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Potential Food Value of Watermelon (*Citrullus Lanatus*) Seed Constituents

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Abstract:
Protein malnutrition in the developing countries is of great importance because a large number of people in the part of the world do not have access to cheap protein source. Water melon seeds are reported to be high in protein content, hence the potential of the seed constituents as source of food protein was evaluated.
Flour was prepared from the seeds' constituents of whole seeds, shelled seeds and the shell and the flour evaluated foe proximate composition, functional properties as well as mineral composition using standard methods reported in the literature.
The crude protein of the constituents ranged between 13.31 and 38.92% with the whole meal, having significantly ($p<0.05$) highest value. The fibre content of the shell (30.03%) was significantly highest. The most abundant minerals we magnesium and potassium with values ranging from 86.67 to 109.63 mg/100g. The shell had significantly ($p<0.05$) highest values of water absorption capacity (2.41 g/g) and oil absorption capacity (1.50 g/g) values. The whole meal recorded the highest value of the least gelation concentration (16.0%). The bulk and tapped density values were highest in the shell (0.54 and 0.71 g/cm^3 respectively).
The high values of the protein, fibre, minerals as well as functional properties could make the constituents good source of food supplements.

Keywords: *Potential, food value, constituents, water melon seeds*

1. Introduction

One possible way of achieving nutrition security in developing countries is through exploitation and utilization of available foods sources and resources (Champ *et al.,* 2003). In such countries, plant foods are the most important dietary sources to satisfy individuals' nutrient requirements due to their availability and low cost. Many of tropical plants yield edible fruits whose seeds are often not consumed. The most common problems in food processing is the disposal of the sub-products generated. This "waste material" produces ecological problems related to the proliferation of insects and rodents and an economic burden because of transportation to repositories; therefore strategies for the profitable use of this material are needed (Hussein *et al.,* 2011). In the food processing industry, edible portions of fruits are processed into products such as puree, canned slices, juice and pickles, whereas seeds often will be discarded as waste since it is not currently utilized for commercial purposes (Ajila *et al.,* 2007), seeds are also promising source of useful compounds because of their favorable nutritional properties (Schieber *et al.,* 2001).
The problem of protein malnutrition in the developing countries is of great importance, as a large number of people in this part of the world do not have access to cheap protein sources (Adebowale and Lawal, 2003). Seeking sources of plant proteins has attracted increasing interest due to consumers' growing concerns over the safety of animal-derived products. Moreover, plant proteins, which can serve as a better alternative to the expensive animal-based protein, have become a major source of dietary protein in many developing countries. Recently, with rising public concern about increasing protein consumption and shortage, has stimulated research on developing new sources of protein from unexploited sources or wastes and by-products (Perumal *et al.,* 2001). The interest in plants and various constituents is growing in many developed countries because of the demand for healthy foods (Aguilera *et al.,* 2011). Plant proteins have been used extensively for many years in the food industry as food product ingredient due to amino acid content (Horax *et al.,* 2004). Watermelon (*Citrullus lanatus*) is one of the fruits whose seeds are not routinely eaten with the pulp. The fruits are widely eaten as snack without due regards to the seed which are discarded each year either as cheap animal feed or simply

thrown away, there is therefore the need to explore the potential of the seeds by evaluating the proximate, minerals and the functional properties.

2. Materials and Methods

2.1. Sources of Materials

Watermelon (*Citrullus lanatus*) seeds were procured from a local market in Ado-Ekiti, Nigeria. The seeds were washed and air-dried (at 50±2 ^oC) for 24 h. The immature seeds and extraneous materials were removed, the remaining seeds were stored in plastic containers at room temperature (30±2 ^oC). All chemicals used were of analytical grade.

2.1.1. Preparation of Seeds Flour

The water melon seed was divided into two parts, one part was shelled manually to remove the shells. The shelled seeds, shells and whole seeds were milled into flour in an electronic blender. These were kept in an air-tight plastic container in a refrigerator at 4 ^oC prior to use.

2.2. Determination of Proximate Composition

The proximate composition of the samples (whole meal, shelled seeds and shel flours) was determined using the standard methods already described in the (AOAC, 2005). The parameters were: moisture, crude protein, lipids, ash and crude fibre. The carbohydrate content was determined as the weight difference using moisture, crude protein, lipids and ash content data.

2.2.1. Determination of Moisture Content

The determination of moisture was carried out using the air-oven method. The petri dishes were washed, dried in the oven, allowed to cool in a desiccator and the weight noted. The samples 5 g was weighed into the petri dishes and dried in the oven at 105 ^oC for 4 h. The sample was finally dried to a constant weight and the moisture content was calculated.

$$\text{Moisture content } = \frac{\text{Weight loss} * 100}{\text{Weight of sample (g)}} \qquad 3.1$$

2.2.2. Determination of Ash Content

One gram (1 g) of sample was weighed into a clean, dry and pre-weighed crucible. The organic matter was burn off on the bursen flame until the samples became char. The crucible was transferred into a muffle furnace at 550 ^oC for 5 h. Ashing continued until a light grey or white ash was obtained. The crucible was cooled in a dessicator and weighed. The ash content was calculated.

$$\text{\% Ash content } = \frac{\text{Weight of Ash} * 100}{\text{Weight of sample (g)}} \qquad 3.2$$

2.2.3. Determination of Crude Fat

Two grams of the samples was weighed in a weighed filter paper and folded neatly, was inserted into a Soxhlet apparatus where extraction was carried out for 4 h using n-hexane (40 to 60 ^oC). At the end of the extraction, the filter paper was placed in the oven for 30 min to evaporate the solvents. This was cooled in a desiccator and weight was noted. The fat extracted from the given quantity of the sample was calculated.

$$\text{\% Fat content } = \frac{\text{Weight of fat extracted (g) } * 100}{\text{Original weight of sample}} \qquad 3.3$$

2.2.4. Determination of Crude Protein

The crude protein was determined using the micro Kjeldah method, sample 0.2 g was weighed into a Kjeldah flask. Catalyst containing sodium sulphate, selenium, and copper was added to the sample along with 10 ml of concentrated sulphuric acid in order to speed up the rate of digestion. The flask was swirled and gently clamped in an inclined position and heated electrically in a fume cupboard. This was heated until a clear solution was obtained. The clear solution was cooled and transferred into a 100 ml volumetric flask and made up to mark with distilled water. The resulting mixture (10 ml) was measured into the distillation set through the funnel. About 5 ml of 2% boric acid was transferred into a 100 ml conical flask containing 2 drops of screened methyl orange and placed at the receiving end of the distillation apparatus.

Sodium hydroxide (40%) was used to liberate ammonia from the digest under alkaline condition during distillation. As soon as the contents became alkaline, the pink colour changed to green showing sodium hydroxide to be in excess. Steam was generated into the distillation set and ammonia was trapped in the boric acid solution and about 50 ml of the solution collected into the conical flask. The solution in the flask was titrated against 0.1 M HCl until the first permanent pink colour change was observed. A blank sample was carried through the procedure and the titre value of the blank was used to correct the titre of the samples. The nitrogen content was determined using the equation.

$$\text{\% N } = \frac{\text{Molarity of HCL} * 0.014 * \text{titre} * \text{dilution factor} * 100}{\text{Weight of sample used}} \qquad 3.4$$

The percentage of nitrogen was converted to crude protein by multiplying with 6.25.

2.2.5. Determination of Crude Fibre

Freshly prepared sulphuric acid (1.25%, 200 ml) was added to 2 g of the sample and heated to boiling. The boiling was continued for 30 min. The mixture was filtered and residues washed until it was free of acid. The residue was transferred quantitatively into the conical flask; 1.25% NaOH was added and contents heated to boiling for 30 min. The mixture was filtered and the residue was free of alkali. The residue was washed thrice with methylated spirit and petroleum ether. The residue was then transferred into a silica dish (previously ignited at 600 ^oC and cooled). The dish and its content were dried to a constant weight at 105 ^oC. The organic matter of this residue was burn off by igniting in a muffle furnace at 600 ^oC for 30 min. The residue was cooled and weighed. The loss on ignition was reported as the crude fibre.

2.2.6. Estimation of Carbohydrate

Carbohydrate content of each sample were determined by difference by adding % (moisture, ash, fat, protein and crude fibre) and subtracted from 100.

2.3. Determination of Mineral Elements

Minerals were determined by the method described by AOAC (2005). A dried and ground sample (1 – 2 g) was pre-ashed on a bunsen flame for 20 min. Thereafter, the sample was subjected to dry ashing in well cleaned porcelain crucibles at 550 ^oC in a muffle furnace. The resultant grayish-white ash was dissolved in 0.1 M HCl solution (10 ml) was added to the crucible to break up the ash and leach the metals. The crucible was washed three times with 0.1 M HCl and made up to 100 ml with distilled water. The metals determined using a Perkin-Elmer 8650 atomic absorption spectrophotometer. Standard stock solutions were prepared for each metal using salts of each metal to prepare a standard curve. Phosphorus was determined by using spectrophotometer, Vanodomolybdate reagent was used at 470 nm.

2.4. Functional Properties

2.4.1. Determination of Bulk Density

This was carried out using the procedure of Mepba *et al.* (2007). A specified quantity of the flour sample was transferred into an already weighed measuring cylinder (W_1). The flour sample was gently tapped to eliminate any air voids and the level was noted to be the volume of the sample, and the cylinder containing the flour was weighed (W_2). The bulk density was determined from the relation:

$$\% \text{ Bulk density} = \frac{(W_2 - W_1)}{\text{Volume of sample}} g/cm^3 \qquad 3.5$$

2.4.2. Determination of Water and Oil Absorption Capacities

Water absorption capacity was determined using the method of Osundahunsi (2003) with slight modifications. Ten (10 ml) of distilled water was added to 1.0 g of the sample in a beaker. The suspension was stirred using a magnetic stirrer (Stuart Model) for 5 min. The suspension obtained was thereafter centrifuged at 3500 rpm for 30 min and the supernatant measured in 10 ml graduated cylinder. The density of water was taken as 1.0 g/cm^3. Water absorbed was calculated as the difference between the initial weight of the sample before the addition of water to the sample and the weight after decanting the supernatant. The same procedure was repeated for oil absorption capacity except that oil was used instead of water.

2.4.3. Determination of the Least Gelation Concentration

The least gelation concentration was determined by the method of Kaur and Singh (2005). Test tubes containing suspensions of 2, 4, 6, 8 up to 20% (w/v) flour in 5 ml distilled water was heated for 1 hour in boiling water, followed by cooling in ice and further cooling for 2 h at 4 ^oC. The least gelation concentration was the one at which the sample did not slip when the test tube was inverted.

3. Results and Discussion

3.1. Proximate Composition of Watermelon Seeds Constituents

The proximate composition of watermelon seeds constituents is presented in Tables 1. The moisture content of whole meal, shelled seeds and shells flours were very low (4.30- 6.40%) which are within the acceptable range for a good keeping period. The results showed low moisture content which is in agreement with 6.39% reported for pawpaw seeds flour (Olorode*et al.,* 2014), lower than the moisture content of cowpea (10.39%) and mung bean (8.30%) (Masood and Rizwana, 2010). Moisture content is a major quality factor in the preservation of some food products and it affects food stability (Nielsen, 2010).The relatively low moisture content is an indication that these seeds' flours will have high shelf life especially when properly packaged against external conditions.

The crude protein content obtained for whole meal, shelled and coat was high, was in the range of 13.31 – 38.92%. The values recorded for whole meal and shelled flours were similar to 39.40% found in the literature for *Cucumeropsis mannii* (Ogunbusola *et al.,* 2012); benoil seed's flour 31.04% (Olorode*et al.,* 2014); cowpea 24.46% (Arawande and Borokini, 2010). Proteins are essential component of the diet needed for survival of animals and humans, which function basically in nutrition by supplying adequate amounts of required amino acids (Pugalenthi *et al.,* 2004); whole meal (26.69%) and shelled (38.92%) flours were higher than 24.69%

and 20.00% obtained for unfermented groundnut and sesame seed by (Ojokoh and Lawal, 2003) and (Nzikou *et al.,* 2009) respectively as well far above 18.13% in the previous work reported

Parameter	Whole meal	Shelled seeds	Shells
Moisture	6.40±0.51a	5.16±0.11b	4.30±0.34c
Protein	26.69±0.22b	38.92±0.16a	13.31±0.11c
Ash	4.38±0.12b	3.45±0.31c	5.23±0.18a
Fat	25.60±0.32b	37.87±0.14a	2.68±0.24c
Crude fibre	8.41±0.11b	3.91±0.10c	30.03±0.03a
Carbohydrate	28.52±0.05b	10.68±0.44c	44.44±0.21a

Table 1: Proximate composition of watermelon seeds (%)
Means with different letters in the same row are significantly different ($p \leq 0.05$).

by Acar*et al.* (2012) for watermelon seeds flour.The shells showed crude protein content of 13.31% higher than what is obtainable in most cereal crops. The shells could be a good source of dietary protein supplement to meet the recommended daily requirement for humans (FND, 2002).This result is in agreement with the fact that watermelon seeds are good source of protein (Hassan *et al.,* 2008). The high protein content of the flours has a good implication in a society with high protein deficiency and will no doubt complement protein from cereals and other plant foods inthe diets of Nigerians. However, availability and quality of amino acids present in the constituents has to be determined before assertions on the suitability or otherwise.
The shells recorded the highest values for crude fibre which was 30.03%. The crude fibre content of the seeds constituents differs significantly from one to another. The value recorded for shells was higher than what is obtainable in most plant foods. The range of fibre contents found in the whole meal and shelled seeds ranged from 3.91 to 8.41%, was similar to 4.61% found in mung bean (Masood and Rizwana, 2010); 7.86% reported for red kidney beans (Sai-Ut *et al*., 2009) and 8.01%*A. trifoliatavar. australis* (Du *et al.,* 2012). Legume fibres are reputed to have several beneficial health effects including delaying the release of carbohydrates, lowering of blood lipids, and prevention of colon cancer, increasing the feacal transit time and improving digestion (Tosh and Yada, 2010). The low fibre level obtained in the shelled flour could be desirable in its incorporation in weaning diets since emphasis has been placed on the importance of keeping fibre intakes low in infants and pre-school children nutrition. High fibre levels in weaning diet can lead to irritation of the gut mucosa, reduced digestibility, vitamin and mineral availability (Eromosele and Eromosele, 1993).
The total ash content obtained for the constituents ranged from 3.45 to 5.23%, which is comparable to 5.88% reported for pawpaw seeds flour (Olorode*et al.,* 2014); 3.96% and 3.48% reported for pigeon pea and peas respectively (Masood and Rizwana, 2010). Ash content is important in food for quite number of reasons, for instance, it is an index of quality in feed material used for cattle and poultry (Pomeranz and Clifton, 1981). Fats are essential due to the ability to provide the body with maximum energy; approximately twice that for an equal amount of protein or carbohydrate, facilitate absorption and transportation of fat-soluble vitamins A, D, E and K (Dreon *et al.,* 1990). The high crude fat content of 25.60% and 37.87% obtained for the whole meal and shelled seed flours is expected of oil seeds flour. The value was higher than 12.91% and 14.28% reported for watermelon and melon seed flours respectively (Olorode *et al.,* 2014). The 2.68% value recorded for shells is comparable to the values reported for other legumes (Ajayi *et al.,* 2010). A diet providing 1-2 g/100 g of its caloric energy as fat is sufficient in human beings as excessive consumption has been implicated in certain cardiovascular disorders such as atherosclerosis, cancer and aging (Antia *et al*., 2006).
The carbohydrate was in the range of 10.68% to 44.44% in agreement with the findings of Penuel*et al.* (2013). Many health benefits are attributed to the carbohydrate components of legume. Seed constituents with low carbohydrate content might be ideal for diabetic and hypertensive patients requiring low sugar diets (Olorode *et al.,* 2014).

3.2. Mineral Composition of Watermelon Seeds Constituents

The mineral content of the seeds constituents in mg/100 g is depicted in Table 2. The most abundant minerals in the studied constituents were magnesium and potassium with values ranging from 86.67 to 109.63 mg/100 g and 55.15 to 82.63 mg/100 g

Elements	Whole meal	Shelled seeds	Shells
Magnesium	86.67±0.12c	94.28±0.34b	109.63±0.58a
Manganese	1.54 ±0.31b	1.83±0.50a	1.42±0.33c
Zinc	7.16 ±0.22c	14.84±0.01b	16.65±0.24a
Sodium	5.51±0.01c	7.0±0.21b	16.04±0.18a
Potassium	82.63±0.21a	80.23±0.01b	55.15±0.22c
Calcium	22.04±0.21b	13.98±0.06c	40.10±0.11a
Phosphorus	16.76±0.14b	15.64±0.11c	20.16±0.10a
Na/K	0.06	0.09	0.29
Ca/P	1.32	0.89	2.00

Table 2: Mineral composition of watermelon seeds (mg/100 g)
Means with different letters in the same row are significantly different ($p \leq 0.05$)
Na/K – Sodium/potassium ratio
Ca/P –Calcium/ phosphorus ratio

respectively. The values recorded for magnesium in this study were higher than 58.0 mg/100 g, 62.40 mg/100 g, 67.70 mg/100 g, 64.40 mg/100 g reported for bambara groundnut seeds, kersting's groundnut, cowpea and cranberry beans respectively (Aremu *et al.,* 2006). Magnesium improves insulin sensitivity and may delay the onset of type 2 diabetes in individuals with high risk factors. It has been reported to be an important co-factor of many regulatory enzymes, particularly the kinases and is fundamental in the energy transfer reactions involving high energy compounds like ATP and creatine phosphate and thus muscle contraction. This also explains the key role of magnesium in heart health and the skeletal system (WHO, 2005).

Potassium ranked second in abundance, this negate the observation of Olaofe and Sanni (1988) who reported potassium as the most predominant mineral element in Nigerian agricultural products. There have been similar observations reported for mucuna beans (Adebowale *et al.,* 2005) but contrary to the report on fluted pumpkin (Fagbemi, 2007) and gingerbread plum (Amza *et al.,* 2011). The potassium values for the whole meal (82.63 mg/100 g) and the shelled (80.23 mg/100 g) seeds flours were high, this is beneficial in the management of diabetes since potassium helps to control blood pressure and possibly prevents stroke (Ibeanu *et al.,* 2012).

The calcium content ranged between 13.98 mg/100 g and 40.10 mg/100 g. Calcium has been known to help in bone formation and blood coagulation; the high calcium content in the seeds coat makes it an incredible natural source of calcium supplementation for pregnant and lactating women, as well as for children and the elderly people. The zinc values of the constituents (14.84 mg/100 g for the shelled seeds and 16.65 mg/100 g for the shells) were higher than 10.24 mg/100 g in watermelon kernel reported in a previous study (Poole, 2010) as well as the recommended daily intake for adult men (11 mg) and adult women (8 mg). Sodium is an important source of electrolytes within the body, in the studied samples it ranges between 5.51 and 16.04 mg/100 g. Manganese was present in appreciable amount.

The Na/K ratio in the body is of great importance for prevention and management of high blood pressure and Na/K ratio less than one is recommended (Aremu *et al.,* 2006). Hence, with sodium/potassium ratio (Na/K) range of 0.06 to 0.29, the samples would probably reduce high blood pressure with Na/K ratio of less than one. Modern diets which are rich in animal proteins and phosphorus may promote the loss of calcium in the urine (Shills and Young, 1988). This has led to the concept of the Ca/P ratio. When the Ca/P ratio is low (low calcium, high phosphorus intake) more than the normal amount of calcium may be loss in the urine, decreasing the calcium level in bones. Food is considered "good" if the ratio is above one and "poor" if the ratio is less than 0.5 (Nieman *et al.,* 1992). The Ca/P ratio in the present study ranged between 0.89 in shelled seeds to 2.00 in shells indicating they would serve as good sources of minerals for bone formation.

3.3. Functional Properties of Watermelon Seeds Constituents

Functional properties are the intrinsic physicochemical characteristics which may affect the behaviour of food systems during processing and storage. Adequate knowledge of these physicochemical properties indicates the usefulness and acceptability for industrial and consumption purpose (Fasasi *et al.,* 2006). Determining the functional properties of proteins is of high significance as they reflect the interaction between the components, structure, confirmation, physicochemical properties and nature of the environment or the food matrix (Kinsella *et al.,* 1985). This also aids in selecting plant food raw material with the required properties in specific food formulations (Jyothi and Kaul, 2011).

The result of functional properties is presented in Table 3. The water and oil absorption capacities ranged between 1.81 to 2.41 g/g and 1.21-1.50 g/g respectively. Whole meal and shells flours have higher water and oil absorption capacities compared with shelled flour. The high water and oil absorption capacities observed in shells flour could be due to low fat content which exposes the water binding sites on the side chain groups of protein units thereby leading to an increase in water absorption capacity values in coat flour. Similar observation has been reported by Adebowale *et al.* (2005) on mucuna bean flour. Water absorption capacity is a critical function of protein food products like soups, gravies, doughs and baked products. Watermelon seeds constituents could be useful in these formulations.

The values for oil absorption capacity compared favourably with oil absorption capacity reported for *Cucumeropsis mannii* seed flour by Ogunbusola *et al.* (2012). Higher values were recorded by Sai-Ut *et al.* (2009), Ogundele*et al.*(2013) in their work on some leguminous seeds crop and plantain flour Osundahunsi (2003). Liquid retention is an index of the ability of proteins to absorb and retain oil/water, which in turn influences the texture and mouth feel characteristics of foods and food products like comminuted meats, extenders or analogues and baked dough. The studied seeds would therefore be useful as a flavor retainer in certain food products.

Parameter	Whole meal	Shelled seeds	Shells
Hydration capacity	1.80±0.11b	1.47±0.03c	2.32±0.03a
WAC (g/g)	2.15±0.12b	1.81±0.01c	2.41±0.02a
OAC (g/g)	1.23±0.03b	1.21±0.02b	1.50±0.10a
LG (%)	16.00±0.00a	12.00±0.00b	ND
LBD (g/cm^3)	0.44±0.11b	0.52±0.10a	0.54±0.03a
TBD (g/cm^3)	0.66±0.05b	0.59±0.04c	0.71±0.21a

Table 3: Functional properties of watermelon seeds
Means with different letters in the same row are significantly different ($p \leq 0.05$).

Key
WAC- water absorption capacity
OAC- oil absorption

LG- least gelation
LBD- loose bulk density
TBD- tapped bulk density
ND –Not detected

Least gelation concentration ranged from 14 to 16% whole meal recorded the highest values (16%) and shelled seeds flour had the lowest value (14%) while there was no gel formation in the shells flour. These values compared favourably with those reported for different chickpea cultivars (12-16%) by Kaur and Singh (2005); mucuna bean flours by Adebowale *et al.* (2005). Moure *et al.* (2006) have associated the variation in gelling properties to the ratio of different constituents such as protein, lipids and carbohydrates in different legumes. Moreover, Makri *et al.* (2006) suggested a direct correlation between least gelation concentration and the level of globulin in legume seeds. Gelation takes place more readily at higher protein concentration because of greater intermolecular contact during heating. High protein solubility is always necessary for gelation. The high least gelation concentration observed in whole meal may be a disadvantage for its application in some foods such as curd and cheese.

The bulk density loose and tapped ranged from 0.44 to 0.54 g/cm^3 and 0.59 to 0.71 g/cm^3 respectively. The values compared favourably with the report of (Samir- El Safy *et al.,* 2012) but significantly higher than 0.347 and 0.357 reported for pawpaw seed's and melon seeds flour respectively (Olorode *et al.,* 2014). This may be related to the fact that these seeds' flours are high in protein. The bulk density content shows that a good weaning food could be produced with the seeds' constituents (Obatolu and Cole, 2000). Also, according to (Omueti *et al.,* 2009), low bulk density is an advantage because high bulk limits the caloric and nutrient intake per feed per child and infants sometimes are unable to consume enough to satisfy their energy and nutrient requirements.

Bulk density is also important in the packaging requirement and material handling of a product (Akubor and Chukwu, 1999). The decrease in loose and packed densities in some of the seeds' constituents is an advantage since according to Akubor and Chukwu (1999), a large free space is undesirable in packaging of foods because it constitute a large oxygen reservoir, whereas a low loose and packed densities results in greater oxygen transmission in packed foods.

3.4. Conclusions

In view of the high contents of protein, fibre, minerals and good functional properties, watermelon seed constituents comprising of the shell, whole meal and the shelled seeds have very good potential food value to serve as supplements in food formulations.

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