



## Physicochemical and Functional Quality of Tigernut Tubers (*Cyperus esculentus*) Composite Flour

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### Authors' contributions

All authors contributed equally to this research and manuscript preparation. Authors LAT, AAO, DDB, IKA and EAA designed the study, performed the statistical analysis and wrote the protocol. Author LAT wrote the first draft of the manuscript and managed literature searches. Authors WTT and IDK managed the analyses of the study and literature searches. All authors read and approved the final manuscript.

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### ABSTRACT

**Aims:** To develop composite flour from Ghana's underutilized tigernut and evaluate its physicochemical and functional properties.

**Place and Duration of Study:** Samples for the tigernut composite flour were obtained from the Madina market in Accra, Ghana, in May, 2014. Laboratory and data analyses were done at the Biotechnology and Nuclear Agriculture Research Institution of the Ghana Atomic Energy Commission, Accra- Ghana.

**Methodology:** Tigernut samples were obtained and dried using a hot air oven, soy bean samples were blanched for 30 mins and dehulled before drying with a hot air oven. Soy bean for germination were soaked, drained and spread on a moist cotton cloth and allowed to germinate. Maize samples were roasted in a hot air oven till they became golden brown. All samples were subsequently milled into flour using a hammer mill. Tigernut, soy bean and maize flour were mixed into composite flour

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in seven different percentage ratios. Physicochemical and functional qualities of tigernut tuber composite flour were analyzed using appropriate protocols.

**Results:** There were significant differences in the physicochemical properties of all seven samples of tigernut composite flour. The highest mean value of moisture content recorded was  $6.31 \pm 0.29\%$  however it was within the acceptable range for flour. The highest mean values of total ash, pH and protein content recorded were  $2.47 \pm 0.08\%$ ,  $6.57 \pm 0.01$  and  $11.37 \pm 0.02\%$  respectively. The functional properties had TMS1 recording the highest water absorption capacity mean value of  $14.33 \pm 0.58\%$  and TMS6 recording the highest bulk density and swelling power mean values of  $0.86 \pm 0.03 \text{ g/cm}^3$  and  $5.40 \pm 0.14 \text{ g/g}$  respectively. TMS4 recorded the highest solubility index mean values  $27.00 \pm 2.00\%$ .

**Conclusion:** Different percentage combination of tigernut, soy bean and maize significantly affect the physicochemical and functional properties of its composite flour. Utilization of tigernut in product development can cater for its underutilization and hence reduce its post harvest loses. Further work is however needed to establish its nutritional quality and shelf stability to determine the appropriate percentage combination.

*Keywords: Tigernut; soy bean; composite flour; physicochemical.*

## 1. INTRODUCTION

Tigernut (*Cyperus esculentus*) is a readily available crop in Ghana, however it is underutilized. Baseline surveys conducted by several researchers indicate that tigernut is cultivated in six out of ten regions in Ghana [1,2]. Tigernuts are basically eaten raw and had received very limited value addition or product development. The tubers contain significant amount of protein, fat, minerals, fibre, ash and vitamins [3-5], which can increase the nutritional quality of our diets. In addition, tigernut tubers could be used for the treatment of flatulence, indigestion, diarrheal, dysentery and excessive thirst [6].

Composite flour is flour prepared by mixing or blending cereals, roots, tubers or legume flour at a predetermined ratio. An important motivation for the production of composite foods is to improve nutritional quality. The benefit of producing cereal- legume composite foods may be considered as twofold: First, there is an overall increase in protein content of the composite food as compared to when the cereal forms the base. Second, there is a better amino acid balance due to the contribution of lysine by legume and methionine by cereals. Compositing affects not only nutritional quality but also functional, sensory and phytochemical quality of the final food product [7]. Legumes such as soy bean has been reported to be an excellent source of high- quality protein, low in saturated fat and free of cholesterol, in addition it has a high dietary fibre [8]. Soy bean is a rich source of vegetable protein for all including growing children. However soy bean contains an

appreciable number of anti-nutrients and germination of the seed is reported to be one of the means to reduce them. Germination is a complex metabolic process during which the lipid, carbohydrate and storage proteins within the seeds are broken down in order to obtain the energy and amino acids necessary for the plant's development [9]. Germination modify starch structure thereby reducing "dietary bulk" which is an important factor relating to child feeding [10].

Combinations of local food crops using simple technologies are economical and help meet the body's nutritional needs. Different composition of banana, soy bean and maize using simple technology recorded appreciable levels of minerals, crude protein and carbohydrate as well as low moisture content [11]. The main objective of this study was to develop a composite flour product from Ghana's underutilized tiger nut and evaluate its physiochemical and functional properties.

## 2. METHODOLOGY

### 2.1 Sample Preparation

A 2000 grams of tigernut, maize and soy bean each were purchased from a local market in Accra, Ghana.

#### 2.1.1 Tigernut flour preparation

Tigernut tubers (yellow type) were sorted to remove damaged and other extraneous materials and then washed with portable water mixed with NaCl for decontamination. The tigernut sample

was dried in an air oven at 65°C for 24 hours and then milled into 25 µm particle size flour using the hammer mill. The milled tigernut flour was stored at -4°C till all analyses were done [12].

### **2.1.2 Soy bean flour**

Soy bean was sorted to remove all debris from the beans and washed under running water. The samples were blanched for 30 mins to remove the beany flavour and bitterness from the bean. After blanching, the soy bean samples were drained and put under running water to allow for easy dehulling. Dehulled soy bean samples were dried in a mechanical dryer at 60°C overnight. Dried soy bean samples were milled into 25 µm particle size flour using the hammer mill. The milled soy bean flour was stored at -4°C till all analyses were done.

### **2.1.3 Germinated soy bean flour**

After cleaning and removal of broken seeds and extraneous materials, the soy bean were washed and soaked in 4-times its volume of potable water for 12 hours at 30°C. The seeds were drained, spread on a moist cotton cloth and allowed to germinate at 30±2°C for 72 hours. The germinated soy bean seeds were blanched for 30 mins with portable tap water twice its volume and then dehulled. The dehulled germinated soy beans were dried in an air oven at 65°C for 24 hours and then milled using a hammer mill and sieved through 25 µm aperture size to obtain germinated soy bean flour [13]. The milled germinated soy flour was stored at -4°C till all analyses were performed.

### **2.1.4 Preparation of maize flour**

Maize samples obtained were sorted to remove all debris. The maize samples were roasted in a hot air oven at 80°C till it turned golden brown and cooked. The roasted maize was milled into 25 µm particle size flour using a hammer mill. The milled maize flour was stored at -4°C till all analyses were performed.

### **2.1.5 Composite flour formulation**

Tigernut, soy bean and maize flour samples were mixed in seven different ratios: TMS1, TMS2, TMS3, TMS4, TMS5, TMS5<sub>b</sub>, and TMS6 as shown in Table 1. This was based on a modified FAO/WHO recommendation [14] of soy bean usage in composite flour for children. A total of

500 grams of each formulation was prepared and used for various laboratory analyses.

## **2.2 Physicochemical Properties**

### **2.2.1 Determination of moisture in Tigernut composite flour (air oven method)**

Five grams of the flour samples was weighed into clean dried petri dish according to AOAC method for moisture analysis [15]. The weighed samples were put in an air oven (Gallenkamp 300 series, England) previously heated to 130±30°C. The oven was provided with an opening for ventilation. The samples were dried to a constant weight at a maintained temperature of 130±30°C for a period of 24 hours. The dish was covered while still in the oven and transferred to a desiccator with activated desiccants and weighed soon after reaching room temperature. The petri-dishes with the dried samples were reweighed immediately at the end of the cooling period of 30 mins and the moisture content calculated from the relation:

$$\% \text{Moisture} = \frac{(\text{Weight of test samples} - \text{Weight of sample after drying})}{(\text{Weight of test samples})} \times 100$$

### **2.2.2 Total ash content**

The total ash content of the tigernut flour samples was determined using the dry Ashing method [15]. Two grams of the sample (on dry matter basis) was weighed into a porcelain crucible. The crucibles containing the samples were placed in a high temperature muffle furnace (Carbolite, England) heated to 600°C for 6 hours. The ash content was then determined and expressed as:

$$\text{Percentage ash} = \frac{(\text{Mass of ash})}{(\text{Mass of dry sample})} \times 100.$$

### **2.2.3 pH**

Ten (10) grams of the sample was weighed into a clean, dry erlenmeyer flask and 100 ml distilled water was added. The mixture was shaken until particles were evenly suspended and free of lumps. The mixture was digested for 30 mins with frequent shaking. The mixture was allowed to stand for 10 mins for the particles to settle. The supernatant was decanted into the 250 ml beaker, and the pH was determined using a pH meter [15].

**Table 1. Percentage Composition for formulation of tigernut, soy bean and maize composite flour**

Sample code	Percentage (%) composition		
	Tiger nut flour	Maize flour	Soy bean flour
TMS1	50	25	25
TMS2	60	25	15
TMS3	50	30	20
TMS4	70	20	10
TMS5	30	45	25
TMS5 <sub>b</sub>	30	45	25
TMS6	20	55	25

*TMS- Tigernut, Soy bean and Maize, TMS5<sub>b</sub>- contains germinated soybean flour*

#### **2.2.4 Titratable acidity**

About 10.0 grams of the sample was weighed into a clean, dry Erlenmeyer flask and 100 ml distilled water was added. The mixture was shaken until particles were evenly suspended and free of lumps. The mixture was homogenized for 30 mins with constant shaking. The mixture was allowed to stand for 10 mins for the particles to settle. The supernatant was decanted into the 250 ml beaker and immediately titrated with 0.1N NaOH, using 0.3 ml phenolphthalein. Titratable acidity was expressed as percentage lactic acid [15].

### **2.3 Functional Properties**

#### **2.3.1 Water absorption capacity (WAC)**

Water absorption capacity of the flour samples was determined using the method described by [16] as modified by [17]. About 1.0 grams (db) of the sample was dispersed in 10 ml distilled water and the suspension stirred using a magnetic stirrer for 5 mins. The suspension was centrifuged at 3500 rpm for 30 mins and the supernatant measured in a 10 ml graduated cylinder. The density of the water is taken as 1.0 g/cm<sup>3</sup>. The water absorption capacity (%) was calculated as the difference between the initial volume of water added to the sample and the volume of the supernatant expressed in percentage.

#### **2.3.2 Bulk density**

A calibrated centrifuge tube was weighed and filled with the samples to the 5 ml mark by constant tapping until there was no further change in volume. The contents were weighed and the difference in weight was noted. The bulk density of the sample was calculated by dividing the difference in weight by the volume [18].

#### **2.3.3 Swelling power and solubility**

The swelling power and solubility determinations were carried out based on method described by [19] with slight modifications. One gram of sample was weighed (on dry matter basis) into a previously weighed 40 ml capacity centrifuge tube and 40 ml of distilled water added. The suspension was stirred uniformly and gently to avoid excess force that might rupture the granules. The suspension was heated in a thermostatically controlled water bath at 85°C for 30 mins, with constant stirring. The tubes were removed from the water bath, wiped and allowed to dry and cool to room temperature. The tubes were centrifuged at 2200 rpm for 15 mins. The supernatants were poured into a weighed crucible and evaporated to dryness in an oven at 105°C. The dried supernatant was weighed after cooling and the weight was used to calculate the solubility. The sedimented paste was weighed and the value used to calculate the swelling power.

### **2.4 Data Analysis**

A factorial design was used for the study. Analysis of variance was conducted to assess whether significant ( $p < 0.05$ ) differences exist between the composite samples using Statgraphics centurion software version XVI. The Least Significant Difference (LSD) at 95% confidence level was computed to ascertain the differences between samples.

## **3. RESULTS AND DISCUSSION**

### **3.1 Physicochemical Properties of Tigernut Composite Flour**

Results for the physicochemical properties are presented in Table 2. There were significant ( $P < 0.05$ ) difference in all the data analysed for

the physicochemical properties. Moisture content values ranged from  $5.52 \pm 0.06\%$  to  $6.57 \pm 0.21\%$ , with the highest value recorded for TMS5 and TMS5<sub>b</sub> having the lowest moisture content. TMS5 recorded the highest ash content of  $2.45 \pm 0.05\%$  and the lowest being TMS 5<sub>b</sub> with  $2.05 \pm 0.05\%$  ash content. The highest pH content was recorded in TMS4 having a value of  $6.57 \pm 0.02$  with TMS6 recording the lowest value of  $6.42 \pm 0.01$ . TMS5 had the highest protein content of  $11.37 \pm 0.2\%$  whilst TMS3 recorded  $8.29 \pm 0.02\%$  protein content.

The moisture content of the samples was within the Codex recommendation for flour product of 8% [20]. The low moisture content has a positive effect on shelf stability, as moisture could lead to product spoilage due to oxidation reactions and microbial growth. High moisture content promotes microbial and insect growth which can affect the quality of the tigernut composite flour [21]. TMS5<sub>b</sub> which contain germinated soy bean and 30% tiger nut recorded the lowest moisture content however TMS5 which also contain the same percentage of tigernut recorded the highest percentage moisture. The total percentage Ash contents of the different tiger nut composite flour were high and were significantly different from each other. A similar research work on infant feed based on soy bean seed and tigernut tubers also recorded a similar range of ash content range [22]. The Ash content represents the total amount of minerals present in foods substance after heating. Composite flour generally has high ash content due to the different combination of ingredients [23-25]. TMS3 which had 50% tigernut and 20% soy bean recorded the highest percentage ash content whilst TMS5 with 30% tigernut and 25% soy bean recorded the lowest percentage ash. However TMS5<sub>b</sub> with the germinated soy bean and same percentage composition as TMS5 recorded a high Ash content. Germinated seeds generally absorb

moisture therefore the mineral content of the water can affect the ash content of the germinated seed. The high ash content in TMS3 may be due to the high ratio of tigernut and soy bean to maize as both have been reported to be good source of minerals. The pH content of the flour was within the normal pH range for food. A research study of banana composite flour [11] recorded similar pH values. TMS5 which had 20% soy bean and 30% tigernut had the highest crude protein content, however the same percentage composition but with germinated soy bean recorded a low percentage crude protein. This is a result of the breakdown of storage protein within the seed in order to obtain the energy and amino acid necessary for the plants development [9]. TMS3 recorded the lowest crude protein content, however it had 20% soy bean and 50% tigernut content, TMS4 which had 10% soy bean and 70% tigernut surprisingly had a crude protein content higher than TMS3. TMS4 had 20% maize whilst TMS3 had 30% maize. It's not clear if the maize content contributed to the percentage crude protein content. Germination is reported to increase moisture and crude protein content in germinated seed flour [26-29], however this study recorded otherwise this could be due to the time and temperature of germination and drying method of the germinated soy bean.

### 3.2 Functional Properties of Tigernut Composite Flour

The analysed data for functional properties for all the samples are presented in Table 3 below. There were significant differences ( $P < 0.05$ ) in all the samples for the various analyses for the functional properties except for water absorption capacity of the tigernut composite flour which had no significant difference. TMS1 had the highest water absorption capacity of

**Table 2. Physicochemical properties of tigernut, maize, soy bean composite flour**

Sample code	Moisture (%)	Ash (%)	pH	Protein (%)
TMS1	$5.74 \pm 0.1^{ab}$	$2.35 \pm 0.13^{bc}$	$6.50 \pm 0.12^c$	$10.37 \pm 0.15^b$
TMS2	$6.21 \pm 0.31^{cd}$	$2.35 \pm 0.09^{bc}$	$6.50 \pm 0.02^c$	$9.18 \pm 0.05^d$
TMS3	$6.31 \pm 0.29^{de}$	$2.67 \pm 0.10^d$	$6.46 \pm 0.01^b$	$8.29 \pm 0.02^e$
TMS4	$5.94 \pm 0.23^{bc}$	$2.17 \pm 0.03^a$	$6.57 \pm 0.02^e$	$9.40 \pm 0.22^d$
TMS5	$6.57 \pm 0.21^e$	$2.05 \pm 0.05^a$	$6.54 \pm 0.01^d$	$11.37 \pm 0.02^a$
TMS5 <sub>b</sub>	$5.52 \pm 0.06^a$	$2.47 \pm 0.08^c$	$6.46 \pm 0.01^b$	$9.92 \pm 0.25^c$
TMS6	$6.01 \pm 0.13^{bcd}$	$2.32 \pm 0.03^b$	$6.42 \pm 0.01^a$	$10.57 \pm 0.11^b$
LSD	0.3650	0.1417	0.0127	0.1641

<sup>a-e</sup> Means in a column with different letters are significantly different ( $P < 0.05$ ) from each other. Values are mean  $\pm$  SD of three replicates ( $n = 3$ )

**Table 3. Functional properties of tigernut, maize and soy bean composite flour**

Sample code	Water absorption capacity (%)	Bulk density (g/cm <sup>3</sup> )	Swelling power (g/g)	Solubility index (%)
TMS1	14.33±0.58 <sup>a</sup>	0.78±0.04 <sup>a</sup>	3.98±0.58 <sup>a</sup>	19.67±8.51 <sup>a</sup>
TMS2	14.33±1.53 <sup>a</sup>	0.79±0.03 <sup>ab</sup>	4.80±0.39 <sup>bc</sup>	26.67±2.52 <sup>bc</sup>
TMS3	13.67±1.53 <sup>a</sup>	0.76±0.03 <sup>a</sup>	4.64±0.13 <sup>bc</sup>	18.00±3.61 <sup>a</sup>
TMS4	14.33±1.53 <sup>a</sup>	0.78±0.01 <sup>a</sup>	4.30±0.39 <sup>ab</sup>	27.00±2.00 <sup>c</sup>
TMS5	14.00±2.00 <sup>a</sup>	0.79±0.01 <sup>ab</sup>	4.55±0.28 <sup>abc</sup>	18.50±0.50 <sup>a</sup>
TMS5 <sub>b</sub>	13.67±1.53 <sup>a</sup>	0.84±0.05 <sup>bc</sup>	5.05±0.20 <sup>cd</sup>	20.00±2.65 <sup>ab</sup>
TMS6	12.67±0.58 <sup>a</sup>	0.86±0.03 <sup>c</sup>	5.40±0.14 <sup>d</sup>	16.67±2.08 <sup>a</sup>
LSD	2.4766	0.0495	0.5874	6.8547

<sup>a-e</sup> Means in a column with different letters are significantly different ( $P < 0.05$ ) from each other.  
Values are mean  $\pm$  SD of three replicates ( $n = 3$ )

14.33±0.58% and 12.67±0.058% been the lowest recorded for TMS6. The bulk density values recorded ranged from 0.76±0.03 to 0.86±0.03 g/cm<sup>3</sup>. TMS 6 had the highest swelling power of 5.40±0.14 g/g and a corresponding solubility index value 16.67±2.08% whilst TMS1 had the lowest swelling power of 3.98±0.58 g/g and a solubility index value of 19.67±8.51%.

Water absorption capacity (WAC) indicates the ability of a sample to absorb water. A sample's ability to absorb water is dependent on its protein content [29]. However, WAC mean values obtained were not based on its protein content but might be due to the nature of the starches present [16]. High WAC is also attributed to the loose structure of the starch polymers in the samples whilst low WAC indicates the compactness of the starch structure. The ability of flour to absorb water is reported to have a significant correlation with its starch content [30]. Even though there were no significant differences in the analysed data visual observation of the mean values of all samples showed differences. TMS5<sub>b</sub> which had the same percentage with TMS5 recorded a low WAC mean value, this can be attributed to the modification during germination. TMS6 recorded a low WAC, this can be good for infant feeding as porridge will absorb less water. Bulk density is dependent on the particle size and it's a measure of the heaviness of a flour sample. TMS1,3, and 4 did not show any significant difference between them, statistically. TMS2 and 5 were also the sample however TMS5<sub>b</sub> and 6 were significantly different from all the other samples. The bulk density of the Tiger nut composite flour may be due to the different maize composition. This is because TMS6 which had the highest mean bulk density value had 55% maize composition. TMS5<sub>b</sub> with germinated soy bean flour in its formulation recorded a higher mean value and

was statistically different from TMS5 which had the same percentage composition of tiger nut, soy bean, and maize. Research work [31], on germinated wheat flour indicated that bulk density increased with wheat germination. The lower the bulk density value, the higher the amount of flour particles that can stay together thereby increasing the energy content derivable from such diets [32]. Furthermore, high bulk density limits the caloric and nutrient intake per feed per child and infants are sometimes unable to consume enough to satisfy their energy and nutrient requirements [33]. Apart from its importance in porridge made for complementary diets in infants, the bulk density is also important in flour foods production, packaging requirement and material handling [34].

Swelling Power (SP) and Solubility index are inversely related. Solubility index increases with decreasing swelling power. Swelling power is the ability of starch to imbibe water whilst solubility is a measure of the dextrinization of starches. TMS6 which had the highest swelling power recorded the lowest solubility index. However TMS1 recorded the lowest swelling power but not the highest solubility index. The individual samples have their own response to functional and physicochemical properties. This may account for the difference in the values obtained. There were significant differences in the values obtained for both the swelling power and solubility index of the tigernut composite flour. The amount of lipid in a starch sample can affect its swelling power and solubility index. Lipids establish connection with amylose and increase its molecular mass which causes the blocking of the binding water molecules, preventing the swelling of granule and distribution of the amylose [35-38]. Tigernut and soy bean have high fat content, this justifies the values obtained in this present work. TMS6 which recorded the

highest swelling power and solubility index had 20% tigernut and 25% soy bean whilst TMS1 had lower swelling power which was as a result of its 50% tigernut and 25% soy bean content. Germination of soybean affected the swelling power and solubility index of the tigernut composite flour. TMS5 and TMS<sub>b</sub> which had the same percentage composition of the individual samples recorded different swelling power and solubility index mean values and are statistically different. Germination is reported to increase solubility and swelling power. A study on the effect of processing on functional properties of jackfruit seed flour showed that germinated samples recorded the highest mean values for both swelling power and solubility index among five processing methods [39]. Another study reported that germination decreases the water soluble index and swelling power of flours [39]. However differences in swelling power and solubility index of starchy materials can be attributed to starch content, the presence of impurities (e.g. protein and lipids) and pre-treatment and processing history [39,40].

#### 4. CONCLUSION

Results from this study show that different percentage composition of tigernut, soy bean and maize had different physicochemical and functional properties. In this study TMS<sub>b</sub> recorded good physicochemical and function property mean values necessary for porridge making. Tigernut is quite abundant in Ghana, however it is underutilized, hence product development and value addition such as this can help reduce post-harvest losses and also improves the income of tigernut farmers. This research had proven that composite flour can be made from tigernut, however more research into its nutritional, anti-nutritional content and shelf stability should be established.

#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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