processed under three different methods to make flour. In Method 1, raw cashew apples were washed with 2% (w/v) sodium metabisulfite (SMS) solution, cut into 3 - 5 mm thick slices and oven dried at 65 °C for 30 h. Dried chips were ground using a grinder (Preethi MG-172E, Preethi Electrical Appliances, India) at high power for 5 min and sifted using a 425 μm sieve to obtain a fine powder (Offia-Olua and Onwubiko, 2015). In Method 2, juice was extracted from cashew apples by squeezing. Thereafter, pieces with 2 cm thickness were cut and boiled in 1% (w/v) SMS solution at 100 °C for 10 min. The slices were drained and oven dried at 50 °C for 40 h (Akubor, 2016a). Dried cashew apple chips were ground and sifted as in Method 1. In Method 3, cashew apples were washed and cut into 0.3 - 1.0 cm pieces. The juice was extracted by squeezing, and the residues were conditioned at a ratio of 1:2 (cashew apple: water) at 4.5 pH and 35 °C. Drained cashew apple residues were oven dried at 55 °C for 48 h, ground and sieved as above (Adegunwa *et al*., 2020). The prepared cashew apple flour (CAF) was stored in aluminium foil bags at 4 °C until further analysis.

Determination of Physicochemical, Functional, and Nutritional Properties of CAF

Colour of CAF was recorded using a colorimeter (PCE-CSM 2, PCE

Instruments, USA). The colour characteristics of L* (L* = 0 for black; L* = 100 for white), a* (-a for greenness; +a for redness), and b* (-b for blueness; +b for yellowness) were derived using the colour coordinates of L*a*b* values. Additionally, the Munsell® colour notations were recorded (Munsell Colour Chart for Plant Tissues, X-Rite Incorporated, USA). pH of the CAF was determined according to the method of Mesías and Morales (2017). A cashew apple flour sample (0.25 g) was mixed with 25 mL of distilled water and vortexed for 3 min. The mixture was held at room temperature for 1 h and centrifuged at 3500 rpm for 10 min, to separate phases. pH of the supernatant was measured using a benchtop pH meter (BP 300i, Trans Instruments).

Bulk density, tapped density, Carr's Index and Hausner ratio of CAF were determined according to Musa *et al*. (2011) with slight modifications. Bulk density (g/mL) was measured by weighing 20 g of flour sample and depositing it into a glass graduated cylinder with a 100 mL capacity. The volume occupied by the flour was measured, and the weight of the flour was divided by the occupied volume. Tapped density is the flour density after applying mechanical compression. Tapped density was determined by measuring the final settled volume of 20 g of flour placed in a graduated cylinder after 50 taps. The cylinder was manually dropped from a height of 20 mm onto a bench to simulate mechanical tapping. Carr's index is an indicator of the compressibility of flour. To determine the Carr's Index, the difference between the tapped density and the bulk density was divided by the tapped density. The resulting value was then expressed as a percentage. Hausner Ratio, which is an indication of the flowability of flour, was obtained by dividing the tapped density by the bulk density.

Swelling power and water solubility index of the flour were determined according to the method described by Gunaratne *et al*. (2011). A flour sample of 100 mg (dry matter basis) was taken into a screw-cap test tube and 10 mL of distilled water was added. The capped tubes were kept on a vortex for 10 s and incubated in a water bath at 85 °C for 30 min under continuous mixing. Thereafter, the tubes were cooled to ambient temperature in an iced water bath and centrifuged at 2000 × g for 30 min. The supernatant was taken out, and the tube was weighed with the remaining sediment (Ws). The supernatant was dried separately to a constant weight (W1) in a forced-air oven at 100 °C. Swelling power (SP) was calculated using equation (1).

$$SP = \frac{\text{Wt. of swollen sediment (Ws)}}{\text{Wt. of dry flour sample (0.1 g)}}. \qquad (1)$$

Water solubility index (WSI) was calculated using equation (2).

$$\text{WSI, \%} = \frac{\text{Wt.of dry solids in supernatant (W1)}}{\text{Wt.of dry flour sample (0.1 g)}} * 100 \qquad (2)$$

The water absorption capacity (WAC) and oil absorption capacity (OAC) of the flour were determined according to the method of Adegunwa *et al.* (2020), with slight modifications. For WAC, 1 g of flour sample was weighed into a pre-weighed, dry centrifuge tube. Then, 10 mL of distilled water was added, and the mixture was stirred thoroughly for 30 min. The suspension was allowed to stand for another 30 min at room temperature before being centrifuged at 3,500 rpm for 30 min. After centrifugation, the supernatant was decanted, and the tube containing the hydrated sample was weighed. The amount of water absorbed was calculated by subtracting the weight of the empty centrifuge tube and dry sample from the final weight. WAC was calculated using equation (3).

$$\text{WAC, \%} = \frac{\text{Wt.of water absorbed (g)}}{\text{Wt.of dry flour sample (g)}} * 100 \qquad (3)$$

To determine OAC, 1 g of flour sample was weighed into a pre-weighed centrifuge tube. Groundnut oil was added to the sample to make up a total volume of 10 mL, and the mixture was thoroughly stirred to form a uniform dispersion. The suspension was then centrifuged at 3,500 rpm for 15 min at room temperature. After centrifugation, the supernatant oil was decanted, and the tube containing the sediment was weighed. The amount of oil absorbed was determined by calculating the weight gain of the centrifuge tube and sample after centrifugation. OAC was then calculated using equation (4).

$$\text{OAC, \%} = \frac{\text{Wt.of oil absorbed (g)}}{\text{Wt.of dry flour sample (g)}} * 100 \qquad (4)$$

The moisture content of CAF was determined gravimetrically to a constant weight in an oven at 105 °C for 24 h according to the Association of Official Analytical Chemists (AOAC) method (AOAC, 2010). Flour samples (50 g) were stored in sealed aluminium foil bags at ambient conditions (27±2 °C; 65% relative humidity). determined after a 4-week storage period using an infrared moisture analyzer (FD-660, Kett, Japan).

Crude ash content was assessed using the muffle incineration method (at 540 °C), and the crude protein was quantified by the Kjeldahl distillation method. A fiber analyzer (Fiber Extraction System F–6P, Spain) was used to quantify crude fibre. The crude fat content was assessed using the solvent extraction technique (Fat Extraction System SX-6 MP, Spain). All tests were performed following the AOAC guidelines (AOAC, 2010). Total gross energy and total carbohydrate content were determined by calculation according to Diddana *et al*. (2021).

Development of Cashew Apple Flour-Based Cookies

Cookie Formulations and Determination of Their Physicochemical Properties

Cashew apple flour was prepared using Method 2, from ripe cashew apples of the varieties WUCC-05 and WUCC-09, which were selected due to their lower tannin content and higher consumer acceptability for fresh consumption (Gunasekara *et al*., 2018; Walgama *et al*., 2020). Cookies were made using a standard recipe with slight modifications based on the method described by Oyewole *et al.* (1996). Butter and sugar were creamed together until a light and fluffy consistency was achieved. One medium-sized whole egg and powdered milk were then incorporated into the mixture while stirring continuously. Subsequently, wheat flour, CAF, baking powder, and salt were gradually added to the mixture to form a uniform dough. The dough was rolled out on a lightly floured surface using a rolling pin and cut into 4 mm thick circular shapes. The cookie discs were placed on greased baking trays and baked at 130 °C for 20 min (Ebere *et al.*, 2015). A preliminary trial was conducted to determine suitable combinations of wheat flour (WF) and CAF. Based on this, five substitution levels of CAF were selected as 0%, 10%, 20%, 30%, and 40% (Table 1).

The diameter and height of cookies were measured using a digital vernier caliper. Weight of cookies was recorded using an electronic top loading balance (YP 3002, Hangzhou West Tune Trading Co., Ltd., China). Cookie volume was determined by the seed displacement method (Akubor and Ishiwu, 2013). The density was

Table 1. Cookie formulations with different proportions of cashew apple flour (CAF) and wheat flour (WF). Ingredient quantities are provided per 200 g of dough.

Ingredients	Quantity				
	0% CAF (Control)	10% CAF	20% CAF	30% CAF	40% CAF
Cashew apple flour (g)	0.0	10.0 g	20.0	30.0	40.0
Wheat flour (g)	100.0	90.00	80.00	70.00	60.00
Sugar (g)	35.0	35.00	35.00	35.00	35.00
Butter (g)	40.0	40.00	40.00	40.00	40.00
Milk powder (g)	10.0	10.00	10.00	10.00	10.00
Baking powder (g)	2.0	2.00	2.00	2.00	2.00
Salt (g)	1.5	1.5	1.5	1.5	1.5
Egg	1.0	1.0	1.0	1.0	1.0

Moisture content of the flour samples was calculated as the ratio of mass to volume (g/cm^3). Spread ratio was determined by dividing the diameter by the height of the cookie (Akubor and Ishiwu, 2013).

Determination of Sensory Attributes of Cookies

The sensory properties of cookies were assessed by 25 semi-trained panelists using a 7-point hedonic scale (7 = Extremely like, 1 = Extremely dislike). Attributes including appearance, colour, flavour, texture, aroma, and overall acceptability were assessed. The best cookie formulation was selected to determine the proximate compositions and storability.

Proximate Analysis and Storage Quality of Cookies

The best-performing cookie formulation and the control sample (100% WF) were subject to proximate analysis. Moisture, ash, crude protein, crude fat, crude fibre, and carbohydrate contents were estimated following standard AOAC procedures (AOAC, 2010). The quality of the best cookie formulation and control sample was assessed after two weeks of storage in LDPE bags at ambient conditions in terms of moisture content (AOAC, 2010).

Statistical Analysis

The physical and chemical analyses were performed on triplicate samples, and the results were analysed by analysis of variance (ANOVA) and Least Significant Difference (LSD) tests using SAS statistical software (version 9.4). Results of sensory evaluation were analyzed using the Friedman test.

RESULTS AND DISCUSSION

Physicochemical, Functional, and Nutritional Properties of CAF

Colour of CAF

Colour is a critical quality attribute in food products, as it significantly influences consumer preferences. The colours of CAF produced using Method 1, Method 2, and Method 3 were described using Munsell notations as 2.5Y 7/4, 2.5Y 6/6, and 2.5Y 7/6, respectively (Table 2). When used as an ingredient, the colour of CAF can directly impact the visual appeal of the final food product. The colour attributes of CAF, measured using the CIE Lab* system, were in the ranges of L* = 65.26–65.78, a* = 12.46 –12.96, and b* = 40.50 – 42.18. The L* value represents lightness, with higher values indicating greater brightness, while a* and b* represent the red-green and yellow-blue colour components, respectively. The positive a* and b* values indicate a slight reddish-yellow hue, characteristic of CAF derived from the variety WUCC-05, which has red skin and cream-coloured flesh. Among the processing methods, L* and a* values were not significantly affected. However, the b* value was significantly higher in the flour produced using Method 2, indicating more intense yellowness, potentially due to differences in thermal exposure and reduced enzymatic browning.

pH of CAF

The pH of CAF ranged from 4.72 - 5.71, with a significantly higher value ($P < 0.05$) observed in the flour produced using Method 2 (Table 2). According to Adewumi *et al*. (2020), starches with pH values between 3.0 and 9.0 are considered suitable for applications in the food and pharmaceutical industries. However, pH values below 4.0 are typically indicative of fermentation or starch degradation, rendering such materials unsuitable for food use (Apea -Bah *et al*., 2007). Based on these criteria, all three CAF samples demonstrated acceptable pH levels, indicating that they are appropriate for incorporation into food formulations.

Moisture Content of CAF

The moisture content of freshly prepared CAF ranged from 4.79% - 6.89%, with the lowest value observed in flour produced via Method 1, where raw cashew apples were dried without pre-treatment such as boiling or blanching (Table 2). All three flour types had moisture levels within acceptable limits for shelf-stable flour products (<10%; Ogunjobi and Ogunwolu, 2010), indicating good storage potential. Moisture contents of the flours from the three methods remained below 10% during a 4-week storage period.

Flour Densities

The bulk density (BD) of CAF ranged from 0.55 to 0.67 g/mL (Table 2). A significantly higher BD (P < 0.05) was observed in flour produced using Method 2, while the lowest BD was recorded for Method 1. These differences are likely attributed to variations in particle size, as smaller and more compact particles tend to exhibit higher bulk density (Akubor *et al*., 2013). Flours with higher bulk density are advantageous in the food industry, particularly as thickening agents in products such as soups and sauces (Musa *et al*., 2011). Conversely, lower bulk density is beneficial in infant food formulations, where higher nutrient and caloric density is desired in smaller serving volumes. According to Offia-Olua and Onwubiko (2015) flours with lower BD are also better suited for instant food and breakfast cereal applications, where improved reconstitution and nutrient delivery are essential.

The tapped density (TD) of CAF ranged from 0.82 to 0.87 g/mL (Table 2). A significantly higher TD (P < 0.05) was observed in flour produced by Method 2, while the lowest TD was recorded in flour from Method 1. These variations may be attributed to differences in flour compaction and particle morphology. Among the three processing methods, Method 3 produced flours with notably higher Carr's index and Hausner ratio, indicating poorer flow characteristics. Carr's index values of CAF ranged from 21.9 to 33.6, and Hausner ratios varied between 1.28 and 1.50 (Table 2). According to Musa *et al*. (2011), Carr's Index values above 23.0 and Hausner Ratios greater than 1.20 suggest poor flowability and reduced compressibility, which may negatively affect flour handling and processing. Therefore, CAF produced using

Method 3 exhibited suboptimal flow and packing properties when compared to flours from Methods 1 and 2, which displayed better suitability for industrial applications where good flowability is essential.

Water and Oil Absorption Capacities

WAC refers to the ability of flour to absorb and retain water under limited moisture conditions, such as in doughs and pastes (Akubor *et al.*, 2013). In the present study, the WAC of CAF ranged from 136.21% to 274.60%, with the highest value observed in Method 2 ($P < 0.05$). This value is substantially higher than that of typical refined wheat flour, which generally exhibits WAC values between 110% and 160% (Offia-Olua and Onwubiko, 2015). The superior WAC of CAF, particularly from Method 2, suggests its potential to improve dough yield and hydration, especially in bakery applications where water retention is critical.

OAC reflects the flour's ability to bind lipids, which is vital for enhancing flavour retention, palatability, and mouthfeel in fat-rich products like cookies (Offia-Olua and Onwubiko, 2015). The OAC of CAF ranged from 54.18% to 70.63%, with Method 2 showing the lowest OAC ($P < 0.05$). This is lower than standard wheat flour, which typically exhibits OAC values around 140–180% depending on protein content and processing conditions (Akubor, 2016a). While high OAC is desirable for improving the sensory attributes of baked products, excessively high values can lead to oily textures and reduced product shelf life, particularly in deep-fried or fat-sensitive formulations (Omimawo and Akubor, 2012). Therefore, the moderate OAC of Method 2 flour offers a balance that supports good flavour binding without compromising the fat content or texture of the final product. This property, combined with its high WAC, makes Method 2-derived CAF a promising ingredient for cookie development.

Swelling Power and Water Solubility Index

Swelling power (SP) of the CAF samples ranged from 5.51 to 8.95 g/g (Table 2), with Method 2 exhibiting the highest SP ($P < 0.05$). Swelling power reflects the capacity of starch granules to absorb water and swell under heat, a process governed primarily by the integrity and arrangement of amylopectin chains and the presence of hydrogen bonding sites (Muazu *et al.*, 2011). A higher SP indicates a greater water holding capacity and better disintegrating behaviour of starches, which is desirable in formulations that require soft textures or rapid rehydration, such as cookies, porridges, or instant foods. The significantly higher SP observed in flour from Method 2 suggests that its starch matrix is more capable of water uptake and swelling, which may improve cookie tenderness and internal structure during baking.

In addition to SP, the water solubility index (WSI) provides insight into the degree of starch degradation and the presence of water-soluble components, such as sugars and short-chain carbohydrates (Ding *et al.,* 2005). Although not detailed here, WSI typically complements SP data; higher WSI values may suggest partial gelatinization or breakdown of polysaccharides during processing, which could influence dough stickiness, sweetness perception, and browning characteristics during baking. Taken together, the high SP and likely moderate WSI of Method 2 flour support its suitability for bakery applications, especially where moisture retention and tender texture are desired.

Proximate Composition of CAF

According to the proximate analysis performed for CAF produced using Method 2 (Table 3), the moisture and ash contents were 6.89% and 2.24%, respectively, suggesting a relatively high mineral content. The crude protein content was recorded at 9.08%, aligning with earlier findings by Offia-Olua and Onwubiko (2015), who reported that thermal processing during drying may lead to protein denaturation. As a result, the substitution of wheat flour with CAF may reduce the overall protein content in composite flour products. However, this limitation can be mitigated by incorporating complementary protein sources, thereby improving the overall protein quality and quantity (Akubor and Badifu, 2004).

The crude fibre content was 4.54%, indicating that CAF could serve as a dietary fibre enhancer in cereal-based formulations (Akubor, 2016a). The crude fat content, recorded at 4.31%, reflects a moderate lipid level, which may contribute to improved storage stability. The total carbohydrate content was 72.12%, representing the primary macronutrient in CAF (Table 3).

Cashew Apple Flour-Based Cookies

During product trials, cookies incorporating CAF from Method 2 demonstrated good dough workability and favourable baking characteristics, supporting its functional suitability for partial substitution of wheat flour. The enhanced WAC likely contributed to improved dough pliability and moisture retention, resulting in a softer crumb texture and better handling properties. Additionally, the desirable SP and WSI may have positively influenced starch hydration and gelatinization during baking, enhancing cookie structure. These functional attributes highlight the potential of Method 2 CAF as a value-added ingredient in baked product development.*Physical Properties of Cookies* The physical properties of cookies prepared using the combinations of WF and CAF are shown in Table 4. The weight, diameter, height and spread ratio of cookies prepared from 100% WF and their blends were not significantly different ($P > 0.05$). The weight of cookies substituted using CAF ranged between 3.52 and 3.72 g, where the values were lower than the control sample. A relatively high weight of cookies was reported in the samples prepared using 100% WF (3.98 g). The weight of each sample indicated a decreasing trend with the increase of CAF in cookies. There were significant differences in the volume and density of cookie formulations. The cookies made of 100% WF indicated a higher volume compared to the cookies formulated using CAF. Nevertheless, a notable variation was absent in the density of cookies made with different formulations (Table 4). Moreover, the spread ratio of cookies ranged between 5.11 (10% CAF) and 5.26 (40% CAF) without indicating significant differences among the values (Table 4).

Sensory Attributes of CAF-Based Cookies

According to the results of the ranking preference test, 30% CAF incorporated cookie (T4) was identified as the best formulation (Figure 1). When considering the sensory attributes, including appearance, colour, flavour, texture, aroma and overall acceptability, there were significant differences among the five treatments ($P < 0.05$).

Table 2. Variation in physicochemical and functional properties of cashew apple flour derived from three processing methods.

Property	Flour preparation method		
	Method 1	Method 2	Method 3
Bulk density (g/mL)	0.64 ± 0.01[b]	0.67 ± 0.03[a]	0.55 ± 0.01[c]
Tapped density (g/mL)	0.82 ± 0.01[b]	0.87 ± 0.00[a]	0.83 ± 0.01[b]
Carr's index	21.89 ± 2.20[b]	22.61 ± 0.38[b]	33.60 ± 0.67[a]
Hausner ratio	1.28 ± 0.04[b]	1.29 ± 0.00[b]	1.50 ± 0.02[a]
Colour			
Munsell notation	2.5Y 7/4	2.5Y 6/6	2.5Y 7/6
L*	65.78	65.77	65.26
a*	12.73	12.96	12.46
b*	41.6	42.18	40.5
pH	4.75 ± 0.00[b]	5.71 ± 0.01[a]	4.72 ± 0.00[c]
Moisture content (Initial) (%)	4.79± 0.47[b]	6.89± 0.24[a]	6.41± 0.18[a]
Water absorption capacity (%)	136.21 ± 2.52[c]	274.60 ± 7.28[a]	172.89 ± 4.71[b]
Oil absorption capacity (%)	63.72 ± 3.09[a]	54.18 ± 1.73[b]	70.63 ± 1.55[a]
Swelling power (g/g)	5.51 ± 0.43[c]	8.95 ± 0.17[a]	6.71 ± 0.15[b]
Water solubility index	34.53 ± 4.62[a]	21.57 ± 3.69[b]	23.33 ± 1.13[ab]

Values are mean ± standard deviation. Between columns, means followed by different superscript letters are significantly different ($P < 0.05$).

Table 3. Proximate composition of cashew apple flour prepared using Method 2.

Parameter	Values (mean ± SD)
Moisture (%)	6.89 ± 0.24
Ash (%)	2.24 ± 0.06
Crude protein (%)	9.08 ± 0.29
Crude fat (%)	4.31 ± 0.13
Crude fiber (%)	4.54 ± 0.14
Total carbohydrate (%)	72.12±1.05

This sensory outcome aligns with the results reported by Osei *et al.* (2025), where the higher consumer acceptability was found in cashew apple pomace powder-incorporated biscuits, mainly due to improved taste, flavour and sweetness developed as a result of higher carbohydrates alongwith fermentable sugars, including sucrose and glucose.

Proximate Composition and Storability of Cookies

The results of proximate analysis of cookies are shown in Table 5. The levels of crude protein, crude fat and ash were substantially higher (P < 0.05) in the control sample (100% WF) compared to the cookies with 30% CAF. Consequently, the protein content of cookies decreased with the increase of CAF content. A similar trend was reported by Salve and Swami (2023) in the cookies produced using osmo-convective dried CAF. Additionally, Elgindy (2017) described a similar tendency in cookies made of different blends of mango seed kernel and WF. When considering the crude fat content, it decreased with the increase of CAF, with a significant effect, consistent with the findings of Salve and Swami (2023).

CAF-incorporated cookies had notably higher levels of crude fibre (6.33%), which could have resulted from the higher fibre content present in cashew apples (Walgama *et al*., 2020). Similar results were reported by Osei *et al*. (2025), where a significantly higher fibre content was detected in 30% CAF-enriched snacks. Furthermore, these results align with the results of Akubor (2016b) obtained for biscuits formulated using cashew apple pomace powder. The presence of higher levels of dietary fibre will enhance the nutritional value of cookies. Alternatively, it can modify the rheological properties of the dough as well as the sensory and quality attributes of cookies, as the increased fibre content may ameliorate the flavour ascribed to the effects of fibre-binding flavour components (Larrea *et al.,* 2005). Besides, CAF is identified as a potential, cheap and healthy source of fibre with remarkable therapeutic value, which can be effectively exploited in the food industry to elevate fibre content of cereal-based products through supplementation (Ebere *et al*., 2015).

The fat content in the 30% CAF-based cookie (16.25%) was lower than the control (18.36%), which would enhance the shelf life of cookies as they have a lower ability to develop rancidity. The carbohydrate content of 30% CAF-added cookies was significantly higher (55.81%) when compared to the control sample made of 100% WF (52.85%). These results are, however, contrary to Osei *et al*. (2025), who outlined a notably higher level of total carbohydrate content in WF-based biscuits.

The moisture content of freshly prepared CAF-incorporated cookies was higher (7.46%) than the control cookie sample (6.43%). After two weeks of storage in LDPE bags at ambient conditions, the moisture content of cookies have increased in both control (6.43% to 9.57%) and 30% CAF incorporated cookies (7.46% to 9.97%; Table 5). Based on the findings of Ogunjobi and Ogunwolu (2010), the moisture content of cassava flour– and CAF-incorporated biscuits should not exceed 14%. However, a moisture level below 10% is considered optimal for baked products, as reduced moisture and water activity minimize the risk of microbial spoilage and enhance the shelf stability of low-moisture foods such as biscuits, cookies, and pastries (Osei *et al.*, 2025). Thus, the moisture content of cookies supplemented with CAF ranged between the admissible levels even after two weeks of storage. Further, it is crucial to select moisture-proof packaging material, such as laminated pouches, to store the cookies.

Table 4. Physical properties of cookies made with the blends of wheat flour (WF) and cashew apple flour (CAF).

Parameter	**Mean values**[1]				
	WF:CAF ratio in the dough				
	100:0 (T1)	**90:10 (T2)**	**80:20 (T3)**	**70:30 (T4)**	**60:40 (T5)**
Weight (g)	3.98^{a}	3.72^{a}	3.66^{a}	3.58^{a}	3.52^{a}
Diameter (cm)	3.50^{a}	3.50^{a}	3.50^{a}	3.45^{a}	3.51^{a}
Height (mm)	6.73^{a}	6.88^{a}	6.80^{a}	6.68^{a}	6.68^{a}
Volume (cm^3)	6.90^{a}	6.83^{a}	6.60^{b}	6.76^{ab}	6.73^{ab}
Density (g/cm^3)	0.57^{ab}	0.56^{ab}	0.54^{b}	0.54^{ab}	0.60^{a}
Spread ratio	5.21^{a}	5.11^{a}	5.17^{a}	5.17^{a}	5.26^{a}

[1]*n=3; Between columns, means with different superscript letters, are significantly different (P < 0.05).*

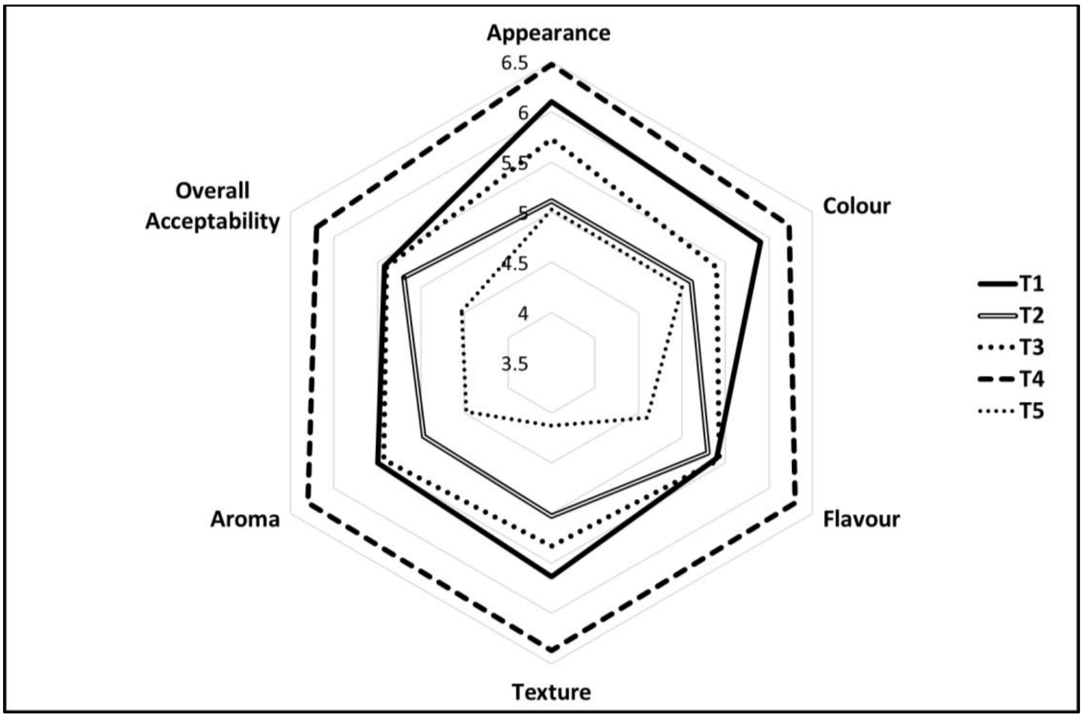

Figure 1. Comparison of mean scores obtained for sensory properties of cookies prepared from blends of wheat flour (WF) and cashew apple flour (CAF)

T1-Control (0% CAF), T2-10% CAF, T3-20% CAF, T4-30% CAF, T5–40% CAF.

Score: 1- Extremely dislike, 7- Extremely like.

Table 5. Proximate compositions of the new cookie formulation [30% cashew apple flour (CAF) + 70% wheat flour (WF)] and control (100% WF).

Parameter	Composition in cookies	
	100% WF (Mean±SD)	30% CAF (Mean±SD)
Crude protein %	15.04±0.13[a]	12.33±0.17[b]
Ash %	1.68±0.03[a]	1.57±0.02[b]
Crude fat %	18.36±0.26[a]	16.25±0.26[b]
Crude fibre %	5.56±0.20[b]	6.33±023[a]
Carbohydrate	52.85±1.09[b]	55.81±034[a]
Moisture %		
Fresh cookies	6.43±0.24[a]	7.46±0.46[b]
After 2 weeks	9.57±0.27[a]	9.97±0.03[a]

Between columns, means followed by different superscript letters, are significantly different (P < 0.05).

CONCLUSION

Among the three processing methods evaluated, Method 2 (boiling for 10 min followed by oven drying) produced CAF with superior functional properties, including higher bulk density (0.67 g/mL), water absorption capacity (274.60%), and swelling power (8.95 g/g). CAF derived from Method 2 resulted in a higher chroma value indicating more intense yellowness. The flour also maintained moisture content within safe limits (<10%) throughout 30 days of storage, confirming its stability for food use. CAF demonstrated strong potential as an ingredient in value-added food applications. Incorporation of 30% CAF with 70% WF yielded cookies with the most favourable sensory attributes and acceptable physical characteristics compared to 100% WF cookies. This formulation also provided nutritional advantages, with reduced fat content and significantly higher dietary fibre. Further research is warranted on the pasting properties, shelf life, and storability of CAF and its products. In addition, investigations into protein fortification strategies (e.g., blending with legume flours) may enhance the nutritional profile and broaden its application in functional food development.

ACKNOWLEDGEMENTS

Authors are thankful to the assistance given by Mr. Indika Karunarathne, and the laboratory and technical staff of the Departments of Horticulture and Landscape Gardening, Biosystems Engineering, Biotechnology, and Food Science and Technology, of the Wayamba University of Sri Lanka.

REFERENCES

Adegunwa, M. O., Kayode, B. I., Kayode, R., Akeem, S. A., Adebowale, A. A., and Bakare, H. A. (2020). Characterization of wheat flour enriched with cashew apple (*Anacardium occidentale* L.) fiber for cake production. *Journal of Food Measurement and Characterization, 14*, 1998–2009.

Adewumi, F. D., Lajide, L., Adetuyi, A. O., and Ayodele, O. (2020). Functional properties of three native starches and their modified derivatives. *Potravinarstvo Slovak Journal of Food Sciences, 14*, 682–691.

Akubor, P. I. (2016a). Chemical composition, functional and pasting properties of cashew pomace and wheat flours. *International Journal of Agricultural and Veterinary Sciences, 2*(1), 28–37.

http://dx.doi.org/10.18819/ijavs.2016.1549.

Akubor, P. I. (2016b). Chemical composition, physical and sensory properties of biscuits supplemented with cashew pomace flour. *NSUK Journal of Science & Technology, 6*(2), 138–141.

Akubor, P. I. and Ishiwui, C. (2013). Chemical composition, physical and sensory properties of cakes supplemented with plantain peel flour. *International Journal of Agricultural Policy and Research, 1*(4), 87–92.

Akubor, P. I., Yusuf, D., and Obiegunam, J. E. (2013). Proximate composition and some functional properties of flour from the kernel of African star apple (*Chrysophyllum albidum*). *International Journal of Agricultural Policy and Research, 1 (3),* 062-066.

Akubor, P. I. and Badifu, G. I. (2004). Chemical composition, functional properties and baking potential of African breadfruit kernel and wheat flour blends. *International Journal of Food Science and Technology, 39*(2), 223–229.

Akyereko, Y. G., Yeboah, G. B., Wireko-Manu, F. D., Alemawor, F., Mills-Robertson, F., and Odoom, W. (2023). Nutritional value and health benefits of cashew apple. *JSFA Reports, 3*, 110–118.

AOAC. (2010). *Official methods of analysis* (19th ed.). Association of Official Analytical Chemists.

Apea-Bah, F., Oduro, I., Ellis, W., and Safo-Kantanka, O. (2007). Time of harvesting and its effect on the quality of flour from four cassava varieties. In *Proceedings of the 13th ISTRC Symposium* (pp. 248–259).

Das, I. and Arora, A. (2017). Post-harvest processing technology for cashew apple—A review. *Journal of Food Engineering, 194*, 87–98.

Diddana, T. Z., Kelkay, G. N., and Tescha, E. E. (2021). Nutritional composition and sensory acceptability of stinging nettle (*Urtica simensis*) flour-supplemented unleavened maize (*Zea mays* L.) flatbread (Kitta). *International Journal of Food Science, 2021*, 6666358.

Ding, Q.-B., Ainsworth, P., Tucker, G., and Marson, H. (2005). The effect of extrusion conditions on the physicochemical properties and sensory characteristics of rice-based expanded snacks. *Journal of Food Engineering, 66*, 283–289.

Ebere, C., Emelike, N., and Kiin-Kabari, D. (2015). Physicochemical and sensory properties of cookies prepared from wheat flour and cashew-apple residue as a source of fibre. *Asian Journal of Agriculture and Food Sciences, 3*(2), 213-218.

Elgindy, A. A. E. (2017). Chemical and technological studies of mango seed kernel. *European Journal of Food Science and Technology, 5*, 32–40.

Gnagne, A. A. G. B., Soro, D., Ouattara, Y., Koui, E., and Koffi, E. (2023). A literature review of cashew apple processing. *African Journal of Food, Agriculture, Nutrition and Development*, *23*, 22452–22469.

Gunaratne, A., Bentota, A., Cai, Y. Z., Collado, L., and Corke, H. (2011). Functional, digestibility, and antioxidant properties of brown and polished rice flour from traditional and new-improved varieties grown in Sri Lanka. *Starch–Stärke, 63*, 485–492.

Gunasekara, S. G. V. D. H., Eeswara, J. P., Ratnayake, R. H. M. K., and Herath, H. M. S. P. (2018). Antioxidant capacity, phenolics and ascorbic acid content of cashew apples of recommended cashew (*Anacardium occidentale* L.) varieties in Sri Lanka. In *Proceedings of the 1st National Symposium on Sustainable Plantation Management (NSSPM)* (pp. 67–76). National Institute of Plantation Management, Sri Lanka.

Larrea, M., Chang, Y., and Martínez-Bustos, F. (2005). Some functional properties of extruded orange pulp and its effect on the quality of cookies. *LWT – Food Science and Technology, 38*, 213–220.

Mesías, M. and Morales, F. J. (2017). Effect of different flours on the formation of hydroxymethylfurfural, furfural, and dicarbonyl compounds in heated glucose–flour systems. *Foods, 6*(2), 14.

Muazu, J., Musa, H., Isah, A., Bhatia, P., and Tom, G. (2011). Extraction and characterization of Kaffir potato starch: A potential source of pharmaceutical raw material. *Journal of Natural Product and Plant Resources, 1*(2), 41–49.

Musa, H., Gambo, A., and Bhatia, P. (2011). Studies on some physicochemical properties of native and modified starches from *Digitaria iburua* and *Zea mays*. *International Journal of Pharmacy and Pharmaceutical Sciences, 3*(1), 28–33.

Offia-Olua, B. and Onwubiko, B. (2015). Physicochemical properties and micronutrients of whole wheat flour partially substituted with cashew apple powder. *Journal of Food Science and Technology, 2*(1), 44–51.

Ogunjobi, M. and Ogunwolu, S. (2010). Physicochemical and sensory properties of cassava flour biscuits supplemented with cashew apple powder. *Journal of Food Technology, 8*(1), 24–29.

Omimawo, I. and Akubor, P. (2012). *Food chemistry: Integrated approach with biochemical background*. Agbowo, Ibadan, Nigeria.

Osei, E. D., Amotoe-Bondzie, A., Laar, W. S., Sarpong, P., Afoakwah, N. A., Harangozo, L., and Ivanišová, E. (2025). Evaluation of nutritional, antioxidant, oxidative stability, and consumer acceptability of biscuits incorporated with cashew apple pomace powder. *Journal of Food Processing and Preservation, 2025*, 2804727.

Oyewole, O., Sanni, L., and Ogunjobi, M. (1996). Production of biscuits using cassava flour. *Nigerian Food Journal, 14*, 25–30.

Perera, L.G.P. and Kandiah, M. (2016). Antioxidant and antimicrobial activity of cashew apples and cashew nuts in Sri Lanka. *GARI International Journal of Multidisciplinary Research, 2 (2), 23-52.*

Salve, V. and Swami, S. (2023). Physicochemical and sensory evaluation of cookies supplemented with osmo-convective dried cashew apple powder. *Journal of Agriculture Research and Technology, 48*(2), 319–328.

SLCC (2020). *Annual Report - 2020*, Sri Lanka Cashew Corporation, Sri Lanka.

Walgama, H. W. D. D., Walakuluge, H. P., Gunasekara, S. G. V. D. H., Ratnayake, R. H. M. K., Eeswara, J. P., and Herath, H. M. S. P. (2020). Physicochemical characteristics, tannin content and sensory attributes of the cashew apple of eight cashew (*Anacardium occidentale* L.) varieties grown in Sri Lanka. In *Proceedings of the 2nd National Symposium on Sustainable Plantation Management (NSSPM)* (pp. 136–142). National Institute of Plantation Management, Sri Lanka.