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# Physical, Chemical and Functional Properties of Flakes from Coconut Flour

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ABSTRACT

Coconut flour is the pulverized residue obtained after the extraction of milk from coconut copra, regarded as coconut waste. The objective of this study was to find a use for this underutilized industrial waste by producing flakes from coconut flour using different binding agents and to evaluate their physical, functional and chemical properties. Coconut flour was produced from coconut copra, followed by processing of six batches of coconut flakes with different binders (xanthan gum, guar gum, ofor seed gum, achi seed gum and cassava starch) and a control sample with no binding agent. The proximate composition, mineral content, caprylic acid, colour and functional properties of the coconut flake samples were evaluated using standard methods. The crude protein, ash, crude fat, crude fibre and moisture content of the coconut flakes ranged from 8.46-10.21%, 1.01-1.40%, 0.94-0.99%, 2.55-2.82% and 1.89-2.45% respectively. The binding agents had a significant effect in retaining the aroma compound (caprylic acid) of the coconut flakes (1.48 - 2.45%), compared with the sample without a binding agent (1.37%). The calcium, iron, magnesium and sodium content in coconut flake samples ranged from 2.71 to 4.52 mg/100g, 1.57 to 2.06 mg/100g, 9.58 to 10.53 mg/100 g and 502 – 943 mg/kg respectively. The binding agents had no significant effect on the bulk density (0.13 to 0.15 g/cm3), but significantly increased the water absorption capacity of the coconut flakes from 78.23% to 126 – 164%. The L*, a* and b*colour parameters of the coconut flakes ranged from 72.41 to 93.38; -0.12 to +4.89 and 10.04 to 21.95 and the colour difference (delta Chroma), colour intensity and hue angle varied from 1.90 to 12.07, 6.75 to 24.17 and 77.13-91.44 respectively. This study showed that coconut flakes, a nutritious and less dense meal can be produced from coconut flour with or without a binding agent, which could serve as a breakfast meal or snack.

## Introduction

Coconut (*Cocos nucifera*) is one of the world's most valuable palm, as evidenced by many traditional uses of the kernel which ranges from food to cosmetics (Glynis, 2013). According to Chan et al. (2006) coconut is referred to as the 'tree of life' by most smallholder farmers, as it forms an important source of income and nutrition. Peris et al. (2000) reported that more than 70% of the world's coconut products contribute to the nutrition of peasant households, whether directly or indirectly. This means it can contribute to alleviating the problem of nutritional deficiencies when substituted with staple foods, as it is high in fat, fibre and other nutrients, including micronutrients (Abioye, 2018). Ramaswamy (2014) referred to coconut as a 'functional food' for its many health benefits in addition to its nutritional content (fat and protein).

The most nutritious part of the coconut plant is the whitish coconut kernel. The coconut kernel can be processed into desiccated coconuts (Muralidharan and Jayashree, 2011), coconut milk (Fife et al., 2011), virgin coconut oil (Divina et al., 2016) and others,

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including roasted coconut and sugar coated-coconut chips. Coconut milk and coconut oil production involve the milling and extraction process, with or without heat application (Abioye, 2018) and the residue is the shaft. Processing of coconut shaft into coconut flour helps to find a use for the waste produced from industrial coconut kernel processing. Caprylic acid, known as octanoic acid, C8:0 is of the class of medium-chain saturated fatty acids (MCFAs) and is found in varieties of lipid sources including palm kernel, dairy products and coconut oil. It is one of the flavour compounds in coconut. MCFAs are known to be beneficial to human health and nutrition (Zhang et al., 2019).

Breakfast meal has been referred to as the most important meal of the day by nutritional experts. People who omit this meal are most likely to have problems with their cardiovascular health (Deedwania and Acharya, 2017; Marangoni et al., 2009). Howarth (1994) described ready-to-eat breakfast cereals as foods that are stable inherently, and with a long shelf-life. In addition to this, they require minimal or no special preparation.

Production of flakes from coconut flour could serve as a means of utilising this waste, which could serve as a ready-to-eat (RTE) breakfast meal or snack. To serve it as a breakfast meal that will be prepared in warm water with (or without) milk and sugar, there may be a need for hydrocolloids to be added. This will serve the role of binding the components, thereby enhancing the rheological properties. Gums or hydrocolloids have been utilised in baked products, beverages and confectioneries as emulsifying and binding agents, serving the role of improvers or monitoring their rheological properties (Sidhu and Bawa, 2002; Calvin, 2016; Baugreet et al., 2018; Kumar et al., 2021). The objective of this study was therefore to find a use for coconut flour by producing coconut flakes using different binding agents (xanthan gum, guar gum, **ofor** seed gum, **achi** seed gum and cassava starch) and to evaluate their nutritional and functional properties.

## Materials and methods

*Materials*

Matured coconut fruits and fresh cassava roots (for cassava starch) were obtained from Odo-ori market, Iwo, Osun state. Xanthan gum, guar gum, **ofor** and **achi** seed gums were obtained from Kosofe market, Lagos. Other ingredients, such as granulated white sugar, salt, water and coconut flavour were purchased in a supermarket in Osun State.

*Methods*

*Preparation of coconut flour*

Coconut flour was processed as described in Figure 1.

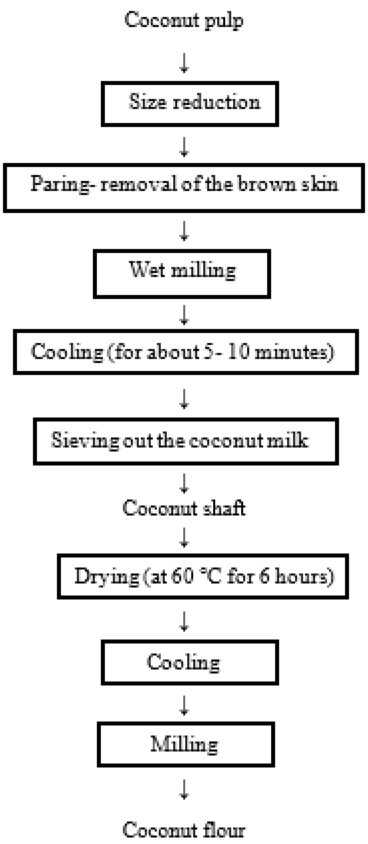



**Figure 1.** Preparation of coconut flour

*Preparation of coconut flakes*

After several trial experiments, the composition of the materials used for the coconut flakes to achieve the desired result of suitable texture, colour and taste using sensory evaluation was: 84.5% coconut flour, 8.5% sugar, 4% binder, 1.2% salt and 1.7% flavour. The ingredients were weighed and mixed with water (about 75% of the weight of the dry ingredients) to form a batter. This was continuously stirred until a smooth batter was formed. The batter was poured to a thickness of 0.25 mm on a pre-oiled oven pan. The pan was transferred into an oven at a temperature of 120 °C until dried, which was then allowed to cool and then packaged. During drying, the batter was marked out in uniform squares (1.5cm by 1.5cm) to form the shape of the desired end product.

*Chemical analysis*

The proximate composition of the coconut flakes was determined according to AOAC (2010): moisture content by oven-drying method, crude protein by the Kjedahl analysis, crude fat by soxhlet extraction, ash content using a muffle furnace, and total carbohydrate, which include soluble fibre, was determined by difference. Bomb calorimeter model method was used to determine the energy value (Passmore and Eastwood, 1986).

Caprylic acid content was determined using gas chromatography-mass spectrometry (GC-MS) by modifying the method of Chen et al. (2009). The peak area and concentrations were computed using a data analysis method developed using different concentrations of standards (octanoic acid).

Mineral content was determined by dry ashing of the sample to prepare the analyte for Absorption Atomic Spectroscopy to determine calcium, iron and magnesium content and flame photometry was used for sodium analysis of the samples (AOAC, 2010).

*Colour and functional properties*

A chroma meter (Konica Minolta, Inc., Japan) was used to determine the colour parameters (L*, a* and b* coordinates) of the samples. The colourimeter was standardized by means of white paper and a black object (Lui-ping et al., 2005). *L (lightness) axis shows- 0 is black, while 100 is white; *a (red-green) axis – positive values are red while negative values are green and 0 is neutral; *b (yellow-blue) axis – positive values are yellow, while negative values are blue and 0 is neutral. Equations i, ii and iii present formulas for calculating the hue angle, delta Chroma (ΔC) and total colour difference (ΔE).

$$\text{Hue angle} = \text{Tan}^{-1}\frac{b*}{a*} \quad \text{(i)}$$

$$\Delta C = \sqrt{[(\Delta a*)^2 + (\Delta b*)^2]} \quad \text{(ii)}$$

$$\Delta E = \sqrt{[(\Delta L*)^2 + (\Delta a*)^2 + (\Delta b*)^2]} \quad \text{(iii)}$$

Bulk density and water absorption capacity of the coconut flake samples were determined by the methods of Asoegwu et al. (2006) and Deshpande and Poshadri (2011) respectively.

Data analysis

Data analysis was done using SPSS package V16 for analysis of variance (ANOVA) and separation of means of replicate results.

## Results and discussion

*Chemical properties*

The proximate composition of the coconut-based flakes is presented in Table 1. The moisture content ranged from 1.89 to 2.45 %, with no significant ($p > 0.05$) differences among the samples. The low moisture content of the samples indicated that the samples may have a long shelf life, as stability and overall quality of food is affected by the moisture content (Samuel and Otegbayo, 2006). Moreover, extended shelf life is guaranteed if food is stored at a relative humidity of not up to 70% (Carter et al., 2015). The ash content, which signifies the inorganic matter, and mineral content showed significant differences among some of the samples and no significant differences among others, and this ranged from 1.01 to 1.40 %. The obtained ash content for the coconut flakes is similar to the value of 1.05 to 1.98 % for breakfast meals from composite flours of rice, soybeans and defatted coconut flours, as reported by Usman et al. (2015).

The protein content of the samples ranged from 8.46 to 10.21 % (Table 1), with the sample containing xanthan gum as the binder (COX) having the highest protein content of 10.21%, followed by the sample with no binder (CON)- 10.10%. There was no significant difference in the protein content among the samples with xanthan gum, cassava starch and the sample without a binder. These results imply that binding agents, otherwise known as hydrocolloids, had a varying effect on the protein content of the samples. The coconut flake samples had similar protein content to ready-to-eat breakfast cereals from food-grade sorghum (10.30- 16.10 %) (Celis et al., 1996), extruded soy-based high-protein breakfast cereal (8.59 - 11.17 %) (Yeu et al., 2008), as well as partially defatted peanut flour in breakfast cereal flakes (10.66%) (Cheewapramong et al., 2002). United States Department of Agriculture (USDA, 2017) reported higher protein content of 14.3% for coconut flour. The results showed that coconut flakes could be embraced as a nutritious meal or snack of considerably high protein content suitable for children and adults.

Binding agents had no significant effect ($p > 0.05$) on the crude fat content of the samples (0.94 to 0.99 %), with the exception of the sample with guar gum (COG), having significantly the lowest crude fat content (0.94%). The fat contents are similar to those reported for an extruded soy-based high-protein breakfast cereal (1%) (Yeu et al., 2008), extruded breakfast cereal made with corn cones (0.93%) (Cheewapramong et al., 2002), and breakfast cereal made with corn flour (1.22%) (Oliveira et al., 2015). However, Fairchild et al. (1995) reported a lower fat content of 0.4% for guar- wheat flake meals. The low-fat content of the coconut flakes was the result of the processing method, as the extraction of coconut milk to produce the coconut flour resulted in defatting. This makes it a suitable diet for a wide range of people including adults, and also a good factor contributing to the extended shelf life, as the rate of rancidity could be greatly reduced.

The insoluble part of the indigestible component of the carbohydrate, known as crude fibre of the samples ranged from 2.72 to 2.82 % (Table 1), with no significant difference (p > 0.05) between the coconut flake samples. Crude fibre content of 2.89% was observed by Oliveira et al. (2015) for breakfast cereal made from corn flour, and between 2.11 to 3.30 % of fibre for breakfast cereal made from blends of local rice, soybeans and defatted coconut flours (Usman et al., 2015). The total carbohydrate content of the samples ranged from 82.68 to 84.26 %, as the addition of binding agents had a significant effect on the samples. The sample with no binding agent had, by far, the lowest carbohydrate content of 82.68%, while others ranged from 82.98 – 84.26 %, with significant differences among some of the samples. The carbohydrate content reported for breakfast meals varied between 75.95 and 89.32 % for breakfast cereal made from partially defatted flour (Cheewapramong et al., 2002), 8.82 to 12.54 % for extruded soy-based high-protein breakfast cereal (Yeu et al., 2008) and 39.74 to 42.61 % for breakfast cereal made from blends of local rice, soybeans and defatted coconut flours (Usman et al., 2015). Coconut flour carbohydrate content ranging from 49.10 to 59.77 % has been reported (Gunathilake et al., 2009; Makinde and Eyitayo, 2019). The relatively high carbohydrate content in this study signifies that coconut flakes are an energy-giving food.

The caloric values (378.12 to 382.09 kcal/100 g) estimated in the samples showed that xanthan gum had the highest impact on the energy value (382.09 kcal/100 g), while sample COG (with guar gum) had by far the lowest energy content. There were no significant differences among energy content of samples COC, COOF, COA and CON. A similar range of energy content has been reported. Mbaeyi (2005) reported 316.46 – 420 kcal for breakfast cereals made from treated and untreated sorghum and pigeon pea; Adeoye et al. (2019) reported values of 383.99 to 394.03 kcal/g for breakfast cereal from selected Nigerian indigenous food crops; Usman (2012) observed a value of 327.54 to 347.72 kcal for breakfast cereal from blends of African yam bean and defatted coconut and a value of 338 kcal was reported for a popular market breakfast cereal (weetabix). The results showed that coconut flakes are a potential source of low energy-dense food as most other breakfast meals, considering the number of calories presented per 100g, which was greatly influenced by the low-fat content of the flakes. Reports have shown that diets like this help people to reduce the intake of energy without necessarily lowering the amount of food consumed (Ledikwe et al., 2006; Drewnowski et al., 2004), as it has reduced a number of calories available for consumption, thereby helping body with weight management.

**Table 1.** Proximate composition and energy contents of coconut flake samples

| Samples | Moisture content (%) | Ash (%) | Crude protein (%) | Crude fat (%) | Crude fibre (%) | Carbohydrate (%) | Energy value (kcal/100g) |
|---|---|---|---|---|---|---|---|
| COX | 1.89±0.72$^{a}$ | 1.01±0.08$^{a}$ | 10.21±0.36$^{c}$ | 0.97±0.01$^{ab}$ | 2.79±0.37$^{a}$ | 83.13±0.38$^{abc}$ | 382.09±1.92$^{b}$ |
| COG | 2.45±0.31$^{a}$ | 1.40±1.12$^{c}$ | 8.46±0.44$^{a}$ | 0.94±0.03$^{a}$ | 2.80±0.25$^{a}$ | 83.95±0.33$^{cd}$ | 378.12±0.92$^{a}$ |
| COC | 2.31±0.09$^{a}$ | 1.15±0.09$^{ab}$ | 9.75±0.62$^{bc}$ | 0.99±0.00$^{b}$ | 2.82±0.30$^{a}$ | 82.98±0.65$^{ab}$ | 379.85±0.56$^{ab}$ |
| COO | 2.28±0.18$^{a}$ | 1.06±0.03$^{a}$ | 8.70±0.36$^{a}$ | 0.98±0.02$^{b}$ | 2.72±0.01$^{a}$ | 84.26±0.56$^{d}$ | 380.61±0.84$^{ab}$ |
| COA | 2.11±0.17$^{a}$ | 1.29±0.14$^{bc}$ | 9.04±0.37$^{ab}$ | 0.97±0.02$^{b}$ | 2.74±0.10$^{a}$ | 83.84±0.33$^{bcd}$ | 380.30±1.62$^{ab}$ |
| CON | 2.39±0.34$^{a}$ | 1.29±0.04$^{bc}$ | 10.10±0.56$^{c}$ | 0.99±0.01$^{b}$ | 2.55±0.40$^{a}$ | 82.68±0.55$^{a}$ | 379.99±1.75$^{ab}$ |

Values are means of triplicate. Means followed by the same letter across the columns are not significantly different from each other (P > 0.05).
COX- Coconut flakes produced with xanthan gum; COG- Coconut flakes produced with guar gum; COC- Coconut flakes produced with cassava starch; COO- Coconut flakes produced with ofor seed gum; COA- Coconut flakes produced with achi seed gum; CON- Coconut flakes produced with no binder

*Flavour compound in the coconut flake samples*

Caprylic acid content of the coconut flakes ranged from 1.37 to 1.80 %, with a sample COC (with cassava starch) having the highest flavour content (caprylic acid), followed by COX and the sample without additive showing the lowest flavour content. The caprylic acid in coconut flakes is lower than that observed in extracted coconut oil reported by Ibrahim et al. (2019), Boateng et al. (2016) and Arumuganathan (2011), which ranged between 4.6 and 11.72 %. Caprylic acid is one of the most important compounds responsible for flavour in coconut oil. The result could imply that binding agents had a significant effect in retaining the flavour compounds in the coconut flour during processing, as shown by the higher caprylic acid content in the samples with a binding agent. Cassava has been reported to contain certain other fatty acids, mainly ioleic and palmitic acids, and linoleic, linolenic, palmitoleic, stearic, myristic, pentadecanoic, heptadecanoic and nonadecanoic acids in decreasing order, excluding caprylic acid from the list (Ezeala, 2007). With the highest caprylic acid content reported for the sample with cassava starch, it could imply that cassava starch contains traces of caprylic acid, which has contributed to the flavour content of the coconut flakes.

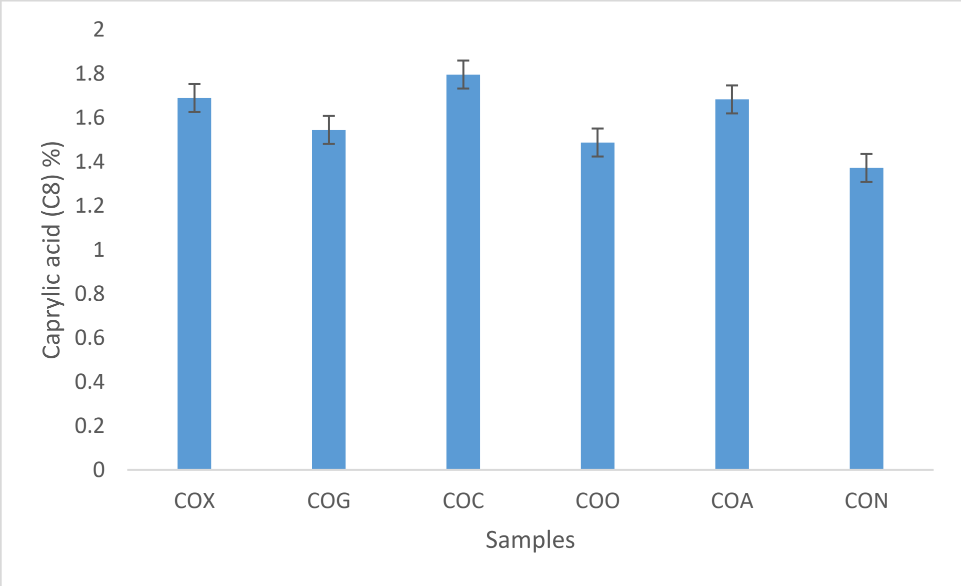



**Figure 1.** Aroma compound in the coconut flake samples
COX- Coconut flakes produced with xanthan gum; COG- Coconut flakes produced with guar gum; COC- Coconut flakes produced with cassava starch; COO- Coconut flakes produced with ofor seed gum; COA- Coconut flakes produced with achi seed gum; CON- Coconut flakes produced with no binder

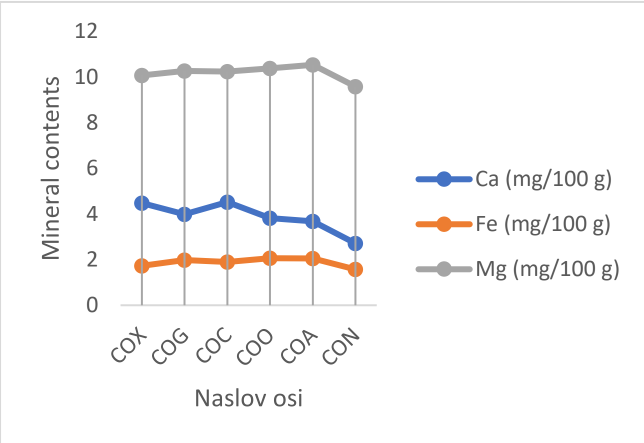
*Mineral content of coconut clake samples*

The calcium, iron and magnesium content of the coconut flakes ranged from 2.71 to 4.52 mg/100 g, 1.57 to 2.06 mg/100 g, and 9.58 to 10.53 mg/100 g respectively (Figure 2a). The results showed that there was no significant difference in the Fe content for all the samples, showing an insignificant effect of the binding agent. However, the magnesium content of the sample without a binding agent (CON) was significantly lower than in the samples with binding agents. Hence, binding agents may have played a role in the retention of magnesium in the coconut meal. USDA (2017) reported higher contents of calcium (57 mg/100 g) and iron (18 mg/100 g) for coconut. The results showed that the sample without a binding agent had the lowest content of magnesium, calcium and iron.
The sodium content was significantly higher in coconut flakes in comparison with other evaluated mineral contents, as it ranged from 502 to 943 mg/kg (Figure 2b). This study showed higher sodium content of coconut flakes, than what was reported by the USDA (2017) for sodium in coconut- 200 mg/100 g, as well as higher than in breakfast cereals samples consumed in large amounts by the Spanish population, which ranged from 44.3 to 819.6 mg/100 g (Villanueva et al., 2000). Reports have shown that these binding agents are considerably high in sodium content. Ofor seed contains 28.29 mg/kg of sodium (Nwokocha and Nwokocha, 2020), xanthan gum was reported by Neimenggu Fufeng Biotechnologies Co. ltd to be close to 1.5g/100 g in sodium content, achi seed contains 24.64 mg/100 g (Ndulaka et al. 2017) whereasguar gum contains 32 mg/100 g of sodium, as reported by MG Ingredients, Brandon. The coconut flake sample without a binding agent was also observed to be high in sodium. These high sodium contents for all the samples could therefore be attributed to the other ingredients that were used in the formulation, especially salt (sodium chloride), which made a significant contribution in adding to the sodium content of the samples.
Generally, coconut is rich in minerals, as it generally thrives in the mineral-rich soil of the tropics and isnaturally fertilized with water containing a complete mixture of trace minerals (Ramaswamy, 2014; USDA, 2017). Minerals are important in maintaining the overall mental, physical well-being and proper development of bones, teeth and muscles (Ohizua et al., 2016). Variations in the mineral content of coconut or coconut-based foods could result from variation in the soil composition of cultivation and varietal differences as it applies to crops (Davidson et al., 2017; Otegbayo, et al., 2017). Other ingredients used in the formulation of the products such as salt (sodium chloride) and binding agents could also be responsible for this variation.

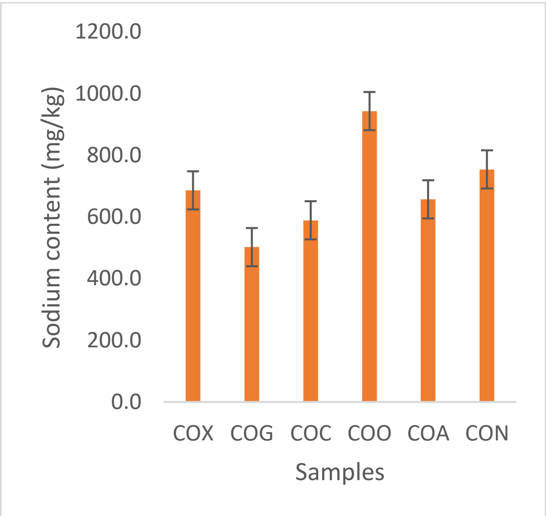
*Functional properties*

The packed bulk density and water absorption capacity of the coconut flake samples are presented in Table 3. The packed bulk density ranged from 0.13 to 0.15 g/cm$^3$ (Table 3) showing no significant differences between COX, COA and CON, but significant differences with others. Higher values of bulk densities for breakfast cereal made from sorghum (1.363 g/cm$^3$ were reported by Celis et al. (1996)) and for extruded cornmeal cereal containing fruit powder (1.00%) (Camire et al., 2007). Inter-particle gaps and intra-particles pores are two factors that contribute to density. The packing fraction of coconut flakes was lower when compared with previous reports of similar products since particles create a more excluded volume effect (Chaikin et al., 2006). This lower bulk density is desired in such a product as this in terms of its utilisation, as it may result to high expansion volume (Sweley et al., 2014).

The water absorption capacity of the samples was significantly affected by the binding agents; the sample without any binding agent had the lowest water absorption capacity of 78.23%, while the water absorption capacity of other samples with binding agents ranged from 126 to 164 % (Table 3). Binding agents increased the ability of the coconut flakes to hold more water, caused by the degree of association of the starch granules in binding agents (Otegbayo et al., 2013). This higher water absorption capacity of the samples with a binding agent would improve the sensory property of the coconut flakes if used as a breakfast meal, thereby increasing satiety and bulkiness, due to the fact that water absorption capacity is an important hydration property, which also causes an increase in swelling power (Akubor and Owuse, 2020). Moreover, coconut flakes without a binding agent could be used as a snack.




a. Ca, Fe and Mg content




b. Na content

**Figure 2.** Mineral content of the coconut flake samples

COX- Coconut flakes produced with xanthan gum; COG- Coconut flakes produced with guar gum; COC- Coconut flakes produced with cassava starch; COO- Coconut flakes produced with ofor seed gum; COA- Coconut flakes produced with achi seed gum; CON- Coconut flakes produced with no binder

**Table 3.** Functional properties of the coconut flake samples

| Samples | Packed Bulk Density (g/cm3) | Water Absorption capacity (%) |
|---|---|---|
| COX | 0.15$^b$ | 151.00$^c$ |
| COG | 0.13$^a$ | 164.00$^c$ |
| COC | 0.13$^a$ | 146.00$^{bc}$ |
| COO | 0.14$^{ab}$ | 126.00$^b$ |
| COA | 0.15$^b$ | 143.00$^{bc}$ |
| CON | 0.15$^b$ | 78.23$^a$ |

COX- Coconut flakes produced with xanthan gum; COG- Coconut flakes produced with guar gum; COC- Coconut flakes produced with cassava starch; COO- Coconut flakes produced with ofor seed gum; COA- Coconut flakes produced with achi seed gum; CON- Coconut flakes produced with no binder

*Colour parameters of coconut flakes*

The Commission Internationale de l'Eclairage (CIE) tristimulus ($L^*$, $a^*$, $b^*$) parameters provided an average evaluation of the colour characteristics of the coconut flakes. The $L^*$ values of the samples were significantly ($p \leq 0.05$) different from one another, and ranged from 72.41 to 93.38 (Table 2). Coconut flake samples prepared without a binding agent (CON) had the highest $L^*$ value, which indicates that it was the lightest sample with a value theoretically close to white (100) while coconut flake samples prepared with achi seed gum (COA) had the lowest value indicating it was the farthest from the white. Hence, the effect of the binding agent in altering the white colour of the coconut flakes. The effect was more pronounced by the darker colour of achi, followed by xanthan gum, ofor seed, cassava starch and the least by guar gum. The $a^*$ varied significantly from -0.12 to + 4.89 (Table 2), with COA having the highest $a^*$ value, indicating higher red- intensity than other samples. The sample with no binding agent had the lowest $a^*$, indicating higher intensity towards green, and lower intensity towards red. This corroborates the result of $L^*$ axis, as shown as its inverse, that is, following a similar trend. The yellow-blue axis ($b^*$) ranged from 10.04 to 21.95, significantly different from each other. The sample without a binding agent had the lowest $b^*$ value, indicating lower yellow intensity, while sample COX (with xanthan gum) had the highest $b^*$ value, which shows higher yellow intensity, followed by COA (with achi seed gum). The calculated values of delta chroma, colour intensity and hue angle varied from 1.90 to 12.07, 6.75 to 24.17 and 77.13 to 91.44 respectively. Delta chroma and total colour difference ($\Delta E$) are measures of differentiating colours between the target samples (COX, COG, COC, COO and COA) and the control sample (CON). The result showed that sample COX and COA, among others, had the highest disparity from CON (the sample without binding agents).

**Table 2.** Colour parameters of coconut flake samples

| Sample | $L^*$ | $a^*$ | $b^*$ | $\Delta C$ | $\Delta E$ | Hue angle |
|---|---|---|---|---|---|---|
| **COX** | $78.49 \pm 0.13^b$ | $2.96 \pm 0.05^e$ | $21.95 \pm 0.10^f$ | 12.07 | 19.17 | 82.32 |
| **COG** | $87.69 \pm 0.36^e$ | $-0.36 \pm 0.02^b$ | $14.29 \pm 0.04^c$ | 4.46 | 7.23 | 91.44 |
| **COC** | $86.00 \pm 0.18^c$ | $-0.12 \pm 0.08^c$ | $16.09 \pm 0.01^d$ | 6.15 | 9.61 | 90.43 |
| **COO** | $86.90 \pm 0.73^d$ | $0.24 \pm 0.02^d$ | $11.79 \pm 0.17^b$ | 1.90 | 6.75 | 88.83 |
| **COA** | $72.41 \pm 0.30^a$ | $4.89 \pm 0.07^f$ | $21.41 \pm 0.11^e$ | 12.02 | 24.17 | 77.13 |
| **CON** | $93.38 \pm 0.30^f$ | $-0.98 \pm 0.05^a$ | $10.04 \pm 0.05^a$ | - | - | 84.43 |

Values are means of triplicate. Means followed by the same letter across the columns are not significantly different from each other ($P > 0.05$).
COX- Coconut flakes produced with xanthan gum; COG- Coconut flakes produced with guar gum; COC- Coconut flakes produced with cassava starch; COO- Coconut flakes produced with ofor seed gum; COA- Coconut flakes produced with achi seed gum; CON- Coconut flakes produced with no binder

## Conclusions

This research has shown that coconut flakes can be produced from coconut flour, which could serve as a breakfast meal (taken with hot milk) or snack (eaten dry). Water absorption capacity was significantly affected by binding agents, making those coconut flakes with binding agents suitable for breakfast meals resulting in increased bulkiness and satiety when consumed. The colour parameters of the coconut flakes were also affected by the binding agents. The use of binding agents had significant effects on the proximate composition, except for the crude fibre content, and also a significant effect in retaining the coconut flavour of the coconut flakes, as shown by the higher caprylic acid content of the samples with binding agents. Hence, the production of coconut flakes with or without binding agents will be dependent on what the flakes are used for and the expected nutritional composition. The use of xanthan gum or guar gum would produce a coconut breakfast meal with higher water absorption capacity, higher retention of flavour compound (caprylic acid) and the lightest effect in terms of colour for the sample with no binding agent, followed by the one containing guar gum.. Coconut flakes help to increase the utilisation of the coconut crop. The composition showed that it is a promising healthy snack or meal, which can be consumed by a wide range of people.

*Author Contributions:* All authors made significant contributions to the success of the research work, from the conceptualisation of the idea to manuscript writing and submission for publication.
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