Techno-functional properties of three species of Cucurbitaceae consumed in Côte d'Ivoire

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Abstract: The techno-functional properties of flours from 3 cucurbit seeds (defatted and non-defatted) consumed in Côte d'Ivoire, were studied in order to evaluate their potential applications in the food industry. Mature dried seeds of *Citrullus lanatus* sp, *Lagenaria siceraria* Molina Standl, and *Cucumeropsis mannii* Naudin, locally named respectively *Wlewle, Bebou* and *Nviele*, were collected, dehulled and processed for analyses. Standard procedures were used for the determination of their nutritive compounds and functional properties. Bulk density (0.49 to 0.70 g/cm3), emulsion activity (37.34 to 43.03%), emulsion stability (30.09 to 43.88%), water absorption capacity (115.73-203.12%), oil absorption capacity (26.67-135.67%), foaming capacity (7.49-18.33%) and foam stability (13.88-80.27%) varied significantly (p <0.001) among the species studied. Defatting increased water and oil absorption capacities, as well as the foaming capacity, while it decreased loose and bulk densities, the emulsion activity and the foaming stability (p < 0.001). Results show that cucurbit seed flours can be used as ingredients in food formulations and protein biofortification of cereal-based foods and/or high-carbohydrate foods.

Keywords: Techno-functional properties, defatted flours, full-fat flours, cucurbits, *Wlewle, Nviele, Bebou.*

1. Introduction

This last decade estimates indicate that more than half of the world's population suffers from diseases caused by inadequate supplies of minerals, vitamins and essential amino acids (Zhu et al, 2010; Tien Lea et al, 2016). Legume seeds, which constitute an essential part of human diet, are good source of proteins, healthy lipids and bioactive substances (Magalhães et al, 2017; Singh et al, 2017). They represent cheap alternatives of proteins for populations, especially in developing countries where many cannot afford meat or dairy products (Jain, 2004; Jain et al., 2015).

Cucurbits are among the most economically important vegetables in the world. In West Africa, Citrullus lanatus sp, Lagenaria siceraria and Cucumeropsis mannii Naudin are among the Cucurbitaceae species regularly cultivated and consumed by populations (Loukou et al., 2011), for which the seeds occupy an important socio-economic place (Zoro et al, 2006). Seeds of these species are source of living income for small-scale female farmers, and the soups processed from the kernels are very prized for home consumption and during festivities (Zoro Bi et al., 2003). In this soup known as ''egusi'' soup in Cameroon, Nigeria and Benin, and ''pistache'' soup in Côte d'Ivoire, the kernel flour or paste functions as thickening, emulsifying, fat binding and flavoring agent (Enujiugha and Ayodele-Oni 2003; Loukou et al.2007).

Previous studies have reported that the kernel flours are not only rich source of lipids and proteins, but also contained nutritionally important fatty acids and amino acids (Kapseu et al, 1998; Amin et al., 2019). Therefore, some reports suggest the use of cucurbit flours as protein supplement in cereal-based diets or as substitute of animal proteins in conventional foods (Ogunbusola et al, 2010).

The efficient use of legumes or any plant protein or nutrient sources as food supplement or in food product development requires the knowledge of their techno-functional properties (Ogunbusola et al, 2012).

The purpose of this work was to assess the techno-functional properties of full-fat and defatted kernel flours of 3 cucurbits species, namely *Citrullus lanatus* sp, *Cucumeropsis mannii* Naudin and *Lagenaria siceraria* Molina Standl consumed in Côte d'Ivoire.

2. MATERIALS AND METHODS

2.1 Plant material

Mature and dried seeds of 3 cucurbit species *Citrullus lanatus* sp, *Cucumeropsis mannii* Naudin and *Lagenaria siceraria* Molina Standl; locally called *Wlewle, Nviele* and *Bebou* respectively, were used in this study.

2.2 Sampling

Seeds were collected in 3 villages in the Moronou region (East of Côte d'Ivoire). In each village, 3 kg of each seed species were bought from 3 different female farmers, thus, a total of 27 samples weighing 81 kg were collected. Upon arrival to the laboratory, cucurbits seeds were shelled, and a pool of 5 kg sample was used for sample preparation and analysis.

2.3 Sample preparation

Dried seeds were ground into flour using a blender and the flour was divided into 2 equal portions. One portion was sieved to pass through 500 µm mesh size, and the second portion was continuously defatted using soxhlet apparatus for 8 h with n-hexane as solvent. The defatted flour was further milled into fine powder and sieved to pass through 150 µm mesh size. All flours were packaged in airtight containers and kept in cool dry area until used for analysis.

2.4 Proximate analysis

Moisture, total ash, crude fat and crude protein contents were determined using the standard methods of Association of Official Analytical Chemists (AOAC, 2005). Crude protein was determined by the Kjeldahl method and the nitrogen content was converted to protein using a 6.25 conversion factor. Carbohydrate content was determined by difference (FAO, 2002).

2.5 Functional properties

Dispersibility

The dispersibility of flours was determined according to Mora-Escobedo et al. (2005). Ten (10) ml of distilled water was added to 1 g of flour in a graduated cylinder. The mixture was stirred for 2 min and allowed to settle for 30 min. Dispersibility of flours is defined as the difference between the total volume and the volume of the settled particles.

Density

Loose and bulk densities were determined according to the method of Narayana and Narasinga (1982). Ten (10) grams of the sample were put into a 50 ml graduated cylinder and slightly levelled out. The loose volume was recorded for the loose density. The cylinder was then tapped gently (about 30 times) on a laboratory bench until there was no further diminution of the volume. The second volume was recorded for the bulk density. Density was calculated as weight (g) per unit of volume (ml) of sample. Hausner ratio of the flour samples was calculated as a ratio of bulk density to loose density.

Water and oil absorption capacity

Water absorption capacity (WAC) was determined by the method of Sosulski (1962). Two (2) grams of sample were dispersed in 16 mL distilled water. The content was vortexed for 30 sec every 10 min. The operation was repeated 7 times. After seven mixings, the tubes were centrifuged at 2000 x g for 15 min. The supernatant was carefully decanted, then the tube was inverted and drained for 10 min and finally weighed. The water absorbed was expressed as the percentage increase of sample weight. Oil absorption capacity (OAC) of meals was assayed by the method of Sosulski et al. (1962) by dispersing 2 g of sample in 12 mL of sunflower oil in a 15 ml centrifuge tube. Water and fat absorption capacities were expressed as grams of water or oil bound per 100 g of flour.Densities of water and oil were 1 and 0.9 g/mL respectively.

Hydrophilic-Lipophilic Index

The HLI as defined by Njintang et al. (2001) was determined as the ratio of water absorption capacity (WAC) to that of oil absorption capacity (OAC).

*HLI (%) = WAC/OAC * 100*

This ratio allows the evaluation of the affinity of the flour for water or oil.

Emulsifying properties

Emulsion activity (EA) and stability (ES) were determined according to a modified method of Yamasutsu (1972). Fifty (50) ml of 7% of flour suspension was blended for 30 s in an electric blender at the maximum speed. Twenty-five (25) mL of sunflower oil was then added and the mixture homogenized for 90 sec. The emulsion was put in 50 mL graduated centrifuge tubes and centrifuged at 1500 rpm (1100g) for 5 min. Emulsifying activity was calculated as followed:

*EA = (volume of the emulsified layer/ total volume of the emulsion before centrifugation) *100*

Emulsion stability (ES) was determined using emulsions prepared as above. Emulsions were heated for 15 min at 85°C, according to the procedure described by Inklaar and Fortuin (1969). Samples were then cooled to room temperature and centrifuged at 1500 rpm for 5 min. The ES was expressed as the emulsifying activity remaining after heating.

*ES (%) = (Volume of remaining emulsified layer / Original emulsion volume) * 100*

Foaming capacity and foaming stability

Foaming capacity and stability of the flour samples were determined according to Booma & Prakash (1990). A 2% aqueous dispersion of the sample was mixed thoroughly in a kitchen blender for 3 min. The content was immediately transferred into a 250 mL graduated cylinder, and the initial foam volume noted. The suspension est then left on the bench and the foam volume is recorded every 10 min for 120 min. Foaming capacity was expressed as the percentage of foam volume of the dispersion upon blending, while foaming stability was estimated as the relative percentage of volume of foam left after time t.

Foaming capacity FC (%) = (Vol. after whipping - Vol. before whipping/ Vol. before whipping) x 100

*Foam stability FS (%) = (Foam volume after time (t) /Initial foam volume) *100*

Effect of pH on foaming properties

The effect of pH on the foaming properties of the flour was evaluated using the same methodology, after adjusting the pH of the 2% dispersion at pH 2, 4, 6, 8 and 10.

Least gelation concentration (LGC)

LGC was determined according to the method of Chau and Cheung (1998). Different percentages of flour suspensions (4, 8, 12, 14, 16, 18 and 20%) were prepared with distilled water. Five (5) ml of each suspension were transferred in test tubes which were heated at 100°C in a water bath for 1h. Thus, the tubes were cooled down in a cold-water bath (4 ± 1°C) for another hour and then placed upside down. The LGC was the smallest concentration for which the sample did not slide down when the test tube was inverted.

2.6 Statistical analyses

All experiments were conducted in triplicates. Data were submitted to analysis of Variance (ANOVA) using SPSS software (SPSS 22.0, USA). Means were expressed with their Standard Deviation (SD) and compared using Student-Newman-Keuls post-hoc tests at 5% significance.

3 RESULTS AND DISCUSSION

3.1 Proximate analysis

Results for the physico-chemical compositions of the 3 cucurbits species are summarized in Table 1.

Moisture content among species is significantly different (p<0.001). It varied from 2.47% ± 0.12 (Wlewle) to 3.13% ± 0.11 (Nviele). Ash content oscillated between 2.89% ± 0.38 and 3.00±0.33, but no significant difference (p≥0.05) was observed between the three species. Lipid content was statistically different for cucurbits species (P<0.001). *Wlewle* species had the highest lipid content (49.88% ± 0.21) and *Nviele* species the lowest (42.42% ± 0.17). As opposed to lipid content, *Wlewle* had the lowest protein content (30.65%±0.42) and *Nviele* the highest (38.09% ±0.3) (p<0.001). Carbohydrate content was significantly different between species (P=0.04), with values varying from 12.30%±0.95 (*Bebou*) to 14%±0.27 (*Wlewle*).

Defatting affected the proximate composition of flours (p<0.05). Protein and total carbohydrate contents were significantly increased, ranging respectively from 65.52%±0.03 (*Wlewle*) to 68.8% ± 0.09 (*Nviele*), and from 19.96% ± 0.1 (*Bebou*) to 23.13% ± 0.06 (*Wlewle*). The defatting process usually leads to an increase in the main components of foods products (Alobo et al., 2009; Ogunsina et al., 2010; Omowaye-Taiwo et al., 2015; There was no significant difference for the moisture content of defatted flours (p≥0.05).

3.2 Techno-Functional properties

Functional properties of foods are defined as physical and chemical properties reflecting complex interactions between the molecules of a food product based on their composition and structure (Kinsella and Melachouris, 1976 Hussain et al, 2008). Those properties affect the behavior of the food during processing, and also the organoleptic attributes.

Results of the functional properties of full fat and defatted flours of *Nviele, Bebou* and *Wlewle* are summarized in Tables 2 to 4.

Bulk density (BD)

Bulk density of cucurbit flours ranged from 0.47g/ml (WDF) to 0.5 g/ml (NDF) for defatted flours, and from 0.62 g/ml (BF) to 0.7 g/ml (WF) for full-fat flours (Table 2). Defatting significantly decreased (p<0.001) loose and bulk densities; however, no significant difference was observed between defatted flours. This may suggest that the density of cucurbit seeds flours is more dependent on their fat content. BD is an important parameter for food processing, packaging, handling and storage (Ogunsina et al., 2010; Oppong et al., 2015). It is an indicator of heaviness of a flour sample (Adejuyitan et al, 2009; Joy and Ledogo, 2016). The lower the BD, the higher the volume required for packaging (Steve O, 2012). Nutritionally speaking, foods with low BD are more digestible food products, thus, are especially good for children because of their immature digestive system (Brou et al, 2018). On the other side, high density foods could be appropriate for infants weaning.

Hausner ratios of cucurbits varied from 1.52 to 1.85. *Bebou* species had the lowest Hausner ratio in each flour type (defatted or not) (p<0.001). No difference was observed between defatted flours and full-fat flours for each specie (p≥0.05). Hausner ratio less than 1.4 represents good flow properties for foods, making them easy to convey, to blend and to package, and thus, encourages their application in the food industry (Ogunsina et al., 2010; Barbosa-Canovas et al, 2005). The cucurbit seed flours will exhibit poor flow and consequently, will be more compressible. This might be due to the high content in fat of non-defatted flours, and to the fine size of particles in defatted flours upon milling (Shervington and Shervington, 1998).

Our results correlated with those obtained for different cultivars of *Citrullus lanatus* (0.68 to 0.88 g/mL) and *Cucumeropsis mannii* (N'Guetta et al., 2015 and Omowaye-Taiwo et al., 2015); and for full-fat and defatted moringa flours (0.38-0.59 g/ml) (Ogunsina et al., 2010). However, lower values of density for *C. mannii* found in Nigeria (0.42 and 0.25, for full fat and defatted flours respectively) were reported by Ogunbusola et al., (2012).

Dispersibility

Dispersibility is an index indicating the ability of flour particles to easily reconstitute in water (Adebowale et al., 2012); it is a useful functional parameter in the formulation of various food products (Mora-Escobedo et al., 1991). Dispersilibity of cucurbit flours ranged from 54.33±1.15% (WDF) to 90.5±0.87% (BF) (Table 3). Defatted flours had lower dispersibility index as compared to full fat flours. Dispersibility of all the flours were statistically different from each other (p<0.001). Difference between samples might be due to the difference observed in their macromolecule contents. Values obtained were higher than those reported for the heart of palm oil tree (32.1 to 55.61 %) (Brou et al., 2018), but similar to the dispersibiity index of soy-enriched tapioca flours (63 to 87%), and local nigerian rice varieties (58 to 67.5%) (Joy and Ledogo, 2016; Otegbayo et al., 2013). It was reported that flours of higher dispersibility reconstitute easily to give fine consistent dough during mixing (Adebowale et al., 2012; Baranwal et al., 2019). Full fat flours of *Nviele, Bebou* and *Wlewle* will reconstitute easily than defatted ones.

Table 1: Nutritive compounds of full-fat and defatted flours of the 3 cucurbits species

Flours	Species	Moi (%)	Ash (%)	Lip (%)	Prot (%)	Carb (%)
Full-fat	***Nviele***	3.13±0.1 ^{b}	2.89±0.3 ^{a}	42.42±0.17 ^{a}	38.09±0.3^{c}	13.47±0.48 ^{ab}
	Bebou	3.06±0.05 ^{b}	3.89±0.5 ^{a}	44.02±0.19 ^{b}	36.73±0.22^{b}	12.30±0.95 ^{b}
	Wlewle	2.47±0.1 ^{a}	3.00±0.3 ^{a}	49.88±0.21 ^{c}	30.65±0.42^{a}	14.00±0.27 ^{a}
	F_{-value}	37.008	5.214	1302.372	454.871	5.645
	P_{-value}	< 0.001	0.049	< 0.001	< 0.001	0.042
Defatted	***Nviele***	3.94±0.05^{a}	4.36±0.04^{a}	2.14±0.07^{a}	68.8±0.09^{c}	20.76±0.23^{b}
	Bebou	4.01±0.03^{a}	5.88±0.05^{c}	2.23±0.03^{b}	67.93±0.04^{b}	19.96±0.1^{a}
	Wlewle	3.96±0.03^{a}	4.99±0.05^{b}	2.41±0.03^{c}	65.52±0.03^{a}	23.13±0.06^{c}
	F_{-value}	3.627	834.197	29.842	2610.9	370.02
	P_{-value}	0.093	< 0.001	0.001	< 0.001	< 0.001

Means±SD with the same superscripts are not different at 5% significance for each nutritive compound. ***Moi****: moisture content;* ***Ash****: ash content;* ***Lip****: lipid content;* ***Prot****: protein content;* ***Carb****: total carbohydrates content;* ***Wlewle****: Citrullus lanatus* sp; ***Nviele****: Cucumeropsis mannii* Naudin; ***Bebou****: Lagenaria siceraria* Molina Standl; F_{-value}*: value of the statistical Fischer test;* P_{-value}*: value of the statistical probability.*

Table 2: Density properties of cucurbit flours

Flours	Species	Loose density (g.cm^{-3})	Bulk density (g.cm^{-3})	Hausner Ratio
Full-fat	***NF***	0.37±0.02 ^{d}	0.67±0.01 ^{c}	1.74±0.07 ^{b}
	BF	0.41±0.01 ^{e}	0.62±0.03 ^{b}	1.52±0.09 ^{a}
	WF	0.4±0 ^{e}	0.7±0.04 ^{c}	1.83±0.7 ^{c}
Defatted	***NDF***	0.29±0.0^{b}	0.5±0.0 ^{a}	1.85±0.02 ^{c}
	BDF	0.32±0^{c}	0.49±.0.04 ^{a}	1.55±0.09 ^{a}
	WDF	0.25±0.0^{a}	0.47±0.01 ^{a}	1.75±0.02^{b}
	F_{-value}	462.303	48.313	159.013
	P_{-value}	< 0.001	< 0.001	< 0.001

Means±SD with the same superscripts are not different at 5% significance. F_{-value}*: value of the statistical Fischer test;* P_{-value}*: value of the statistical probability.* ***NF, WF, BF****: Nviele, Wlewle and Bebou full-fat flours.* ***NDF, BDF, WDF****: Nviele, Wlewle, Bebou defatted flours*

Water and oil absorption capacities

Results for water absorption capacity (WAC) and oil absorption capacity (OAC) of studied flours are summarized in Table 3. Significant differences were observed for both water and oil absorption capacities (p<0.001). WAC ranged from 114.55±1.78% (WF) to 203.12±6.56% (WDF). There was no significant difference in the WAC of WDF and NDF (p≥0.05). Defatting clearly increased (p<0.001) the WAC of each species. Since lipid molecules are hydrophobic, low lipids level may favor high water binding capacity, which could lead to an increase in the WAC values with defatting. Ended, the WAC values observed for the full fat flours corroborate this statement. NF with the lowest lipid content had the highest WAC value of full fat flours. Moreover, protein content in seeds may also increase the WAC of the flour (Abou et al., 2010). Therefore, the high protein content of NF may also explain its high WAC. Water absorption capacity represents the ability of a product to associate with water under conditions where water is limiting (Singh, 2001). It determines the suitability of the utilization of a food material in the formulation of products where high WAC; for instance in bakeries, sausage, etc. (Chandra et al., 2015; Koné et al., 2014). Adegunwa et al., 2015 stated that high WAC is attributed to loose structure of starch polymers while low value indicates the compactness of the structure. Moreover, it is stated that flours with high WAC have high content of hydrophilic constituents, such as polysaccharides (Aremu et al., 2009). This last statement could explain the increase of WAC of defatted cucurbit flours. The removal of lipids led to an increase in concentration of remaining components, especially proteins and total carbohydrates. Yam variety, *Dioscorea cayenensis rotundata*, from Côte d'Ivoire exhibited WAC values higher than those of the cucurbit samples (155.31 to 351.14%) (Daouda et al., 2014). Our water absorption values are comparable to those of local rice from Nigeria (164 to 214%) (Joy and Ledogo, 2015), and higher than reported by Ogunbusola et al., (2012) on full-fat and defatted flours of *C. mannii* (55 and 125%).

Oil absorption capacity values ranged from 26.67±2.2% (BF) to 33.61±2.68% (NF) for full-fat flours and from 110.56±3.15% (WDF) to 135.66±5.03% (BDF) for defatted ones. No significant difference was observed between the OAC values of the full-fat flours (p≥0.05), however OAC of defatted flours were significantly different from each other (p<0.001). As observed with WAC, defatting increased OAC values of flours. Other authors observed the same phenomenon (Ogunbusola et al, 2012; Ogunsina et al., 2012). Ended, since African cucurbit seeds are oilseeds, they might get saturated with a certain amount of oil. Thus, defatting results in increased ability to absorb oil, hence the increase of the oil absorption capacity. Ogunbusola et al, (2012) obtained higher values of OAC for *C. mannii*. Comparable or higher amount of OAC were also reported for *Citrullus lanatus* (113-140%), *C.mannii* (120-260%) and Ivorian breadfruit pulp (95.67-142.65%) (N'Guetta et al., 2015; Omowaye-Taiwo et al, 2012; Oulaï et al, 2014).

Oil absorption capacity refers to the quantity absorbed by the flour (N'Guetta et al., 2015). Oil helps retain flavors in foods. It also increases soft texture of foods, especially in bakeries (Akobundu, 2009). Differences observed in the OAC of cucurbit flours could be due to the various proportions of nonpolar amino acids on the surface area of their protein molecules, because more hydrophobic proteins show superior binding of lipids (Kinsella and Melachouris, 1976).

The hydrophilic-lipophilic index (HLI) ranged from 1.28 (BDF) to 4.98 (NDF). The HLI of defatted flours (1.28-1.84 %) are comparable to that of *C. lanatus* (1.36-2.14%) (N'Guetta et al., 2015) and a little higher than that of *Phaseolus vulgaris* flour (1.12 %) (Njintang et al., 2001).

Table 3: Dispersibility and water and oil absorption properties of cucurbits flours

Flours	Species	D (%)	WAC (%)	OAC (%)	HLI (%)
Full-fat	***NF***	88±1^{e}	167.46±2.71^{c}	33.61±2.68^{a}	4.98
	BF	90.5±0.87^{f}	145.94±2^{b}	26.67±2.2^{a}	5.47
	WF	85±1^{d}	114.55±1.78^{a}	31.94±3.76 a	3.59
Defatted	***NDF***	68.67±0.58^{b}	197.25±5.69^{d}	122.33±3.21^{c}	1.61
	BDF	79±1.73^{c}	174.25±5.81^{c}	135.66±5.03^{d}	1.28
	WDF	54.33±1.15^{a}	203.12±6.56^{d}	110.56±3.15^{b}	1.84
	$F_{\text{-value}}$	462.303	159.013	655.456	-
	$P_{\text{-value}}$	< 0.001	< 0.001	< 0.001	-

Means±SD with the same superscripts are not different at 5% significance. $F_{\text{-value}}$: value of the statistical Fischer test; $P_{\text{-value}}$: value of the statistical probability. ***NF, WF, BF****: Nviele, Wlewle and Bebou full fat.* ***NDF, BDF, WDF****: Nviele, Wlewle, Bebou defatted.* ***D****: dispersibility;* ***WAC****: Water absorption capacity;* ***OAC****: oil absorption capacity;* ***HLI****: Hydrophilic-Lipophilic Index*

Foaming and emulsifying properties

Results of the emulsifying and foaming properties of cucurbit flours are presented in Table 4.

The foaming capacity (FC) and stability (FS) mostly depend on the interfacial area formed by proteins, stabilizing against gravitational and mechanical stresses, thus maintaining air bubbles in suspensions and slowing down the rate of coalescence (Suresh., 2013). Foaming capacity of cucurbits ranged from 7.49±0.55% (BF) to 18.33±0.58% (NDF); *Nviele* species

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exhibited the highest FC in both flour types and *Bebou* species had the lowest FC values (p<0.001).
Defatting increased the FC values of cucurbits. Sreerama et al., (2012) stated that foaming properties depend on proteins and some other components such as carbohydrates. Defatting increased the protein and carbohydrates concentrations of flours. Thus, the increase of FC following defatting is understandable. Omowaye-Taiwo et al., (2015) and Ogunbusola et al, (2012) observed the same results with *C. mannii* cultivars from Nigeria. Except for BF (13%), foaming stability was high (61 to 80%) for full fat flours. Defatting decreased the foaming stability of cucurbits. This could be due to the structure of protein and the type of amino acids side chain on the surface area, as well as to the pH of suspensions. In both flour types, foam volume reduced drastically after 20-30 mins and collapsed by an hour.

The effect of pH on the foaming capacity of defatted flours was investigated (Figure 1). Foaming capacity of 2% suspensions decreased from pH 2 to 6 and picked up from pH 8 to 10. This was probably due to the effect of pH on proteins function, which is linked to the structure and the interaction between amino-acids.

The emulsion activity (EA) of flours varied from 37.34±0.68% (NDF) to 4303±0.29 % (WF). Emulsion activity of full-fat flours as well as those of BDF and WDF were not statistically different (p≥0.05). But EA of defatted *Nviele* flour was different from the others (p<0.001). Other authors have reported higher emulsion activity for cashew nut (21.7–78.3 %, Fagbemi et al., 2008), and for small red bean and chickpea flours (92.20 and 61.14%, Du et al, 2013). However, EA of cucurbit flours was higher than those reported by N'Guetta et al., (2015) for *C.lanatus* cultivars (23.48 to 29.99%). The formation and stability of emulsion is very important in food systems such as salad dressing.

Table 4: ***Foaming and emulsifying properties***

Flours	Species	EA (%)	ES (%)	FC (%)	FS (%) (30min)	LGC (%)
Full-fat	***NF***	42.99±2.37^{c}	37.96±1.06 ^{d}	13.22±1.41 ^{b}	80.28±2.93^{f}	14
	BF	41.13±0.29^{bc}	43.88±1.47 f	7.49±0.55 ^{a}	61.67±2.89^{e}	10
	WF	43.03±0.55^{c}	35.56±0.62 ^{c}	11.99±0.07 ^{b}	13.89±0.96^{a}	16
Defatted	***NDF***	37.34±0.68^{a}	31.98±1.42^{b}	18.33±0.58 ^{d}	45.08±2.86 ^{d}	16
	BDF	40.39±0.71^{bc}	39.46±1.03^{e}	11.85±0.97 ^{b}	26.19±2.06^{b}	12
	WDF	39.34±0.74 ^{b}	30.09±1.56^{a}	15.53±0.23 ^{c}	20.53±1.98^{c}	12
	F_{-value}	11.555	64.212	66.340	515.13	-
	P_{-value}	0.001	< 0.001	< 0.001	< 0.001	-

Means±SD with the same superscripts are not different at 5% significance. $\boldsymbol{F_{-value}}$*: value of the statistical Fischer test;* $\boldsymbol{P_{-value}}$*: value of the statistical probability.* ***NF, WF, BF****: Nviele, Wlewle and Bebou full fat.* ***NDF, BDF, WDF****: Nviele, Wlewle, Bebou defatted.* ***EA****: Emulsion Activity;* ***ES****: Emulsion Stability;* ***FC****: Foaming Capacity;* ***FS****: Foaming Stability;* ***LGC****: Least Gelation Concentration.*

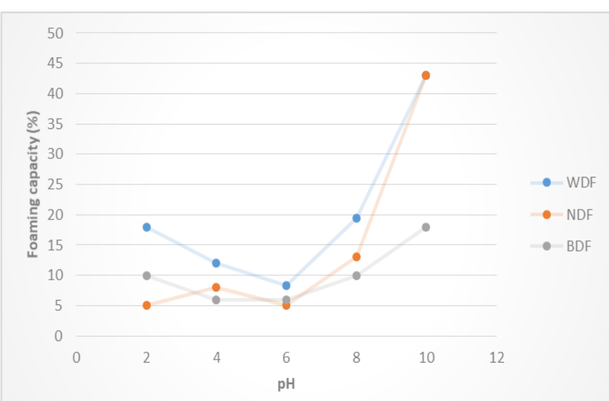

Figure 1: Effect of pH on foam capacity of defatted cucurbit flours.
NDF, BDF, WDF: *Nviele, Wlewle, Bebou* defatted flours.

Least Gelation Concentration (LGC)

LGC represents the lowest concentration at which a flour can form a gel. LGC of cucurbit flours ranged from 10% (BF) to 16% (WF and NDF). Defatting decreased the LGC of *Wlewle* species, while increasing those of *Bebou* and *Nviele.* Generally, beyond the least gelation concentration, higher concentration of suspensions exhibited higher gel strength. That could be due to the decrease in thermodynamic affinity of proteins for the aqueous solution, which increased the interaction between proteins (Aremo and Olaofe, 2007).

3.3. Correlations between the studied variables

Correlations between the biochemical characteristics and the functional properties of the cucurbits samples have also been evaluated by the Pearson r index. Table 5 provides a general trend for all the samples. Significant r values, with p-values of 0.01, were considered over |±0.750|. Thus, the dispersibility, loose and bulk densities and emulsifying activity are positively correlated to lipid content (r≥0.769) and negatively correlated to protein and carbohydrates content. On the other side, water and oil absorption capacities, as well as foaming capacity are strongly negatively correlated to lipids and positively linked to proteins and carbohydrates.

4. CONCLUSION

The results of our study showed that cucurbits flours exhibit functional properties comparable to those of some legume seeds and cereals. Defatting resulted in significant variation of chemical characteristics and techno-functional properties of cucurbit seed flours from Côte d'Ivoire. Defatted seed flours had higher water and oil absorption capacities and foaming capacity values. However dispersibility, bulk density, emulsion capacity and stability and foam stability were decreased by the defatting process. Nevertheless, each flour type could be used in the food processing system, with different applications. They could serve as thickener or gelling agent in various food products. Defatted flours could also be used for protein fortification of cereal-based foods in the food industry.

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Table 5: Matrix of Pearson correlation r of functional and physico-chemical characteristics of the 3 studied cucurbits

	Disp (%)	*Loose density (g/ml)*	*Bulk density (g/ml)*	*WAC (%)*	*OAC (%)*	*EA %*	*FC %*	*Moi (%)*	*Ash (%)*	*Lip (%)*	*Prot (%)*	*Carb (%)*
Disp (%)	*1*											
LD (g/ml)	*0.930***	*1*										
BD (g/ml)	*0.787***	*0.873***	*1*									
WAC (%)	*-0.760***	*-0.902***	*-0.809***	*1*								
OAC (%)	*-0.717***	*-0.862***	*-0.907***	*0.749***	*1*							
EA %	*0.645***	*0.733***	*0.762***	*-0.705***	*-0.721***	*1*						
FC %	*-0.715***	*-0.773***	*-0.477**	*0.668***	*0.603***	*-0.603***	*1*					
Moi	*-0.700***	*-0.879***	*-0.933***	*0.905***	*0.913***	*-0.756***	*0.532**	*1*				
Ash	*-0.540**	*-0.646***	*-0.855***	*0.582**	*0.847***	*-0.532**	*0.151*	*0.817***	*1*			
Lip	***0.795*****	***0.921*****	***0.946*****	***-0.850*****	***-0.980*****	***0.769*****	***-0.625*****	*-0.958***	*-0.838***	*1*		
Prot	***-0.762*****	***-0.906*****	***-0.940*****	***0.855*****	***0.979*****	***-0.782*****	***0.623*****	*0.966***	*0.833***	*-0.998***	*1*	
Carb	***-0.920*****	***-0.958*****	***-0.889*****	***0.801*****	***0.918*****	***-0.700*****	***0.701*****	*0.855***	*0.726***	*-0.949***	*0.928***	*1*

***Moi**: moisture content; **Ash**: ash content; **Lip**: lipid content; **Prot**: protein content; **Carb**: total carbohydrates content; **Disp**: Dispersibility; **WAC, OAC**: water and oil absorption capacity; **EA:** Emulsion activity; **FC**: Foaming capacity, **LD :** Loose density; **BD**: Bulk density.*

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