Journal of Food Technology 3 (3): 370-377, 2005

Effects of Processing on the Functional Properties of Full Fat and Defatted Fluted Pumpkin (*Telfairia occidentalis*) Seed Flours

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Abstract: Mature fluted pumpkin seeds were processed into raw dried, boiled, naturally fermented, germinated and roasted seeds. The seeds were milled into flours in the laboratory. Samples of the seed flours were defatted using n-hexane, dried at 50°C and sieved to pass through 500 μm sieves. The full fat and defatted seed flours were evaluated for functional properties. The results showed that different processing and pH significantly (p=0.05) affected the functional properties of fluted pumpkin seed flours. The functional properties of full fat and defatted seed flours respectively ranged as follows; water absorption capacity (WAC), 174.50-250.0% and 423.00-500.0% g g^{-1}; oil absorption capacity (OAC) 134.26-179.11% and 316.77-423.11% g g^{-1}; Bulk density {BD),0.33-0.55 and 0.18-0.38 g mL^{-1}; least gelation concentration (LGC), 12.0-28.0 and 4.0-10.0% g mL^{-1}; foaming capacity of 12.0-115.0% and 20.5-200.0% while the foaming stability was 4.0-70.0% and 10.0-86.0% after 6 h. The emulsion capacity was 20.0-61.67 and 31.44-88.12 mL g^{-1} while protein solubility in water was 7.46-31.94% and 5.61-36.33%. Functional properties were dependent on pH; pH 2 and pH 9 enhanced functional properties while they were reduced at pH 4. Heat processing and fermentation reduced foaming capacity, emulsion capacity and protein solubility but enhanced water and oil absorption capacity. There was a positive correlation (p=0.05) between protein solubility and foaming properties or emulsion properties of fluted pumpkin seed flours.

Key words: Processing, functional properties, fluted pumpkin seed flours

INTRODUCTION

Fluted pumpkin (*Telfairia occidentalis*) is a tropical crop that belongs to the cucurbitaceae family [1]. It is reported to be indigenous to the West tropical rain forest area of Nigeria [2]. The cultivation of fluted pumpkin Esiaba,[3] Okoli and Mgbeogu, [4] its yield, Oyolu [5] and the chemical composition have been reported by Maduewesi [6] Longe *et al.*,[7] Asiegbu [8] and [9].

There is limited information on the functional properties of fluted pumpkin seed flour and its protein isolate, Fagbemi and Oshodi [10] Oshodi and Fagbemi [11] as well as processing effects on its functional properties[12]. The previous works on functional properties focused mainly on its raw dried form. Fluted pumpkin is mainly cultivated as a leafy vegetable Okigbo[13] that are used for soup while its fruit and seeds are wasted. There is limited information on the seed utilization. Johnson and Johnson [14], ogiri-ugu and livestock feed, Akoroda[15]. The productions of marmalade from the pumpkin pulp have been reported Egbekun *et al.*, [16] while Ezeji and Ojimelukwe [17] produced weaning food from it. The protein content and amino acid profile of fluted pumpkin is better than *Colocynthis citrullus* Akobundu *et al*, [18] and sunflower seed, Lin *et al.*,[19] and comparable with that of soy flour. The successes of soy protein, peanut protein and sunflower protein as functional ingredient in food system depend on the versatility of their functional properties.

This study investigates processing effects on the functional properties of the seed flour and the influence of the food environment (pH) on them in order to obtain information on the potentiality of the seed flour as a functional ingredient in food system.

MATERIALS AND METHODS

Sample preparation: The fluted pumpkin fruits were obtained from the University Teaching and Research farm. The seeds were extracted from the fruits dehulled and sliced into small pieces. Parts of the sliced seeds were oven dried at 50°C and labelled F_1. Parts of the seed were boiled for 1 h as described by Giami and Bakebain [12], drained and cooled. The boiled slices were oven dried at 50°C F_2. Part of the boiled seeds were cooled, wrapped in blanched banana leaves and allowed to ferment naturally for 7 days [12,20]. The fermented seeds were dried in forced

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air oven at 50°C (F_3). Part of the seeds extracted from fluted pumpkin fruit were germinated as described by Giami and Bakebain [12] using sawdust in a locally woven reed basket. The seeds were arranged in layers of the sawdust and wetted daily and observed for sprouting. Seeds with sprouts of about 1cm long (6-8 days) were picked, washed dehulled, sliced and dried at 50°C{F_4) part of the F_1 were roasted in hot cast iron pan at 75-85°C and cooled (F_5). The differently processed seeds i.e. F_1, F_2, F_3, F_4 and F_5 were pulverized using coffee grinder and sieved to pass through 500µm sieve. The full fat seed flours were defatted using soxhlet extractor and n-hexane solvent continuously for 8 h at room temperature. The defatted meal was allowed to dry at 50°C until it is free from the solvent. They were pulverized and sieved through 500 µm sieve, packaged and labelled as F_6, F_7, F_8, F_9 and F_{10}, respectively.

Determination of functional properties

Water and oil absorption capacity: The WAC of the full fat and defatted seed flours was determined by using the procedure of Solsulski [21] as modified by [22]. The OAC was determined by replacing the distilled water with executive chef vegetable oil 0.92 g mL^{-1} obtained from Jof Ideal Family Farm, Owo, Ondo State. The water/oil absorbed in seed flour were expressed on percentage g g^{-1} basis.

Bulk density (BD): The bulk density of the seed flours was determined using the procedure of Wand and Kinsella [23] as modified by Akpapunam and Markakis [24] and Narayana and Narasinga Rao [25].

Protein solubility: The protein solubility of the seed flours was determined as described by Ige *et al*, {1984). The effect of pH on protein solubility of the seed flours was determined by adjusting the pH of the mixture as desired using either 0.1 M HCl or 0.1 M NaOH. The slurry was centrifuged and the protein of the supernatant was then determined. The pH of 2.0 to 11.0 was used.

Foaming properties: The foaming capacity (FC) of the seed flours was determined using the procedure of (Coffman and Garcia, 1977). The FC was calculated as percentage volume increase due to whipping.

$$\text{Foaming capacity (FC) \%} = \frac{\text{volume after whipping - volume before chipping}}{\text{Volume before whipping}} \times 100$$

The foaming stability (FS) was determined as foaming capacity after 6 h. The effect of seed flour concentration on foaming capacity was determined by increasing the flour concentration used for whipping; 2, 4, 6, 8 and 10% m/v of seed flours were used. The effect of pH on the foaming capacity and foaming stability was determined by adjusting the pH of the medium to the desired value using 0.1 M HCl or 0.1 M NaOH. pH range of 2 to 10 was used.

Emulsification property: The emulsion capacity (EC) of the seed flours was determined by modifying the method of Pearce and Kinsella, [23] as described by Wanasundara and Shahidi [26] and Chavan *et al.*, [27] which used turbidimetric technique. 0.5% m/v protein (about 1g per 50ml water) was prepared and stirred for 5 mins. using magnetic stirrer at 500 RPM. 30 mL of the sample suspension was pipetted into 100 mL measuring cylinder and 10ml Chef Executive Oil (refined soy bean oil) was added to the mixture. The mixture was homogenized at 2000 RPM using Funkentsrort Bystral GMBN Homogenizer Chavan *et al.*,[27] . 0.5 mL of the emulsion formed was pipetted and made up to 100 mL in a volumetric flask. The absorbance of the diluted emulsion was measured at 500 nm against distilled water. The absorbance was taken as emulsion activity (EA). The volume of the emulsion formed after homogenizing was measured (exactly after 1 min) and computed as emulsion capacity in percentage emulsion volume per gram sample. The emulsion stability (ES) was determined by taking 0.5 mL of the emulsion formed at time intervals and determining its emulsion activity (i.e. measure absorbance at 500 nm after dilution), the time in days required for the absorbance to be half or (50%) of the absorbance at zero time or half life is taken as the emulsion stability [28].

The effect of pH on the emulsion activity and Emulsion Capacity was determined by adjusting the pH of the sample mixture to the desired value using 0.1 M HCl and 0.1 M NaOH and repeating the above process, pH of 2 to 10 was used.

Least gelation concentration: The Least Gelation Concentration of the seed flours was determined by using the procedure of [29].

Statistical analysis: At least three determinations were carried out for each test. Statistical analysis was carried out on each test using Analysis of Variance (ANOVA) and the means separated by Duncan method. The statistical package in SPSS 10.0 computer program was used. Significant differences were taken at 5% confidence limit.

The relationship between the protein solubility and emulsion capacity, emulsion activity or foaming capacity were determined using correlation matrices with the aid of SPSS 10.0 computer programme and interpreted as described by Oloyo [5].

RESULTS AND DISCUSSION

Water absorption capacity: From Table 1 and 2, processing has significant effects on the water absorption capacity of full fat and defatted fluted pumpkin seed flours. Boiling, fermentation, germination and roasting significantly (p=0.05) improved WAC. Processing i.e. boiling, fermentation, germination and roasting increase the WAC of the full fat fluted pumpkin seed flours by 11.75, 42.27, 5.44 and 3.15%, respectively when compared with the raw dried seed. In the case of the defatted seed flour, boiling, fermentation, germination and roasting increase the WAC by 17.73, 32.39, 3.78 and 17.26%, respectively. Fermented seed flour has the highest WAC. The high WAC suggests that the seed flour can be used as a thickener in food system [30].The high WAC of the fermented, boiled and roasted samples may be due to protein denaturation, which caused increase in its WAC. Padmashree *et al.*, [31] and Giami and Bakebain [12] made similar observations on traditionally processed cowpea and fluted pumpkin respectively. Defatting was observed to lead to increase in WAC of fluted pumpkin seed flours. The increase in WAC of the seed flours due to defatting ranged between 124-175%. The result agreed with the observations of Sathe *et al.*, [22a] on Lupid seed. The increase in WAC of the defatted fluted pumpkin seed flour might have been due to the exposure of hydrophilic sites on the side chain groups of proteins previously blocked in a lipophilic environment. Water binding by proteins is influenced by its physico chemical environment [32]. Defatted fluted pumpkin seed flour may be a better thickener than the full fat sample in a food system where swelling without solvation is required such as custard where it can impart body, thickening, viscosity and improve its protein content [33].

The order of Water absorption capacity of fluted pumpkin seed as affected by processing is $F_3>F_2>F_4>F_5>F_1$

Fat absorption capacity: From Table 1 and 2, processing significantly (p=0.05) affected FAC of fluted pumpkin seed flours. Boiling, germination and roasting increased the FAC of the seed flour by 10.87, 26.50 and 21.3%, respectively while fermentation reduced it by 5.3%. The above result is consistent with the observation of Giami and Bakebain [12] and Giami and Isichei [34] on germinated fluted pumpkin seed flour. Fermented fluted pumpkin appeared very oily and clustered together this may account for its low FAC when compared with the raw dried sample. Severe denaturation has been reported to destroy hydrophobicity, Hutton and Campbell [35].This may be responsible for the low FAC in the fermented sample. Heat treatment generally enhance high FAC, del Rosario and Flores , Narayana and Narasinga Rao [36], made similar observations on some heat treated legumes and fruits.Defatting increased the FAC of the seed flours. This may be due to increase in the protein content of the defatted flours leading to greater interactions among the lipoproteins and oil thereby encouraging hydrophobicity [35,36]. Denaturation and dissociation of protein due to heat treatment as well as synthesis and hydrolysis of protein during seed germination may be responsible for high FAC in the heat- treated and germinated fluted pumpkin seed flours. The apolar amino acid of the seed protein unfolded during heat treatment thereby encouraging hydrophobicity [35]. Fat Absorption Capacity is of great importance in ground meat formulation, baked goods soups del Rosario and Flores , in such application the boiled, germinated and toasted fluted pumpkin seed flours especially in defatted form may play a prominent role.

Bulk density: Processing significantly (p= 0.05) affected the bulk density of the seed flours. Boiling and fermentation increased the bulk density while germination reduced it for both full fat and the defatted flours, while toasting seemed to have no significant effect on it. Similar observations were reported by Padmashree *et al.*, [31] on cowpea flours.

The high bulk density observed for the boiled and fermented fluted pumpkin seed flours may be due to shrinkage that occurred during boiling. The low bulk density of the germinated seed flours may be attributed to the hydrolysis of its carbohydrate and fat and their subsequent utilization for growth leading to reduction in its weight, Asiedu *et al.*, made similar observations on sprouted sorghum and maize.

Boiling and fermentation may offer packaging advantage to fluted pumpkin seed flours. Germinated seed flours with low bulk density apart from improved protein quality and vitamins have been reported to cause reduced viscosity on the thickening of cereal based gruels thereby making it suitable for the formulation of high nutrient density weaning foods. Germinated fluted pumpkin seed flours may be useful in the manufacture of high nutrient density weaning food. Defatting reduced the bulk density of fluted pumpkin seed flour irrespective of the processing applied. Fluted pumpkin seed is high in oil, hence, defatting lead to substantial reduction in the seed flour weight without corresponding reduction in its volume, resulting in low bulk density of the defatted seed flour. The bulk density of full fat fluted pumpkin (0.33-0.55 g mL^{-1}) is comparable with the value reported for soybeans flour (0.47 g mL^{-1}), Chau and Cheung [37].

Protein solubility: Figure 1 and 2 show that both pH and processing affected the protein solubility of full fat and the defatted seed flours. Minimum protein solubility was observed at pH 4 for all the fluted pumpkin seed flours irrespective of the processing technique. The minimum solubility ranged between 21.05-34.70% for the full fat and 8.13-22.2% for the defatted seed flours.

The maximum protein solubility was observed at pH9 for all the processed seed flours. The maximum protein solubility ranged between 56.25-90.39% and 42.50-88.36% for both full fat and the defatted flours respectively. At the either side of pH4, there was an increase in protein solubility though the protein solubility dropped after pH9. The pH4 may be the isoelectric point (IEP) of fluted pumpkin seed flour. Similar trend have been reported by Fagbemi and Oshodi, [10] as well as Oshodi and Fagbemi [11]. Generally, vegetable proteins have been reported to have IEP at about pH 4-5 and show high protein solubility at alkaline pH [30,38]. The dependency of protein solubility on pH has been attributed to the change in the net charges carried by the protein as the pH changes. Fluted pumpkin seed flours irrespective of the processing show similar protein solubility trend (Fig. 1 and 2).

Boiling, fermentation and roasting reduced the protein solubility of fluted pumpkin while germination enhanced it. Narayana and Rao [36] and Giami and Bakebain, [11], have reported similar results.

Germination have been reported to improve protein content and quality of sorghum and maize and lettuce seeds. Thus, the high protein solubility observed in germinated fluted pumpkin seed flours may be due to protein synthesis and dissociation during germination which enhance protein solubility. del Rosario and Flores[30] and King and Puwastein reported similar observations on Mung bean while Lin *et al.*, [39] and McWatters *et al.*,[40] reported similar observations on sunflower flour and soy bean protein respectively. Germinated and raw dried fluted pumpkin seed flours may be useful in vegetable milk production.

The low protein solubility observed in boiled, fermented and roasted fluted pumpkin seed flours may be due to heat denaturation and precipitation of the seed protein[36] reported similar observations. Heat-treated protein cause irreversible denaturation leading to association and precipitation of the polypeptide chains as high molecular weight compounds[41].

Emulsification potentials: The emulsion consistency of fluted pumpkin seed flours using the description of McWatters and Cherry [40] showed that it is pH and processing dependent (Table 3). The emulsion capacity (Table 4) increased on the either side of the IEP of pH 3-4. Similar results have been reported for winged bean, Narayana and Narasinga Rao,[36] cowpea, Abbey and Ibeh [42] and Chau and Cheung [38] on Chinese indigenous legumes.The increase in emulsion capacity and activity might suggest that droplet size decreased as the pH increased or decreased beyond IEP [27]. The emulsion activity and capacity vs pH profile (Fig. 3 and Table 4) is similar to the percentage protein solubility vs pH profile (Fig. 1 and 2) for the differently processed seed flours.

It was observed that emulsion capacity and activity are closely associated with protein solubility; hence, emulsification of fluted pumpkin may be due to solubilized protein. A correlation of F_{1EA}=0.72, F_{2EA}=0.38; F_{3EA}=0.67, F_{4EA}=0.62 and F_{5EA}=0.50 was established between protein solubility and emulsion activity of the differently processed seed flours, respectively. In the case of emulsion capacity, a correlation of F_{1EC} = 0.87; F_{2EC}=0.38; F_{3EC} = 0.67; F_{4EC} = 0.62 and F_{5EC} = 0.50 was obtained.

Emulsion stability of fluted pumpkin seed flours (Fig. 4) was observed to be affected by pH and processing. Emulsion stability increased at the either side of the iso-electric point.[43] made similar observations cowpea and beach pea protein isolate[27]. Coulombic interaction at low pH and frequent repulsion at high pH had been adduced for higher ES at very low and high pH [27]. The ES Vs pH curve (Fig. 4) is similar to that of protein solubility Vs pH. This may imply that protein solubility is closely associated with emulsion stability. Processing was observed to affect the ES at all the pH investigated. The order of the emulsion stability obtained as affected by processing is $F_5 > F_1 > F_3 > F_4 > F_2$.

Processing affected emulsion activity and capacity of fluted pumpkin seed flours (Fig. 3 and Table 3). Raw, fermented, germinated and roasted fluted pumpkin seed flour at pH 2.0 and alkaline pH 9-10 may be useful as food ingredients in aqueous emulsions like soups, ice cream, mayonnaise[30]. Seed protein concentrates that are soluble at pH 4-7 could be used in such beverages as vegetable milk [30], hence, fluted pumpkin may be very useful in vegetable milk production.

Foaming properties: From Table 5, the raw dried, fermented, germinated and roasted full fat fluted pumpkin seed flours produced medium thick foams with small air cells while the boiled seed flours produced thin foams with medium size air cells.

The defatted, raw dried, fermented, germinated and roasted fluted pumpkin seed flours produced very thick, egg white foams with small air cells especially at very high meal concentration (8-10%). This observation is close to the result obtained by McWatter and Cherry [40] except the fermented and defatted seed flour which showed high foaming property.

The very thick foams obtained for the defatted raw dried, germinated and roasted seed flours with increasing flour concentration may be due to higher protein concentration and solubilization which resulted in high reduction of surface tension and better foaming properties. The high foams observed in the defatted fermented fluted pumpkin seed flours especially at high flour concentration may be attributed to synthesis of undenaturated protein and protein solubilization. The thin and low foam observed in the boiled samples may be due to the denaturation of the protein as a result of moist heat, Fleming *et al.*, [46] and Lin *et al.*, [39] made similar observations on soy beans.At pH 4, the foams obtained especially from the defatted samples except F_7, though low in volume were very thick, dense, egg white type with tiny air cells while it was medium thick for the full fat samples except F_2. At pH 2 and pH 10, the foams were medium thick for full fat seed flours F_1, F_3, F_4 and F_5 and very thick foams were obtained for their defatted samples F_6, F_8, F_9 and F_{10}. The results agreed with the report of Kinsella, *et al.*, [33] on soybean proteins.

It is postulated that at iso electric pH, there is minimum protein solubility and protein assume a compact or ordered state and more protein are adsorbed at the interface resulting in maximal reduction in surface tension. Hence, the adsorbed protein at the iso electric point is thickest resulting in high viscosity and elasticity of foams due to excessive electrostatic bonding between molecules in the film layer. This results in formation of stable molecular layers in air-water interface of foams [47].

The foaming capacity of the full fat fluted pumpkin seed flours (12.0-115%) is higher than that of full fat soybean flour (70%) Lin *et al.*, [39] and cowpea flour (40%) [42]. It is comparable with the values reported for peanut flours (100-120%) McWatters and Cherry (1977) but less than that of sunflower flour (230%) [39]. Oil seed proteins (particularly soybeans) continue to gain prominence as aerating agents that can replace or complement egg white in whipped toppings, frozen desserts [42]. Since soybean proteins have been used to complement or replace egg white in cake formulations and other cookies [41,44,45] full fat and defatted fluted pumpkin seed flours may effectively replace or complement the use of soybean protein as aerating agents in the production of aerated food products such as whipped toppings, frozen desserts and chiffon mixes [30].

Processing significantly (p=0.05) affected the foaming properties of fluted pumpkin seed flours (Table 1 and 2). All the processing techniques reduced the foaming capacity of fluted pumpkin seed flours. Figure 5 and 6 show that foaming capacity of both the full fat and defatted fluted pumpkin seed flours increased with increasing flour concentration irrespective of the processing applied. The increase in foaming capacity due to increasing flour concentration was very high in the raw dried, fermented, germinated and roasted samples while it was very low in the boiled seed flours. The results agree with the observations of Sathe and Salunkhe, [49] on great Northern bean proteins; Sathe *et al.*, [50a] on lupin seed Sathe *et al.*, [22] on winged bean and glandless cotton seed flour [48].The foaming capacity of full fat and defatted fluted pumpkin flours (Fig. 7 and 8) respectively were pH dependent and showed a curve that is close to protein solubility Vs pH curve (Fig. 1 and 2). Minimum foaming capacity was obtained at pH 4 while maximum foaming was observed at pH 10 for all the seed flours irrespective of processing used. Foaming capacity was also high at pH 2.0 thus giving high foaming capacity at the either side of the iso-electric pH.The pH dependence of foaming properties of fluted pumpkin seed flour agreed with the observation of Lin *et al.*, [39] for soy flour and sunflower proteins; succinylated and acetylated sunflower proteins Canella *et al.* and some Chinese legumes Chau and Cheung,[37] . The high foaming capacity observed at the acidic and alkaline pH may be attributed to the high solubility of fluted pumpkin proteins at those pH, Aluko and Yada [43] reported that solubilized protein diffuse more rapidly at the air-water interface to encapsulate air particles resulting in high foamability. The resemblance of foaming capacity Vs pH curve (Fig. 7 and 8) and protein solubility Vs pH curve (Fig. 1 and 2) may imply that foamability of fluted pumpkin flours may also be dependent on its soluble proteins. A correlation of (F_{1FC}=0.49; F_{2FC} = 0.28; F_{3FC} = 0.26; F_{4FC} = 0.51 and F_{5FC}=0.51) was established between protein solubility of the differently processed full fat fluted pumpkin flours and their corresponding foaming capacity. Similarly, correlation coefficient of F_{6FC} = 0.60; F_{7FC} = 0.26; F_{8FC}=0.37; F_{9FC} = 0.67 and F_{10FC} = 0.75) was established between the protein solubility of the defatted differently processed fluted pumpkin seed flour and their foaming capacity.

When fluted pumpkin is desired to be used as aerating agent in food systems like ice cream whipped toppings e.t.c. the raw dried, germinated and roasted seed flours especially in defatted form may be considered at low pH 2.0 or alkaline pH 9-10.

Gelation property: The LGC of raw dried full fat fluted pumpkin seed obtained in this work (12% g mL^{-1}) is less than the values reported for some oil seeds and legumes; soybean flour (17% g m^{-1}) Chau and Cheung [31] Lupin seed 14% g mL^{-1} and winged bean 18% g mL^{-1} (Sathe *et al.*, 1982a; 1982b). Fluted pumpkin seed flour may be a potential binder or thickener in food system. The low LGC may be attributed to the nature of constituent in the seed i.e. protein, gums, carbohydrate and lipids Schmidt [51] and Catsimpoolas and Meyer,[52] and their interactions during heat treatment. Defatting improve gelation potential of fluted pumpkin seed flour probably due to very high protein content of the defatted sample. Defatting promotes electrostatic repulsion among the protein molecules thereby resulting in improved protein solubility and gelation property. Defatting also promotes better hydrogen and ionic bond, which are required for the stabilization of the conversion of progel to gel [52] hence, gelation ability. Processing affected the gelation ability of both full fat and defatted fluted pumpkin seed flours (Table 1 and 2). Germination did not reduce the gelation ability, however, boiling, fermentation and toasting increased the LGC from 12% g mL^{-1} in the raw dried full fat seed to 26% gm mL^{+} and 16% g mL^{+} respectively. In the case of the defatted seed flour, the LGC increased from 4% g mL^{-1} to 6% g mL^{-1}, 10% g mL^{-1} and 6% g mL^{-1} due to boiling, fermentation and toasting respectively. This implied that heat treatment reduced gelation property of the seed flours. Abbey and Ibeh [42] and Padmashree *et al.*, [31] made similar observations on cowpea. The lower gelation ability of the heat-treated fluted pumpkin seed flours may be due to the denaturation of the proteins in the heat-treated seeds with the fermented and boiled seed flours mostly affected. Denaturated proteins coagulated and aggregate randomly [53] instead of the desired continuous ordered network required for formation of the progel and gel [52].

CONCLUSION

Processing and manipulation of food environment can be used to enhance the utilization of fluted pumpkin seed flours as a functional ingredient in food system. Raw dried and germinated fluted pumpkin seed flour at low pH 2.0 or alkaline pH 9-10 may be useful in vegetable milk and food emulsion where protein solubility is desired while the boiled and fermented sample may be useful as a thickener in food system and texturized vegetable protein production.

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