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Functional Properties of Seed Flours from Different Cultivars of *Citrullus lanatus* (Cucurbitaceae) Cultivated in Côte d'Ivoire

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Abstract: *The functional properties of four cultivar seed flours from Citrullus lanatus var. citroides (Thumb.) Matsum. & Nakai cultivated in Côte d'Ivoire, were studied in order to explore their potentials in food systems. Unhulled and hulled seeds were obtained from four cultivars namely Wlewle S, Wlewle M, Wlewle B and Bebu. The water absorption capacity (WAC), oil absorption capacity (OAC),foaming capacity (FC) and foam stability (FS) within the range of 191.23 to 254.42%, 107.50 to 140.11%, 3.96 to 5.77% and 39.56 to 52.94%, respectively, varied significantly ($p \leq 0.05$) among the cultivars tested. The levels of bulk density (BD), hydrophilic-lipophilic index (HLI), emulsion activity (EA) and emulsion stability (ES) in the cultivar seeds tested were found to be 0.68 to 0.88 g/mL, 1.36 to 2.14%, 23.48 to 29.99% and 11.53 to 14.67%, respectively. The functional properties of the seed flours analyzed varied significantly ($p \leq 0.05$) with hulling among the cultivars tested. However, C. lanatus seed flours were found to have good functional properties for use in food industry.*

Keywords: *Functional properties, hulled seed, unhulled seed,* Citrullus lanatus*, flours.*

1. INTRODUCTION

Cucurbits are among the most economically important crops worldwide and are grown in both temperate and tropical regions [1]. Cucurbits cultivated for seed consumption are reported to be good source of lipid (~60%) and proteins (~30%) [1]. After the hull is removed, cucurbit seeds contain about 50% lipidand up to 35% proteins[2].

In Sub-Saharan Africa, the indigenous species are prized for their oleaginous seeds that are consumed as thickeners of a traditional soup called *pistachio* soup in Côte d'Ivoire and *egusi* soup in Nigeria and Benin. In Côte d'Ivoire, surveys made in various departments, have allowed to identify five species of *pistachio*: *Citrillus lanatus*, *Cucubita moschata*, *Cucumeropsis mannii*, *Curcumis melo* and *Lagenaria siceraria* [3; 4]. These species are neglected and relegated tominor or orphan crops [5].However, they are rustic plants, characteristics of farming systems that do not use fertilizer or herbicide; which significantly reduces the cost of seeds production and may contribute to their extension[6].

Citrillus lanatus is cultivated in Côte d'Ivoire for its edible kernels which are used as a soup thickener. This soup is highly valued by the Akan during rejoicing times such as new year, births and wedding ceremonies[4]. *Citrillus lanatus* fruits are subdivided into two groups according to the seeds morphology. The first morphotype (*Wlewle*), including three cultivars (defined on the basis of seed size), is characterized by glossy seeds with a tapered proximal extremity. In the second morphotype (*Bebu*), including one cultivar, the seeds have a flat ovoid shape with rugged and thick ends [6].

The seeds are obtained either in hulled or unhulled forms in southern markets and are used greatly in West African cookery [7]. The hulled seeds can be ground or milled before and after roasting used in soups and as soup condiments.

The nutritional properties of flour from *Citrullus lanatus* seeds cultivated in Côte d'Ivoire have been previously reported [1; 2; 8; 9], but no study has been conducted on their functional properties. The current paper focuses on the functional properties of hulled and unhulled seed flours from four cultivars of *Citrullus lanatus*. Indeed, functional properties of foods are intrinsic physicochemical characteristics, which affect the behaviour of protein in food systems during processing, manufacturing, storage and preparation [10]. This project was undertaken to assess the functional properties of four cultivar seed flours from *Citrullus lanatus* in order to determine the suitability or otherwise of this seed in food industry.

2. MATERIALS AND METHODS

2.1. Materials

The seeds of four (4) cultivars from *Citrullus lanatus* var. *citroides* (Thumb.) Matsum. & Nakai have been studied: three (3) named *Wlewle* with different seed sizes, small seeds (*Wlewle S*), medium seeds (*Wlewle M*) and big seeds (*WlewleB*); and one (1) named *Bebu* with thickened margin seeds. The fresh fruit of *Citrullus lanatus* were randomly harvested at maturityfrom an experimental plot located on the site of the University Nangui Abrogoua, Abidjan-Côte d'Ivoire (West Africa). After fermentation, seeds were extracted, washed and sun-dried. The cleaned dried seeds were hulled or not and finally ground prior to analysis.

All other chemicals and reagents used were of analytical grade and purchased from Sigma Chemical Co. (St. Louis, MO).

2.2. Methods

2.2.1. Water Absorption Capacity

The water absorption capacity (WAC) of flours was evaluated according to the method of [11]. Exactly 2 g of flour ($M0$) were mixed with a 20 mL of distilled water in a centrifuge tube and shaken for 30 min in a KS10 agitator. The mixture was kept in a water-bath (37°C) for 30 min and centrifuged (Bioblockscientific, France) at 5000 rpm for 15 min. The resulting sediment ($M2$) was weighed and then dried at 105°C to constant weight ($M1$). The WAC was then calculated as follows:

$$WAC\ (\%) = \frac{M2 - M1}{M1} \times 100 \quad (1)$$

2.2.2. Oil Absorption Capacity and Hydrophilic-Lipophilic Index

The oil absorption capacity (OAC) and hydrophilic-lipophilic index (HLI) of flours were assayed according to [12] and [13] methods, respectively. One (1) g of flour ($M0$) were mixed with a 10 mL of oil. The mixture was shaken for 30 min in a KS10 agitator and centrifuged (Ditton LAB centrifuge, UK) at 4500 rpm for 10 min. The resulting sediment ($M1$) was weighed and the OAC was then calculated as follows:

$$OAC\ (\%) = \frac{M1 - M0}{M0} \times 100 \quad (2)$$

while HLI was determined as the ratio of WAC to that of OAC:

$$HLI\ (\%) = \frac{WAC}{OAC} \times 100 \quad (3)$$

2.2.3. Emulsion Activity and Emulsion Stability

Emulsion activity (EA) and stability (ES) were determined according to the method of [14]. Three (3) g of sample was blended with 25 mL distilled water for 30 s in an electric blender at the maximum speed. Fifty (50) mL of corn oil was then added to the flour suspension, and homogenized for a further minute. The emulsions were centrifuged in 50 mL graduated centrifuge tubes at 1500 rpm for 5min and the volume of the remaining emulsion was measured. Emulsion activity (EA) was calculated as follows:

$$EA\ (\%) = \frac{Volume\ of\ emulsified\ layer}{Volume\ of\ whole\ layer\ in\ centrifuge\ tube} \times 100 \quad (4)$$

To determine the emulsion stability (ES), emulsions prepared by the above procedures were heated at 85°C for 15 min, cooled to room temperature and centrifuged at 1500 rpm for 5 min. The ES was calculated as follows:

$$ES\ (\%) = \frac{Volume\ of\ remaining\ emulsified\ layer}{Original\ emulsion\ volume} \times 100 \quad (5)$$

2.2.4. Foaming Capacity and Stability

The foam capacity (FC) and stability (FS) of flours were studied by the method of[15]. Five (5) g of flour sample were transferred into clean, dry and graduated (250 mL) cylinders. The flour samples were gently leveled and the volumes noted. Distilled water (100 mL) was added to each sample; the cylinder was swirled and foam volumes were recorded after 30 s. The FC was expressed as percent increase in foam volume measured after 30 s, and FS was determined by measuring the FC after standing for 10, 30 and 60 min.

$$FC\ (\%) = \frac{Volume\ after\ homogenization - Volume\ before\ homogenization}{Volume\ before\ homogenization} \times 100 \quad (6)$$

$$FS\ (\%) = \frac{Foam\ volume\ after\ time\ (t)}{Initial\ foam\ volume} \times 100 \quad (7)$$

2.2.5. Bulk Density

The bulk density (BD) was determined by the method of [16].A specified quantity of the flour sample was transferred into an already weighed measuring cylinder ($W1$). For the packed bulk density determination, the flour sample was gently tapped to eliminate spaces between the flour and the level was noted to be the volume of the sample and then weighed ($W2$). No tapping was made in the case of loosed bulk density and the level was also noted to be the volume of the sample and then weighed. Bulk density was defined as grams per milliliter of the sample.

$$BD\ (g/ml) = \frac{W2-W1}{Volume\ of\ sample} \times 100 \quad (8)$$

2.2.6. Statistical Analysis

All the analyses reported in this study were carried out in triplicates. One-way analysis of variance (ANOVA) was carried out to compare between the mean values of different cultivars of the seeds. Differences in the mean values were determined using Duncan Multiple Range Test at p≤0.05 [17].

3. Results and Discussion

3.1. Bulk Density

Bulk density (BD) is a measure of heaviness of a flour sample[18]. It is important for determining packaging requirements, material handling and application in wet processing in the food industry [19]. BD of the four cultivar hulled and unhulled seed flours from *C. lanatus* are presented in Fig. 1. The results obtained indicate that BD decreased following hulling of seeds, but no significant (p≤0.05) difference was observed among the cultivar seeds. BD of *C. lanatus*culti var seed flours ranged from 0.68 to 0.88 g/mL. Similar results were reported intigernutflour (*Cyperus esculentus*) (0.63 g/cm^3)[20]and in wheat flours (*Triticum aestivum*)(0.80-0.86 g/cm^3)[21]. According to [21], the lower loose BD implies that less quantity of the food samples would be packaged in constant volume thereby ensuring an economical packaging. However, the packaged BD would ensure more quantities of the food samples being packaged, but less economical. Nutritionally, loose BD promotes easy digestibility of food products, particularly among children with immature digestive system.

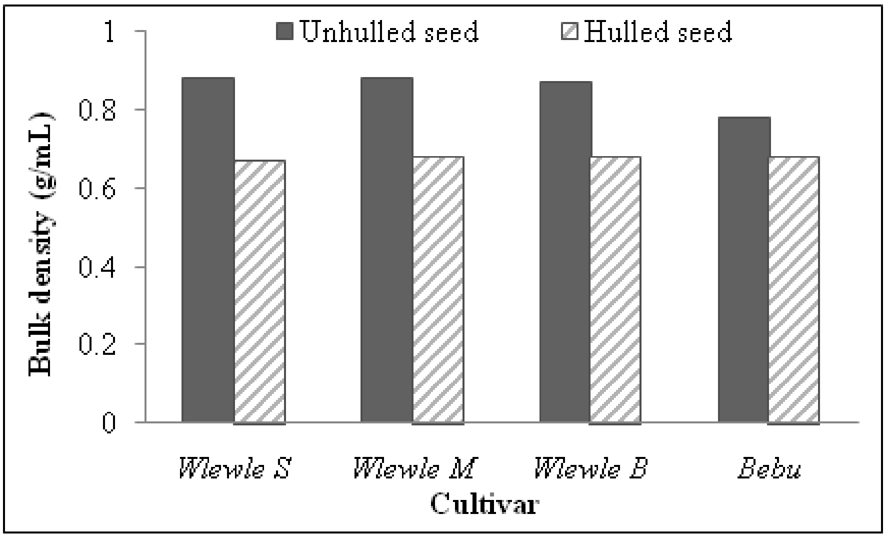

Fig1. *Bulk density of four cultivar seed flours from Citrullus lanatus.*

3.2. Water Absorption Capacity

The water absorption capacity (WAC) is a functional property used in determining the suitability of utilizing a material in baked foods such as bread where high WAC is needed [22]. The WAC of the four cultivar seed flours from *C. lanatus* is shown in Table 1. They were significant ($p \leq 0.05$) differences in WAC among investigated cultivars. Flours from unhulled seed have higher WAC compared with hulled seed samples. The WACs ranged between 191.23 (*Wlewle M*) to 208.42% (*Wlewle B*) for hulled seed and 230.36 (*Wlewle M*) to 254.42% (*Bebu*) for unhulled seed flours. The observed WACs of cultivar seed flours were comparable to those of flours from taro (*Colocasia esculenta*) corms cultivated in Chad (242.45%)[23] and yam “kponan” (*Dioscorea cayenensis-rotundata*) tubers cultivated in Côte d’Ivoire (155.31-351.14%) [22]. This behavior indicates that flours from *C. lanatus* cultivar seeds has more hydrophilic constituents, such as polysaccharides. This pattern is in close conformity with the results of[24]. According to [25], the inherent proteins in cultivar seed flours may also have played some role in the higher WAC.

Table1. *Functional properties of four cultivars seed flours from Citrullus lanatus* [a,b]

Parameter (%)	Cultivars							
	Wlewle S		*Wlewle M*		*Wlewle B*		*Bebu*	
	Unhulled	Hulled	Unhulled	Hulled	Unhulled	Hulled	Unhulled	Hulled
WAC	238.18 ± 1.01^{b}	201.73 ± 1.21^{de}	230.36 ± 3.12^{c}	191.23 ± 0.58^{f}	241.29 ± 1.29^{b}	208.42 ± 1.00^{d}	254.42 ± 4.17^{a}	195.84 ± 3.57^{ef}
OAC	118.16 ± 0.91^{cd}	122.90 ± 1.39^{b}	113.20 ± 1.31^{e}	140.11 ± 0.57^{a}	115.03 ± 1.01^{de}	121.37 ± 1.63^{bc}	107.50 ± 0.78^{cd}	118.58 ± 1.61^{f}
HLI	2.01 ± 0.02^{b}	1.64 ± 0.01^{d}	2.03 ± 0.02^{b}	1.36 ± 0.01^{e}	2.09 ± 0.02^{ab}	1.71 ± 0.03^{d}	2.14 ± 0.02^{a}	1.82 ± 0.05^{c}

[a] *Values given are mean ± standard deviation of triplicate determination. Means with different letters within the same row denote significant differences among cultivars ($p \leq 0.05$).*

[b] *WAC, water absorption capacity; OAC, oil absorption capacity; HLI, hydrophilic-lipophilic index.*

3.3. Oil Absorption Capacity

The oil absorption capacity (OAC) of the four cultivar seed flours from *C. lanatus* are represented in Table 1.OAC is defined as the difference in the flour weight before and after its oil absorption [26]. It is great importance, since oil acts as flavor retainer and also increases soft texture to mouth feel of foods, especially bread and other baked foods [27]. They are also important because of their storage stability and particularly in the rancidity development [28].Significant ($p \leq 0.05$) differences in OAC among investigated cultivars were observed and the maximum OAC was recorded in hulled seed flours. *C. lanatus* flours OAC (107.50-140.11%) were similar to those of flour from Ivorian breadfruit (*Artocarpus altilis*) pulp (95.67-142.65%) [29]. Moreover they were lower than those of flour from Ghanian breadfruit (150-250%) [30].Variations in *C. lanatus* flours OAC might be partially due to the different proportions of non-polar side chains of the amino acids on the surfaces of their protein molecules. Indeed, according to [31], more hydrophobic proteins show superior binding of lipids, indicating that non-polar amino acid side chains bind the paraffin chains of fats.

3.4. Hydrophilic-Lipophilic Index

Among the *C. lanatus* cultivar seeds tested, Table 1 shows that there is no significant ($p \leq 0.05$) difference in hydrophilic-lipophilic index (HLI). *C. lanatus* flours HLI (1.36-2.14%) are higher than those reported for cowpea (*Phaseolus vulgaris*) flour (1.12%) [13], suggesting that *C. lanatus* flour has more affinity for water than for oil. Thus, *C. lanatus* flour could be used in products formulation which require a high WAC.

3.5. Emulsifying Properties

The emulsifying properties are usually attributed to the flexibility of solutes and exposure of hydrophobic domains. Food emulsions are thermodynamically unstable mixtures of immiscible liquids. The formation and stability of emulsion is very important in food systems such as salad dressing[32].Results show no significant ($p \leq 0.05$) difference in emulsifying properties of cultivar seed flours tested. The emulsion activity (EA) and stability (ES) of flours from *C. lanatus* cultivar seeds ranged from 23.48 to 29.99% and 11.53 to 14.67%, respectively (Table 2).These values were lower than those reported in literature [33; 34]. According to [33], the differences among the emulsifying properties are related to the protein contents (soluble and insoluble) and other components (starch, fat…) contents of flour. The capacity of proteins to enhance the formation and stabilization of emulsion is important for many applications in cakes, coffee whiteners, and frozen desserts.

Table2. *Functional properties of four cultivars seed flours from Citrullus lanatus*

Parameter (%)	Cultivars							
	Wlewle S		*Wlewle M*		*Wlewle B*		*Bebu*	
	Unhulled	Hulled	Unhulled	Hulled	Unhulled	Hulled	Unhulled	Hulled
Emulsion activity	28.41 ± 0.46[a]	24.43 ± 0.76[b]	29.99 ± 0.82[a]	23.63 ± 0.34[b]	28.81 ± 0.52[a]	24.22 ± 0.61[b]	23.97 ± 0.68[b]	23.48 ± 0.89[b]
Emulsion stability	14.67 ± 0.37[a]	11.89 ± 0.92[a]	14.25 ± 0.63[a]	11.73 ± 0.87[a]	14.18 ± 0.80[a]	11.53 ± 0.88[a]	11.54 ± 0.77[a]	11.53 ± 0.88[a]
Foam capacity	5.49 ± 0.25[ab]	4.51 ± 0.19[bc]	5.19 ± 0.52[abc]	3.96 ± 0.03[c]	5.77 ± 0.29[a]	4.03 ± 0.19[c]	4.26 ± 0.04[bc]	4.21 ± 0.11[c]
Foam stability	52.94 ± 1.61[a]	42.51 ± 0,73[bc]	50.17 ± 0.06[a]	41.32 ± 0.54[c]	49.64 ± 0.46[a]	45.47 ± 0.36[b]	41.52 ± 0.63[c]	39.56 ± 0.70[c]

Values given are mean ± standard deviation of triplicate determination. Means with different letters within the same row denote significant differences among cultivars ($p \leq 0.05$).

3.6. Foaming Properties

The foaming capacity (FC) of a protein refers to the amount of interfacial area that can be created by the protein and foam stability (FS) refers to the ability of protein to stabilize against gravitational and mechanical stresses [35].In this study, they were significant ($p \leq 0.05$) differences in foaming properties from *C. lanatus* cultivars investigated. Flours from unhulled seed have higher FC and FS compared with hulled seed samples. FC ranged between 4.26 (*Bebu*) to 5.77% (*Wlewle B*) for unhulled seed and 3.96 (*WlewleM*) to 4.51% (*Wlewle S*) for hulled seed flours. However, FS ranged between 41.52 (*Bebu*) to 52.94% (*Wlewle S*) and 39.56 (*Bebu*) to 45.47% (*Wlewle B*)for unhulled seed and hulled seed flours, respectively(Table 2).*C. lanatus* flours FC (3.96-5.77%) were lower than those of cassava pulp flour (13.70%)[27], yam (*D. cayenensis-rotundata*) tuber flour (25.80%) [22]and breadfruit (*A. altilis*) pulp flour (14.51%)[29].Foams are used to improve the texture, consistency and appearance of foods [36]. According to [37], foam formation and stability depend on pH, viscosity, surface tension processing methods and especially on protein. Low foamability on the other hand can be related to highly ordered globular proteins, which resists surface denaturation. The basic requirements of proteins as good foaming agents are the ability to (i) adsorb rapidly at air water interface during bubbling, (ii) undergo rapid conformational change and rearrangement at the interface, and (iii) form a cohesive viscoelastic film via intermolecular interactions. The first two factors are essential for better foamability whereas the third is important for the stability of the foam[35].

4. Conclusion

The result of the study reveals that hulling has significant ($p \leq 0.05$) effect on functional properties of cultivar seed flours from *Citrullus lanatus* grown in Côte d'Ivoire. Unhulled seed flours has higher values than hulled seed flours in its functional properties, excepted for oil absorption capacity where the lower value were recorded. Significant difference ($p \leq 0.05$) were also observed among the cultivar seeds in water and oil absorption capacities, foaming properties, but not in the bulk density, hydrophilic-lipophilic index and emulsifying properties. *Citrullus lanatus* seed flours cultivated in Côte d'Ivoire exhibited highest water absorption capacity and lowest foaming capacity in comparison to other flours. The high water absorption capacity of flours was good providing agent and can thus be used as a thickener or gelling agent in various food products. Based on these results, *Citrullus lanatus* seed flours have a good potential to be used as ingredients in many food products formulation.

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REFERENCES

[1] Loukou A. L., Gnakri D., Djè Y., Kippré A. V., Malice M. J. P. B., Baudoin J.-P. and Zoro Bi I. A., Macronutrient composition of three cucurbit species cultivated for seed consumption in Côte d'Ivoire, African Journal of Biotechnology. 6, 529-533 (2007).

[2] N'guetta A. M. N., Dué E. A., Koné F. M. T., N'guessan E. J. P., Zoro Bi A. I. and Kouamé L. P., Physico-chemical properties and mineral composition of four cultivar seed flours from *Citrullus lanatus* (Cucurbitaceae) cultivated in Côte d'Ivoire, International Journal of Agronomy and Agricultural Research. 6, 45-53 (2015).

[3] Koffi A. M.-H., Atta D. H. and Zoro Bi I. A., Identification of fungus flora associated with *Lagenaria siceraria* (Molina) Standl in Côte d'Ivoire, Asian Journal of Agriculture and Rural Development. 3, 767-779 (2013).

[4] Zoro Bi I. A., Koffi K. K. and Djè Y., Caractérisation botanique et agronomique de trois espèces de cucurbites consommées en sauce en Afrique de l'Ouest: *Citrullus sp*., *Cucumeropsis mannii* Naudin et *Lagenaria siceraria* (Molina) Standl, Biotechnologie, Agronomie, Société et Environnement. 7, 189-199 (2003).

[5] IPGRI. Neglected and underutilized plant species: strategic action plan of the International Plant Genetic Resources Institute (IPGRI). Rome, Italy: IPGRI; pp. 30 (2002).

[6] Zoro Bi I. A., Koffi K. K., Djè Y., Malice M. and Baudoin J. P., Indigenous cucurbits of Côte d'Ivoire: a review of their genetic resources, Sciences et Nature. 3, 1-9 (2006).

[7] Anhwange B. A., Ikyenge B. A., Nyiatagher D. T. and Ageh J. T., Chemical analysis of *Citrullus lanatus* (Thunb.), *Cucumeropsis mannii* (Naud.) and *Telfairia occidentalis* (Hook F.) seeds oils, Journal of Applied Sciences Research. 6, 265-268 (2010).

[8] Gbogouri G. A., Brou K., Linder M., Tehrany E. A., Gnakri D. and Zoro Bi I. A., Comparative study of physicochemical and thermal properties of the seed oils of three cucurbit species, International Journal of Biological and Chemical Sciences. 5, 1165-1177 (2011).

[9] N'guetta A. M. N., Digbeu Y. D., Binaté S., Kouadio J. P. E. N., Dabonné S. and Dué E. A., Fatty acid composition and physicochemical properties of four varieties of *Citrullus lanatus* seed oils cultivated in Côte d'Ivoire, British Biotechnology Journal. 5, 140-147 (2015).

[10] Onimawo I. A. and Akubor P. I., Functional properties of food. In: Food Chemistry, integrated approach with biochemical background. Ambik Press Ltd, Benin City, 208-221 (2005).

[11] Phillips R. D., Chinnan M. S., Branch A. L., Miller J. and McWatters K. H., Effects of pretreatment on functional and nutritional properties of cowpea meal, Journal of Food Science. 53, 805-809 (1988).

[12] Sosulski F. W., The centrifuge method for determining flour absorption in hard red spring wheat, Cereal Chemistry. 39, 344-350 (1962).

[13] Njintang N. Y., Mbofung C. M. F. and Waldron K. W., In vitro protein digestibility and physicochemical properties of dry red bean (*Phaseol*us *vulgaris*) flour: effect of processing and incorporation of soybean and cowpea flour, Journal of Agricultural and Food Chemistry. 49, 2465-2471 (2001).

[14] Naczk M., Diosady L. L. and Rubin L. J., Functional properties of Canola meals produced by a two- phase solvent extraction system, Journal of Food Science. 50, 1685-1688 (1985).

[15] Coffmann C. W. and Garciaj V. V., Functional properties and amino acid content of a protein isolate from *Mung bean* flour, International Journal of Food Science and Technology. 12, 473-484 (1977).

[16] Narayana K. and Rao M. S. N., Effect of partial proteolysis on the functional properties of Winged Bean (*Psophocarpus tetragonolobus*) flour, Journal of Food Science. 49, 944-947 (1984).

[17] Duncan D. B., Multiple range and Multiple F-tests, *Biometrics*. 11, 1-42 (1955).

[18] Adejuyitan J. A., Otunola E. T., Akande E. A., Bolarinwa I. F. and Oladokun F. M., Some physicochemical properties of flour obtained from fermentation of tigernut (*Cyperus esculentus*) sourced from a market in Ogbomoso, Nigeria, African Journal of Food Science. 3, 051-055 (2009).

[19] Shittu T. A., Sanni L. O., Awonorin S. O., Maziya-Dixon B. and Dixon A., Use of multivariate techniques in studying the flour making properties of some CMD resistant cassava clones, Food Chemistry. 101, 1606-1615 (2007).

[20] Oladele A. and Aina J., Chemical composition and functional properties of flour produced from two varieties of tigernut (*Cyperus esculentus*), African Journal of Biotechnology. 6, 2473-2476 (2007).

[21] Steve I. O., Influence of germination and fermentation on chemical composition, protein quality and physical properties of wheat flour (*Triticum aestivum*), Journal of Cereals and Oil seeds. 3, 35-47 (2012).

[22] Koné D., Koné F. M. T., Djè M. K., Dabonné S. and Kouamé L. P., Effect of cooking time on biochemical and functional properties of flours from yam "kponan" (*Dioscorea cayenensis-rotundata*) tubers, British journal of applied science and technology. 4, 3402-3418 (2014).

[23] Mbofung C. M. F., Aboubakar N. Y. N., Abdou Bouba A. and Balaam F., Physicochemical and functional properties of six varieties of taro (*Colocasia esculenta* L. Schott) flour, Journal of Food Technology. 4, 135-142 (2006).

[24] Aremu M. O. Jr., Basu S. K., Gyar S. D., Goyal A., Bhowmik P. K. and Datta Banik S., Proximate composition and functional properties of mushroom flours from *Ganoderma* spp., *Omphalotus olearius* (DC.) Sing. and *Hebeloma mesophaeum* (Pers.) Quel. used in Nasarawa State, Nigeria, Malaysian Journal of Nutrition, 2, 233-241 (2009).

[25] Abou Arab E. A., Helmy I. M. F. and Bareh G. F., Nutritional evaluation and functional properties of chickpea (*Cicer arietinum* L.) flour and the improvement of spaghetti produced from its, Journal of American Science. 6, 1055-1072 (2010).

[26] Giami S. Y., Okonkwo V. I. and Akusu M. O., Chemical composition and functional properties of raw, heat-treated and partially proteolysed wild mango (*Irvingia gabonensis*) seed flour, Food Chemistry. 49, 237-243 (1994).

[27] Ubbor S. C. and Akobundu E. N. T., Quality characteristics of cookies from composite flours of watermelon seed, cassava and wheat, Pakistan Journal of Nutrition. 8, 1097-1102 (2009).

[28] Siddiq M., Ravi R., Harte J. B. and Dolan K. D., Physical and functional characteristics of selected dry bean (*Phaseolus vulgaris* L.) flours, LWT-Food Science and Technology. 43, 232-237 (2010).

[29] Oulaï S. F., Ahi A. P., Kouassi-Koffi J. D., Gonnety J. T., Faulet B. M., Djè M. K. and Kouamé L. P., Treatments effects on functional properties of breadfruit (*Artocarpus altilis*) pulp flour harvested in Côte d'Ivoire, International Journal of Recent Biotechnology. 2, 1-12 (2014).

[30] Appiah F., Oduro I. and Ellis W. O., Functional properties of *Artocarpus altilis* pulp flour as affected by Fermentation, Agriculture & Biology Journal of North America. 2, 773-779 (2011).

[31] Kinsella J. E. and Melachouris N., Functional properties of proteins in foods: a survey, Critical Reviews in Food Science and Nutrition. 7, 219-280 (1976).

[32] Fekria A. M., Isam A. M. A., Suha O. A. and Elfadil E. B., Nutritional and functional characterization of defatted seed cake flour of two Sudanese groundnut (*Arachis hypogaea*) cultivars, International Food Research Journal. 19, 629-637 (2012).

[33] Du S.-k., Jiang H., Yu X. and Jane J.-l., Physicochemical and functional properties of whole legume flour, LWT-Food Science and Technology. 55, 308-313 (2014).

[34] Lestari D., Mulder W. J. and Sanders J. P., Jatropha seed protein functional properties for technical applications, Biochemical Engineering Journal. 53, 297-304 (2011).

[35] Fennema R. O., Food chemistry, (3rd edition). Marcel Dekker, Inc. New York, Basel. Hongkong, 365-396 (1996).

[36] Akubor P. I. and Chukwu J. K., Proximate composition and selected functional properties of fermented and unfermented African oil bean (*Pentaclethra macrophylla*) seed flour, Plant foods for human Nutrition. 54, 227-238 (1999).

[37] Morr C., Current status of soy protein functionality in food systems, Journal of the American Oil Chemists' Society. 67, 265-271 (1990).