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6

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# Physicochemical and functional properties of wheat-rain tree (Samanea saman) pod composite flours

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#### ABSTRACT

Rain tree pod (RTP) has the potential to contribute to food security, but it is underutilized in Ghana. In this study, the physicochemical, mineral, functional, and pasting properties of RTP flour as a composite with wheat flour at different inclusion levels (5-30%) were evaluated. The moisture, crude protein, ash, crude fat, crude fiber, and carbohydrate were in the range of 8.3-9.2%, 12.3-14.89%, 0.80-1.42%, 1.25-1.45%, 0.32-1.35%, and 72.13-75.47%, respectively. The composite flours had considerable mineral content (Ca, Mg, Na, and P) with K (807-1153 mg/100 g) being the most abundant, but K and Na were improved in the composite flour T3 (15%). The composite flours had varied bulk densities with Hausner's ratio in the range 1.32–1.59, 4.47–6.72% foaming capacity, 86.32-96.61% foaming stability, 9.09-15.44% solubility, 6.3-6.96% swelling power, 137.4-63.8% oil absorption capacity, and 149.74-202.97% water absorption capacity. The pasting properties of the composite flour samples ranged from 9.87 to 11.07 min peak time, 50.7-90.83°C pasting temperature, 555.0-1527.0 RVU peak viscosity, 384.0-1004.5 RVU trough viscosity, 95-768RVU breakdown viscosity, 150.0-371 setback viscosity, and 600.0-1141.0 RVU final viscosity. Overall, the findings showed that the RTP-wheat composite flours had appreciable nutrient and functional properties that could be exploited in potential food formulations.

#### **ARTICLE HISTORY**

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#### **KEYWORDS**

Rain tree pod; Composite flour; Physicochemical properties; Functional properties

# Introduction

The rain tree (*Samanea saman*) is a leguminous tree and a member of the Fabaceae family. The tree is widely distributed in Asia, Africa, North America, South America, Central America, and the Caribbean.<sup>[1]</sup> The pods of the rain tree are underutilized in Ghana. The mature pods when ripe, falls and go to waste, however, pods and seeds are edible and rich in protein.<sup>[2</sup> The pods have a sweet licorice-like, brownish, sweet-flavored pulp that serves as a minor food for humans eaten by South-West Nigerian children. In Latin America, a lemonade drink is made from the pul.<sup>[3</sup> The rain tree pod has been reported to be effective in the treatment and prevention of diarrhea, colds, headaches, intestinal ailments, and stomach-ache.

Wheat (*Triticum spp.*) is the most dominant, desired, and contributes more calories and proteins to diet of the world as a staple food crop than other cereals.<sup>[4</sup> Ghana imports large amount of wheat flour from foreign countries and about 80% of the imported wheat flour is used for breadmaking.<sup>[5,6</sup> From an economic perspective, Ghana's dependence on imported wheat negatively impact the consumer, especially when there is a global increase in the price of wheat. Hence, having wheat alternatives, which are easily accessible and more sustainable will greatly contribute to food security. Thus, there is a growing interest in exploring possible ways of partial or total replacement of wheat flour.<sup>[7]</sup>

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This article has been corrected with minor changes. These changes do not impact the academic content of the article.

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Composite flour from underutilized crops and potential wheat alternatives will reduce the huge cost of importation and promote high yielding local species with both nutritional and health benefits.<sup>[4,8]</sup> Legumes have emerged as a new plant protein source with high lysine and bioactive compounds, such as vitamins and carotenoids.<sup>[9]</sup> Moreover, leguminous flour has been considered as potentially safe and could be deployed in developing functional foods having therapeutic value, aiding in disease prevention and body management. Products made from composite flour of cereal and legume have improved nutrient density, because cereal proteins are high in methionine and cystine, while legumes are high in lysine.<sup>[10]</sup> The rain tree pod presents a potential supply of protein, phytochemicals, and micronutrients but underutilized in food applications.<sup>[1]</sup> The objective of this study, therefore, was to determine the physicochemical, functional, and pasting properties of wheat-rain tree pod composite flour.

# **Materials And Methods**

# Materials and sample preparation

Wheat (soft flour) was purchased from a local market in Ayigya, Kumasi-Ashanti region, Ghana. The rain tree pods were harvested from trees at KNUST, Kumasi. All the reagents used in the study were of analytical grade. The rain tree pods were cleaned, soaked, oven-dried (at 50°C for 72 h), and milled into flour using a Binatone kitchen blender (model: BLG 402). The milled flour was sieved using 1 mm mesh-sized sieve and then defatted with petroleum ether at a ratio of 1:3 (w/v) for 120 h while shaking periodically. The defatted flour was dried for 2 h and milled using Binatone kitchen grinder (model: BLG 402). It was then packaged in an airtight polyethylene bag and stored at  $-18^{\circ}$ C prior to analysis. Six composites were made by mixing wheat flour and rain tree pod flour with proportions as shown in Table 1.

# **Proximate analysis**

Moisture, crude protein, ash, crude fat and crude fiber contents were determined following the Official Methods of Analysis of.<sup>[11</sup> Crude protein was calculated by multiplying the obtained nitrogen content by 6.25. Available carbohydrate content was calculated by difference <sup>[11,12</sup>

# **Mineral content**

Magnesium and calcium contents were determined by using atomic absorption spectrophotometer (Buck 210, Buck Scientific, USA) as previously reported.<sup>[13]</sup> Potassium and sodium were analyzed using a Jenway digital flame photometer (Jenway Digital, Model PFP7, USA). Standard calibration curves were plotted using standard solutions of NaCl and KCl with concentrations of 20, 40, 60, 80, and 100 ppm. The concentrations of sodium and potassium in ash solutions were determined from the corresponding calibration curves. Also, the concentrations of minerals (ppm) were recorded and the mineral concentration in mg/100 g was calculated using the following equation:

 Table 1. Formulation of composite flours from wheat flour and rain tree pod flour.

Samples	TO	T1	T2	T3	T4	T5	T6
Wheat Flour (%)	100	95	90	85	80	75	70
Rain tree Flour (%)	0	5	10	15	20	25	30

T0 = 100% Wheat flour [Control), T1 = 95% Wheat Flour/5% *S. saman*, T2 = 90%/10% *S. saman*, T3 = 85% Wheat Flour/15% *S. saman*, T4 = 80% Wheat Flour/20% *S. saman*, T5 = 75% Wheat Flour/25% *S. saman*, T6 = 70% Wheat Flour/30% *S. saman*.

$$\% Totalmineral(mg/100g) = \frac{concentration(ppm) \times dilutionfactor}{wt.ofsample \times 1000} \times 100$$

The phosphorus content of each sample was estimated using spectrophotometer [model: Lemfield Spectrulab 23A] as described in.<sup>[11</sup> Solution A was prepared by dissolving 22.5 g of aqueous ammonium heptamolybate in 400 ml deionized water, whereas solution B was prepared by dissolving 1.25 g of ammonium vanadate in 300 ml deionized water. The solution B was added to solution A and cooled to room temperature, after which 250 ml of concentrated HNO<sub>3</sub> was added to the mixture and diluted to 1.0 L color reagent. One milliliter of each ash solution was taken and 4 mL deionized water added in a beaker. Approximately 5 mL of the color regent was introduced to the volume and the total volume of the final solution was made to 25 ml to give a resultant resulting yellow solution whose absorbance was read using the spectrophotometer. The absorbance read from the spectrophotometer were plotted on a standard curve to determine the phosphorus concentration (ppm]. The total phosphorus (P) concentration in mg/100 g was calculated using the equation below:

$$P(mg/100g) = \frac{concentration(ppm) \times dilutionfactor}{weight of sample \times 1000} \times 100$$

#### **Functional properties**

The determination of the water absorption capacity (WAC) and oil absorption capacity (OAC) of the flour samples were performed as previously reported.<sup>[12,14,15</sup> 2 grams of the composite flour was mixed in 40 mL of distilled water or refined oil in a 50 mL centrifuge tube placed on a shaker for 1 h (Edmund Buhler SM 30) and was allowed to stand at room temperature (25°C) for 1 h. This was followed by centrifugation for 15 min at 2200 rpm, the oil or water was decanted and the wet flour weight estimated by difference.

Bulk densities were estimated using.<sup>[16</sup> 10 mL of composite flours was filled in a 100 mL graduated cylinder weighed and tapped gently on a bench several times until no decrease. The loose and tapped densities were calculated as weight of sample per unit volume of samples [g/ml]. According to,<sup>[17]</sup> the Hausner ratios were estimated as ratio of the tapped density to loose density of flour.

Foaming capacity and foaming stability were determined using a method according to,<sup>[18]</sup> with slight modifications. Some modifications to the procedure described by,<sup>[19]</sup> were used in the estimation of both swelling power [SP] and solubility of composite flours. One gram of flour samples was transferred into a centrifuge tube 50 mL having 40 mL of distilled water and vortexed for 30 min. The tubes were transferred to thermostatically regulated water bath at 85°C for 30 min, cooled to room temperature, centrifuged at 2200 rpm for 5 min, decanted gently into a pre-weighed petri dish weighed.

#### **Pasting properties**

The pasting properties were performed in duplicate with a Rapid Visco Analyzer (RVA Model 4500, Perten Instruments, Australia) as previously reported.<sup>[20,21]</sup> Depending on the moisture of the samples, both the corrected sample weight and corrected weight sample were provided by the instrument. The temperature profile that was used started at 50°C and increased linearly to 90°C, followed by a holding step at 95°C, then cooling to 50°C, for a total time of 12.5 min. The peak, trough, final, breakdown, and setback viscosities, pasting temperature, and peak time were determined.

# **Statistical analysis**

The data obtained in triplicates were subjected to statistical analysis using a general linear model of analysis of variance as described Minitab version 18.0, Turkeys' Pairwise Comparison was used to separate the means among treatments where difference was deemed significant (p < .05).

# **Results And Discussion**

# **Physicochemical properties**

The proximate compositions of the defatted rain tree pod flour used in this study were as follows: ash  $(3.17 \pm 0.06\%)$ , moisture (9.80  $\pm 0.88\%$ ), crude fat (2.37  $\pm 0.54\%$ ), crude fiber (6.87  $\pm 0.39\%$ ), crude protein (18.56  $\pm 0.19\%$ ), and carbohydrate (59.24  $\pm 1.63\%$ ). The proximate composition of the composite flour samples is shown in Table 2. There was no difference in significance (p > .05) in the moisture of T0 and five of the blends T1, T3, T4, T5, and T6. However, T2 was significantly different (p < .05) from T0. The moisture contents (on wet basis) of all the blends ranged from 8.37% to 9.47%, with sample T0 (0% rain tree pod flour) having the highest moisture content (10.00%), while T6 (30% rain tree pod flour) had the lowest value (8.37%). The moisture content of the composite flours was lower than the wheat flour (T0) and would be due to the efficiency of the drying method used. The relative low moisture composition enhances storage stability and prolongs the shelf life. However, lower moisture content was reported in malted sorghum-soy flour mixes (5.66% – 6.76%). <sup>[22]</sup> The moisture content of all the wheat-rain tree pod flour composite flour reported in this study is within the recommended moisture content of dried food where flour specification states, moisture less than 14% can be stored for long period, resisting micro-organism, or mold attack. <sup>[4]</sup>

The ash content presented in Table 2 differs significantly (p < .05) among the composite flours and control. The ash content of the composite wheat-rain tree pod flour increased with increasing substitution of the rain tree pod flour. The ash content ranged from 0.80% to 1.42% with T6 (30%) having the highest value (1.42%), while T1 recorded the lowest (0.85%). The increase in the inorganic content of the composite flour may be attributed to the higher mineral content of to the rain tree pod flour (3.17%) (Table 2). The ash content (0.80–1.42%) of the composite flour reported in this study was lower than 2.5% for chickpea flour, 6.51% for Jack bean, 4.58% for pigeon pea, 4.73% for cowpea, and 2.53% mung bean.<sup>[23]</sup> The ash content of a food material could be used as an index for mineral constituents of the food product<sup>[24]</sup> hence, the inclusion of rain tree pod in wheat flour increased the ash content.

Parameter	T0	T1	T2	T3	T4	T5	T6
	0%	5%	10%	15%	20%	25%	30%
Ash (%)	0.45	0.80	0.93	1.12	1.15	1.3	1.42
	±0.05 <sup>e</sup>	±0.05 <sup>d</sup>	± 0.08 <sup>d</sup>	±0.08 <sup>c</sup>	±0.05 <sup>bc</sup>	±0.50 <sup>ab</sup>	±0.08 <sup>a</sup>
Moisture (%)	10.0	9.32	8.72	9.42	9.22	9.47	8.37
	±0.5 <sup>a</sup>	±0.08 <sup>ab</sup>	±0.2 <sup>bc</sup>	±0.08 <sup>ab</sup>	±0.10 <sup>ab</sup>	±0.55 <sup>ab</sup>	±0.13 <sup>ab</sup>
Crude Fat (%)	1.88	1.25	1.45	1.33	1.35	1.3	1.27
	±0.18ª	±0.05 <sup>b</sup>	±0.10 <sup>b</sup>	±0.10 <sup>b</sup>	±0.05 <sup>b</sup>	±0.10 <sup>b</sup>	±0.12 <sup>b</sup>
Crude Fiber	0.49	0.32	0.62	0.78	1.12	1.23	1.35
(%)	±0.03 <sup>de</sup>	±0.04 <sup>e</sup>	±0.04 <sup>cd</sup>	±0.10 <sup>c</sup>	±0.08 <sup>b</sup>	±0.08 <sup>ab</sup>	±0.04 <sup>a</sup>
Crude Protein (%)	10.67	12.84	13.14	13.46	14.07	14.55	14.89
	±0.15 <sup>e</sup>	±0.32 <sup>d</sup>	±0.11 <sup>cd</sup>	±0.11 <sup>c</sup>	±0.11 <sup>b</sup>	±0.11ª	±0.06ª
Carbohydrate	76.51	75.47	75.14	73.89	73.08	72.13	72.7
(%)	±0.20ª	±0.18 <sup>b</sup>	±0.30 <sup>b</sup>	±0.21 <sup>c</sup>	±0.13 <sup>d</sup>	±0.51 <sup>e</sup>	±0.24 <sup>de</sup>

Table 2. Proximate composition of composited flours.

Values in a row in with different superscript letters were significantly different (p < .05)

The protein content of the wheat-rain tree pod flours increased with increasing rain tree pod flour inclusion in the blends. Protein content of the flour samples ranged from 12.84% to 14.89% (Table 2). The protein content of the six blends and the T0 (control-100% wheat) (10.67%) were significantly different (p < .05) from each other. Among the composite flour, T6 (30% rain tree pod flour) had the highest protein content (14.89%), while the lowest value (12.84%) was observed in T1 (5% rain tree pod flour). The increase in the crude protein content of the composite flour could be attributed to the high protein content of the rain tree pod flour, which is a legume. Similar studies also reported high protein for wheat soy plantain bread<sup>[7]</sup> and malted sorghum-soy composite flour.<sup>[22]</sup> The high protein content of wheat-rain tree composite flour indicates that wheat flour can be improved, and the composite flour can serve as a cheap protein source addressing the problem of protein-energy malnutrition in Africa among children and pregnant women.

The fat content of the wheat-rain tree pod flour reduced with increasing substitution of the rain tree pod flour (Table 2). The fat content of the composite flour ranged from 1.25% to 1.45%. T2 (10% rain tree pod flour) had the highest, while T6 (30% rain tree pod flour) recorded the lowest (1.25%). The fat content of the composite flours was significantly difference (p < .05) from the control T0; however, there was no difference in significance (p > .05) among the composite flours. The fat content of the composite flours was relatively lower than the wheat flour (1.88%) because defatted rain tree pod flour was used for the blends. The fat content of the wheat-rain tree pod flour obtained in this study was higher to those reported by,<sup>[4]</sup> in wheat -taro corms composite flours (1.12% –1.19%).

The fiber content of the composite flour varied 0.32% to 1.35% (Table 2). T6 (30% rain tree pod flour) had the highest crude fiber (1.35%), while the lowest (0.32%) was recorded for T1 (5% rain tree pod flour). Fiber content were significantly different (p < .05) for the wheat flour T0 and the all six blends, however, there was a higher fiber content in wheat-rain tree pod composite flour than wheat flour (0.49%). This may be as a result of the higher fiber content in the rain tree pod flour. The fiber content (0.32–1.45%) obtained in this study is in line with the fiber content (1.2–1.72%) of rice and soy bean flour blends.<sup>[25]</sup> However, higher fiber content (3.64–4.38%) and (3.3–5.7%) was reported for malted sorghum-soy composite flour<sup>[22]</sup> and wheat-soy composite flour.<sup>[26]</sup> Wheat flour had a significantly lower fiber, hence the inclusion of rain tree pod improves the fiber content, making it useful in food formulation to help relieve constipation.<sup>[23]</sup>

The highest carbohydrate content was observed in T1 (5% rain tree pod flour), while T6 (30% rain tree pod flour) had the lowest value 72.13%. The carbohydrate content of the wheat-rain tree pod composite flour decreased with an increase in the inclusion levels of the rain tree pod flour, while wheat flour T0 was 76.51%. The results in this study are similar to the findings of <sup>[4]</sup> who reported a range of 71.55–73.38% for wheat-taro corms composite flour. The high carbohydrate content of wheat-rain tree pod composite flour is an indication of them being good source of energy for human consumption especially in breakfast, and weaning formulas.<sup>[23]</sup>

The mineral composition (mg/100 g) of the wheat-rain tree pod composite flours is shown in Table 3. The results indicated that potassium was predominant among others ranging from 589 mg/ 100 g to 1343 mg/100 g, while sodium had the least mineral values 37 mg to 102 mg/100 g for all the composite flours.<sup>[27]</sup> reported the potassium content of flours made from cocoyam, Bambara ground-nut, and cassava starch ranged from 117.0 mg/100 g to 149 mg/100 g lower than that recorded in this study.<sup>[7]</sup> reported the sodium content of wheat – cocoyam corms as 32.45 mg/100 g to 124.44 mg/100 g similar to this study. The phosphorus content reported by,<sup>[4]</sup> ranged from147.37 mg/100 g to 181.13 mg/100 g was lower than that obtained in this research. High phosphorus concentrations of the composite flour may be an indication of good quality, promoting proper growth in children. The magnesium and calcium contents recorded in the composite flour in this study are higher than that reported by,<sup>[7]</sup> for composite flour from wheat flour and three cultivars of cocoyam 22.30–26.01 mg/ 100 g and 34.10–40.24 mg/100 g, respectively. Mineral elements in the composite flour may be beneficial to consumers.

1322 👄 N. Y. A. AMANKWAH ET AL.

Table 3. Mineral composition	of th	e flours.
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	TO	T1	T2	T3	T4	T5	T6
Parameter	0%	5%	10%	15%	20%	25%	30%
Phosphorus	311	308	486	531	275	158	430
(mg/100 g)	$\pm 0.0^{d}$	$\pm 0.0^{a}$	$\pm 0.0^{e}$	$\pm 0.0^{a}$	$\pm 0.0^{e}$	±0.0 <sup>f</sup>	±0.0 <sup>c</sup>
Potassium	1167	807	1153	1343	841	589	1150
(mg/100 g)	±0.1 <sup>b</sup>	$\pm 0.0^{\circ}$	$\pm 0.0^{b}$	$\pm 0.0^{a}$	±0.1 <sup>c</sup>	$\pm 0.0^{d}$	±0.1 <sup>b</sup>
Calcium	1040	600	400	570	520	560	810
(mg/100 g)	$\pm 0.0^{a}$	±0.1 <sup>c</sup>	$\pm 0.0^{d}$	±0.1 <sup>c</sup>	±0.0 <sup>c</sup>	$\pm 0.0^{\circ}$	$\pm 0.0^{d}$
Magnesium (mg/100 g)	149	167	168	216	72	120	96
	$\pm 0.0^{b}$	$\pm 0.0^{b}$	$\pm 0.0^{b}$	$\pm 0.0^{a}$	$\pm 0.0^{e}$	$\pm 0.0^{\circ}$	$\pm 0.0^{d}$
Sodium	38	59	59	102	37	38	59
(mg/100 g)	±0.0 <sup>c</sup>	$\pm 0.0^{b}$	$\pm 0.0^{b}$	$\pm 0.0^{a}$	±0.0 <sup>c</sup>	±0.0 <sup>c</sup>	$\pm 0.0^{b}$

Values in a row in with different superscript letters were significantly different (p < .05)

# **Functional properties**

The functional properties of food samples have a significant role in the storage, manufacturing, transportation, taste, and flavor of the food materials.<sup>[28]</sup> According to,<sup>[29]</sup> these properties have direct or indirect dependence on types, varieties, particle sizes, processing method, and chemical composition. The composite flours had varied loose bulk density values (LBD) for the composite flours were 0.50 g/ml to 0.54 g/ml, while the tapped bulk density values (TBD) were 0.71 g/ml to 0.83 g/ml (Table 4). T6 (30%) had the highest LDB, while T1 (5%) had the lowest; however, T4 (20%) had the highest TDB, while T (25%) had the lowest value. The Hausner ratio of the composite flours ranged from 1.32 to 1.59, wheat flour (T0) 1.53. The TBD obtained from this research was similar to that of,<sup>[23]</sup> 082g/ml cowpea and wheat flour, respectively, also, within the range reported by.<sup>[30]</sup> Low bulk density is desired for flour blends because it contributes by lowering dietary bulk and easing packing, selecting suitable packaging material <sup>[31]</sup>. The Hausner ratio of the composite flours was higher than that of the defatted moringa kernel flours,<sup>[17,32]</sup> estimated the flow characteristics of powder and reported a ranged of 1.35 to 1.45 as poor but would be able to flow.

Water absorption capacity (WAC) of the composite flour ranged from 149.74% to 202.97% as in Table 5 with a statistical difference significant (p < .05) among some treatments. The WAC of the composite flour increased with the inclusion of the rain tree pod flour.<sup>[33]</sup> stated that sample having high fiber and starch composition could increase the WAC while,<sup>[34]</sup> attributed the difference in WAC to the variance in the protein concentrations, the extend of water interaction, conformational, and the presence of hydrophobic amino acids that interfered with the ability of starch. <sup>[35]</sup> The WAC of the composite flour obtained in this study is lower than the values (240 ± 0.05–275 ± 0.03%) reported for composite flour made from wheat, breadfruit, and cassava starch.<sup>[36]</sup> Low WAC of the composite flour could be due to the high protein content of the rain tree pod hence improves the textural abilities of the composites.

The oil absorption capacity (OAC) for the composite had no significant (p > .05) difference with a range 137.4% to 163.8% (Table 5). The values obtained from this study were similar to that (143% -204%) reported for wheat, mushroom, and cassava composite flour.<sup>[37]</sup> The

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T0	T1	T2	T3	T4	T5	T6
0%	5%	10%	15%	20%	25%	30%
0.49	0.50	0.53	0.53	0.52	0.53	0.54
±0.02 <sup>b</sup>	±0.02 <sup>ab</sup>	$\pm$ 0.02 <sup>ab</sup>	±0.02 <sup>ab</sup>	±0.02 <sup>ab</sup>	±0.02 <sup>ab</sup>	±0.03 <sup>a</sup>
0.74	0.71	0.80	0.80	0.83	0.71	0.71
±0.03 <sup>b</sup>	±0.03 <sup>c</sup>	±0.03 <sup>ab</sup>	±0.03 <sup>ab</sup>	±0.04 <sup>a</sup>	±0.03 <sup>c</sup>	±0.03 <sup>c</sup>
1.53	1.44	1.52	1.52	1.59	1.34	1.32
±0.11 <sup>ab</sup>	±0.09 <sup>ab</sup>	±0.02 <sup>ab</sup>	±0.10 <sup>ab</sup>	±0.07 <sup>a</sup>	±0.06 <sup>b</sup>	±0.06 <sup>b</sup>
	$\begin{array}{c} T0 \\ 0\% \\ 0.49 \\ \pm 0.02^{b} \\ 0.74 \\ \pm 0.03^{b} \\ 1.53 \\ \pm 0.11^{ab} \end{array}$	$\begin{array}{c c c c c c c c c c c c c c c c c c c $	$\begin{array}{c c c c c c c c c c c c c c c c c c c $	$\begin{array}{c c c c c c c c c c c c c c c c c c c $	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$

Table 4. Bulk densities and Hausner ratio of composite flours.

Values in a row with different superscript letters were significantly different (p < .05)

	T0	T1	T2	T3	T4	T5	T6
Parameter	0%	5%	10%	15%	20%	25%	30%
Water Absorption Capacity (%)	157.0	202.9	149.7	163.0	185.7	182.4	199.7
	±11.0 <sup>cd</sup>	±5.8 <sup>a</sup>	± 9.9 <sup>d</sup>	±15.3 <sup>bcd</sup>	±5.3 <sup>ab</sup>	$\pm 6.4^{\rm abc}$	±9.9 <sup>a</sup>
Oil Absorption Capacity (%)	154.8	137.4	163.1	157.4	152.1	151.1	136.6
	±15.4 <sup>a</sup>	±19.2 <sup>a</sup>	±2.5 <sup>a</sup>	$\pm 0.8^{a}$	±3.0 <sup>a</sup>	±11.1 <sup>ª</sup>	±3.1 <sup>a</sup>
Solubility	7.9	9.1	9.6	10.5	13.0	13.7	15.4
(%)	±0.1 <sup>e</sup>	$\pm 0.0^{d}$	± 0.5 <sup>d</sup>	±0.1 <sup>c</sup>	±0.5 <sup>b</sup>	±0.27 <sup>b</sup>	±0.25 <sup>a</sup>
Swelling Power (SP) (%)	6.7	6.3	6.6	6.5	6.9	6.9	6.7
	$\pm 0.0^{a}$	$\pm 0.0^{b}$	$\pm 0.3^{ab}$	±0.2 <sup>ab</sup>	$\pm 0.0^{a}$	±0.3 <sup>a</sup>	±0.2 <sup>ab</sup>
Foaming	2.22	6.7	4.47	5.9	6.6	6.7	6.7
Capacity (FC) (%)	±0.0 <sup>c</sup>	±0.1 <sup>a</sup>	± 0.0 <sup>b</sup>	±1.3 <sup>a</sup>	±0.1 <sup>a</sup>	$\pm 0.1^{a}$	±0.1 <sup>a</sup>
Foaming Stability (FS) (%)	91.1	93.3	94.5	86.3	94.8	96.6	95.7
after 5 min	±2.4 <sup>ab</sup>	±1.5 <sup>a</sup>	±1.0 <sup>a</sup>	±5.2 <sup>b</sup>	±1.04 <sup>a</sup>	±0.6 <sup>a</sup>	±2.0 <sup>a</sup>

Table 5. Functional properties of composite flours.

Values in row having non-identical alphabets in superscript were significantly different (p < .05).

variation in the OAC values of composite flour might be due to the use of defatted rain tree pod flour. Flours with lower OAC have higher flavor retention abilities.<sup>[38]</sup> Also, a relatively high OAC suggests that it could be useful in food formulations where oil-holding capacity is needed, such as sausage and bakery products.<sup>[23]</sup>

The solubility and swelling power of the composite flour are shown in Table 5, with no significant (p > .005) difference in relation to the blends. The swelling power ranged from 6.3% to 6.96% with T5 (25%) having the highest value and T (5%) recording the lowest value. The observed values were comparably similar to that reported for glutinous rice flours (6.83%–13.26%)<sup>[39]</sup> but lower than flour from cassava and sweet potato cultivars (10.59%–27.53%).<sup>[40]</sup> An increase in WAC increases the swelling power that leads to an increased solubility<sup>[23]</sup>, hence the composite flour could be useful for foods where swelling is required. Solubility values ranged from 9.09% to 15.44% was recorded for the composite flour with T1 (5%) and T6 (30%) had the lowest and highest value, respectively. The solubility of the composite flour increased with increasing addition of rain tree pod flour, due to its protein content. The solubility and swelling power were affected by the ability of sample flour to bind to water. High lipids found in flour reduce WAC of flours hence, reducing the swelling and solubility.<sup>[41]</sup> However, low OAC in this study resulted in high solubility that suggests potential use for baby foods.

The foaming capacity (FC) and stability (FS) after 5 min showed that T6 (30%) the highest FC value, whereas T5 (25%) had the highest FS value (Table 5). The FC of the composite flour increased with increasing inclusion of the rain tree pod flour. Foaming capacity is defined as the ability of a substance in solution to produce foam after shaking vigorously.<sup>[23]</sup> In view of this, high FC might be due to the protein content of the rain tree pod flour. The FC results of flours in this study had low valves compared to cocoyam and cassava starch as 5.1% to 13.75%.<sup>[27]</sup> The FS values for the composite flours are comparably close to those of different Macadamia cultivars reported by.<sup>[18]</sup> The foaming stability of the composite flour was higher than that of wheat flour. An ingredient with high forming capacity is suitable for food products, such as cakes, sponges, ice creams, marshmallows, whipped creams, and bread. However, requiring food ingredients with high food ingredients with low foaming capacity is useful in biscuits, crackers, and cookies. Therefore, the wheat-rain tree pod composite flours could, therefore, be used in the production of biscuits, crackers, and cookies due to their relatively low foaming capacity.<sup>[42]</sup>

# Pasting properties of wheat-rain tree composite flour

The values of the pasting properties of the wheat-rain tree composite flour are presented in Table 6. There was no significant (p > .05) difference in relation to pasting properties among composite flour except in pasting temperature. The peak viscosity ranged from 555.0 RVU to 1527.0 RVU with T6

					14		16
					20%	T5 25%	30%
Parameters	T0 0% (SSF)	T1 5% (SSF)	T2 10% (SSF)	T3 15% (SSF)	(SSF)	(SSF)	(SSF)
Peak Viscosity	780.0	1527.0	1319.0	756.0	646.0	555.0	555.0
(RVU)	$\pm 4.0^{a}$	±16.2 <sup>a</sup>	± 2.5ª	$\pm 9.90^{a}$	±5.66 <sup>a</sup>	±8.5 <sup>a</sup>	±3.5 <sup>a</sup>
Trough Viscosity	665	770	1004.5	583.5	481.5	384.0	460.5
(RVU)	±3.2 <sup>a</sup>	±6.1 <sup>a</sup>	±6.7 <sup>a</sup>	±2.1 <sup>a</sup>	±6.5 <sup>a</sup>	±4.2 <sup>a</sup>	±2.8 <sup>a</sup>
Breakdown	115.0	768.0	315.0	172.5	164.5	171.0	95.0
(RVU)	±7.9 <sup>a</sup>	±10.1 <sup>a</sup>	±18.2 <sup>a</sup>	±7.8 <sup>a</sup>	±0.7 <sup>a</sup>	±12.7 <sup>a</sup>	±2.8 <sup>a</sup>
Final Viscosity	869.0	1141.0	1420.0	845.0	730.0	600.0	610.5
(RVU)	±4.3 <sup>a</sup>	±9.5 <sup>ª</sup>	±2.3 <sup>a</sup>	±11.3 <sup>ª</sup>	±8.5 <sup>a</sup>	±8.5 <sup>a</sup>	±0.7 <sup>a</sup>
Setback Viscosity	204.5	371	416	261.50	248.5	216.0	150
(RVU)	±10.5 <sup>a</sup>	±3.4 <sup>a</sup>	±15.9 <sup>a</sup>	±9.2 <sup>a</sup>	±2.1 <sup>a</sup>	±12.7 <sup>a</sup>	±1.4 <sup>a</sup>
Peak Time	11.1	9.9	10.5	11.1	10.7	11.0	10.7
Min	$\pm 0.6^{a}$	$\pm 0.5^{a}$	±1.3 <sup>a</sup>	$\pm 0.0^{a}$	±0.1 <sup>a</sup>	±0.1 <sup>a</sup>	$\pm 0.0^{a}$
Pasting	90.5	50.7	84.3	90.8	90.80	90.9	90.8
Temperature	±0.6 <sup>a</sup>	±0.2 <sup>b</sup>	±8.5 <sup>a</sup>	$\pm 0.0^{a}$	±0.1 <sup>a</sup>	±0.1 <sup>a</sup>	$\pm 0.0^{a}$
(° <b>C</b> )							

Table 6. Pasting properties of composite flours.

Mean values with different superscripts are different significantly (p < .05)

(30%)/T5(25%) and T1 (5%) lowest and highest values, respectively. It was observed that the peak viscosity decreased with increasing levels of rain tree pod flour (Table 6). The peak viscosity in this study was higher than that reported for wheat, breadfruit, and cassava starch (102.8–123.4 RVU).,<sup>[22, 36]</sup> reported that peak viscosity is the measure of the propensity of starch to form paste during cooking. Hence, relative low peak viscosity of the composite flours (T3 to T6) was a sign that the blends may be excellent for products that require gel strength to be low and elasticity.<sup>[43]</sup>

Trough viscosity of the composite flour ranged from 384.0 RVU-1004.5RVU (Table 6). Trough viscosity is the minimum viscosity at constant temperature phase to withstand breakdown during heating,<sup>[27,44]</sup> reported trough viscosity values for composite flour made from cocoyam and cassava starch (126.5 RVU-176.8RVU) which was lower than that in this study. High trough values indicate low breakdown of starch molecules, hence the composite flours exhibited little breakdown of paste during heating/cooking.

The breakdown viscosity, also known as shearing thinning, exhibited no statistical difference (p > .05) across the samples. Breakdown viscosity is a measure of the extent to which starch disintegrates or the stability of hot paste.<sup>[45–47]</sup> T1 (5%) recorded the highest breakdown viscosity and T6 (30%) had the lowest value. With the exception of T6 (30%) all the composite flours had a higher breakdown viscosity than wheat flour (T1) indicating the inclusion of rain tree pod decreased the gelling stability hence agreed with,<sup>[44]</sup> stating that increasing okra flour in composite of wheat, decreased gelling stability of composite flours. Hence, the composite flour with high breakdown values may be resistant to shear stress and heat <sup>[48]</sup>

Final viscosity (FV) measures the stability of the gelatinized starch and the ability of starch to form a viscous paste on cooling.<sup>[47]</sup> The final viscosity decreased with increasing level of rain tree pod flour inclusion (Table 6). The final viscosity of the composite flours in this study ranged from 600.0 to 1420.0 RVU with T1 (5%) had the highest compared to the control T0 (869.0 RVU). The decrease in the final viscosity of the composite flour might be due to low contention and aggregation of the fragments of amylose,<sup>[36]</sup> high protein, and fiber content.<sup>[44]</sup> The high final viscosity of the composite flours T1 (1141.0 RVU) and T2 (1240.0 RVU) indicates that they may be excellent and acceptable for various food products which require high viscosity and gels not to break.<sup>[49]</sup> The increase in their final viscosity might be due to the aggregation of amylose molecules that indicates quick retrogradation. However, T3-T6 composite flour may be suitable for products that require low viscosity.

The setback viscosity (SV) of the composite flour ranged from 150 to 416.0 RVU with T2 (10%) having the highest value and T6 (30%) the lowest value. The setback viscosity decreased with increasing level of rain tree pod flour. The setback viscosity reported by,<sup>[28]</sup> ranged from 402.6 RVU to 413.4 RVU for *Brachystegia* 

*spp.* was higher than that obtained in this study. However, low setback viscosity values during cooling of paste indicate more resistance to retrogradation and high stability<sup>[50]</sup> hence T6 (30%) may indicate excellent resistance to retrogradation, thus suggesting potential applications in the confectionary industries.<sup>[36]</sup>

The peak time (PT) was considered as an indicator for cooking time<sup>[22]</sup> by measuring the time it takes to cook a sample.<sup>[51]</sup> The PT data showed no significant difference (p > .05) between composite flours (Table 6). T3 (15%) had the highest PT similar to the control T0, while T1 (5%) had the lowest value. The PT generally decreases in composite flours, which could be attributed to the substitution with rain tree pod flour. Flours having short peak time have lower resistance to swelling; hence, swelling rapidly is expected to make the flours prolong to concurrent shear-induced disintegration.<sup>[6]</sup> The PT values for the wheat-rain tree pod composite flour (9.87–11.07 min) were higher than that reported for flours made from wheat and okra (5.17–6.6 min).<sup>[44]</sup> The composite flours in this study had moderate peak times making them not susceptible to mechanical damage during cooling.

The pasting temperature of the composite flour ranged from 50.7°C to 90°C with T1 (5%) having the lowest value and significant difference from all the blends including the control T0 (Table 6). Pasting temperature provides an indication of the minimum temperature required to cook the flour.<sup>[52]</sup> The lower the pasting temperature, the easier the flour forms paste in hot water at boiling point making it cost saving. Hence, T1 (5%) may have this advantage over the others, thus saving the energy cost of preparing the product.

# Conclusion

The substitution of the wheat flour with rain tree pod flour influenced the nutrient, mineral, functional, and pasting characteristics. The wheat-rain tree composite flour produced in this study was found to be nutritionally superior (in terms of protein, ash, and crude fiber) to the wheat flour. The mineral composition (magnesium, sodium, phosphorus, and potassium) of the wheat flour were improved with the inclusion of the rain tree pod flour. T3 (15%) composite flour provided significantly higher amounts of mineral and proximate composition relative to the control (T0)/wheat flour. The wheat-rain tree pod flour shows good potential for use as a functional agent in bakery products. This study suggests that rain tree pod flour might be useful in the baking industry, especially in Ghana. Hence, further studies need to be conducted on toxicity, sensing and levels of inclusion for product development.

#### **Disclosure statement**

No potential conflict of interest was reported by the author(s).

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- 1326 🛞 N. Y. A. AMANKWAH ET AL.
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