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Effect of germination time on the proximate composition and functional properties of *moringa* seed flour

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ABSTRACT

Moringa seed was germinated at different periods (0, 24, 48 and 72 h) and changes in the proximate composition and functional properties of the germinated *moringa* seed flour were evaluated using standard methods and compared with the native *moringa* seed flour. Germination increased the protein and ash contents while fat, crude fiber and carbohydrate contents decreased. Germination increased the water and oil absorption capacities, foaming capacity, protein solubility and gel consistency. Germination decreased bulk density, emulsifying capacity, dispersibility and swelling power of the *moringa* seed flour. Germination resulted in decrease in peak, trough, breakdown, final and setback viscosities of *moringa* seed flour. Lower percentage syneresis value was observed in native *moringa* seed flour than the treated flour which increased with germination time. Germinated *moringa* seed flour paste had higher paste clarity value than the native flour paste. The results of the study suggest that germination is a low cost and natural means of preparing modified *moringa* seed flour with enhanced functional properties without thermal treatment or chemical modification which may not be desirable in food systems where natural modified flour is required.

Keywords: *Moringa* seed flour, germination, functional properties

INTRODUCTION

At the present time, the food industry is mostly focused on the development of high-quality products that satisfy nutritional requirements and provide health benefits to consumers (Guajardo-Flores *et al*., 2016). Vegetable seeds constitute an essential part of the human diet as they are excellent sources of proteins, minerals, vitamins and bioactive compounds (Magalhães *et al*., 2017). The seeds are good source of bioactive phenolic compounds for humans as they play a significant role in many physiological and metabolic processes. *Moringa* seed is of immense value in human nutrition (Ogunsina *et al*., 2010). *Moringa* seed is fast gaining recognition in many regions of the world due to its health benefits. There is an increased awareness in

the consumption and use of *moringa* seeds in food systems in the tropics (Ogunsina *et al*., 2015). Ogunsina *et al*. (2015) highlighted the need to deepen research on its processing into edible products given the high nutritional and antioxidant properties in *moringa* seeds; since flour in its native form, could not provide industry with ideal functional properties (Bucsella *et al*., 2016).

There are few research documentations on the improvement of *moringa* seed flour functional properties. Ogunsina et al. (2010) studied the physicochemical and functional properties of full-fat and defatted *moringa* flour. Ogunsina and Radha (2010) reported a non-chemical heat-assisted processing method for debittering and detoxifying moringa seeds. Ijarotimi *et al*. (2013) studied the nutrient composition, phytochemical, and functional characteristics of raw, germinated, and fermented *moringa* seed flour. The authors germinated *moringa* seeds at 96 h only without varying the germination time in order to document the actual effect of germination on the functional properties of *moringa* seed flour, since most chemical component in seeds changes as germination time proceeds which influence flour functionality. The authors also did not provide information on functional properties such as pasting properties, protein solubility, syneresis, stability and clarity of the flour paste which could determine the application of germinated flour in food system. Oloyede *et al*. (2016) studied the effects of fermentation time on the functional and pasting properties of defatted *moringa* seed flour. Ogunsina *et al*. (2015) studied the effect of hydrothermal processing on the proximate composition and organoleptic characteristics of dehulled *moringa* seeds. To date, limited information is available regarding the functional characteristics (such as oil and water absorption capacity, bulk density, dispersability, foam capacity, emulsion capacity, pasting parameters, protein solubility, swelling power, syneresis, paste clarity and stability) of flour prepared from *moringa* seeds after germination at 0, 24, 48 and 72 h.

Germination is inexpensive and cost effective technology which results in structural modification and synthesis of new compounds with high biological activity, increased nutritional value and stability of seeds (Singh and Sharma, 2017), and flour prepared from germinated seeds are suitable for the preparation of wide consumed speciality foods and value added products across the globe (Malleshi and Klopfenstein 1998; Xu *et al*., 2017). The changes in the chemical composition influence the spatial arrangements of molecules and therefore affect the functional properties of flour (Siddiq *et al*., 2009). Functional properties are the physiochemical characteristics that interact with the chemical properties of food components (Sibian *et al*., 2016). Knowledge of the functional properties of flours prepared from germinated grains or seeds are desirable for their enhanced utilization (Singh *et al*., 2017). The present study investigated the effect of germination time on the proximate composition and functional properties of *moringa* seed flour for application in food preparations.

MATERIALS AND METHODS

Source of raw material

Ten kilograms of *moringa* seeds were purchased from central market, Minna, Nigeria.

Germination of *moringa* seeds

Moringa seeds were sorted, pretreated with 0.1 % (v/v) sodium hypochlorite for 20 min and
later rinsed with distilled water to prevent microbial growth. The seeds were soaked in

cold tap water for 12 h at room temperature (30 ± 2 ^{o}C). After draining the soaking water, the hydrated seeds were spread on a clean jute bag. The jute bag was covered with a damp cotton cloth. The seeds were germinated for 0, 24, 48 and 72 h. Water was sprinkled at 12 h interval to facilitate the germination process. At the end of germination, root hairs were removed from the germinated *moringa* seeds, winnowed, dried at 60 ^{o}C for 10 h in an air draft oven (Gallen kamp 300 Plus series, England) and milled through a 45 mm mesh size sieve. The flour samples were stored at 4 ^{o}C for further analysis.

Evaluation of proximate composition

The proximate composition (moisture, protein, fat, crude fiber and ash) was determined using the method described by AOAC (2010). Total carbohydrate content was calculated by difference as described by the AOAC (2010) method.

Evaluation of functional properties of *moringa* seed flour

Determination of bulk density

The bulk density was determined using the method of Okezie and Bello (1988). Two gram of sample was weighed into a 10 ml graduated cylinder and tapped 10 times. The ratio of mass of the samples to the volume was recorded as the bulk density. Average values of 3 replications were recorded.

Determination of water and oil absorption capacities

Water and oil absorption capacities were determined using the method of Okezie and Bello (1988). One gram of each flour samples was thoroughly mixed at high speed in a flask shaker with 20 ml distilled water or oil (Gino vegetable oil) as the case may be for 5 min. Samples were allowed to stand for 1 h and centrifuged at 500 rpm for 30 min at room temperature for 30 min. The volume of supernatant in a graduated cylinder was noted. . Density of water was taken to be 1 g/ml and that of oil 0.92 g/ml.

Determination of emulsion capacity

Emulsion capacity was determined by method described by Yasumatsu *et al*. (1972). Two grams of sample were weighed and 20 ml cold distilled water and 20 ml vegetable oil was added to the sample in a 50 ml graduated centrifuge tube. The samples were stirred and centrifuged at 500 rpm for 10 min, and the height of the emulsion layer formed was measured. The emulsion capacity was calculated using the formula:

$$\text{Emulsion capacity} = \frac{\text{Volume of emulsion layer}}{\text{Volume of emulsion before centrifuging}} \times 100$$

Determination of foaming capacity

The method of Okezie and Bello (1988) with slight modification was used to determine the foaming capacity. One gram of each sample blended with 50 ml distilled water for 5 min at room temperature was transferred into 250 ml measuring cylinder. The volume of the foam was recorded. Foaming capacity of samples was expressed as the percentage increase in volume as indicated in the formula:

$$\text{Foam capacity} = \frac{(\text{Volume after whipping} - \text{volume before whipping})}{\text{Volume before whipping}} \times 100$$

Determination of least gelation concentration

The least gelation capacity was determined by the method described by Sathe and Salunkhe (1981) using 2, 4, 6, 8, 10, 12, 14, 16, 18 and 20 g/100 mL flour dispersions for each flour in 20 mL test tubes. Least gelation capacity is the minimum concentration at which the cooked and subsequently cooled sample from the inverted tube did not fall or slip from wall of the tube (Joshi *et al*., 2015).

Determination of swelling power

The method of Sathe and Salunkhe (1981) with slight modification was adopted to determine the swelling power. One gramme of sample was weighed into a previously tarred 50 ml centrifuge tube and 40 ml of 1% (w/v) of suspension was incubated in a water bath at temperatures ranging from 60 to 90 ^{o}C for 15 min. The suspensions were centrifuged at 3000 rpm for 10 min. The supernatant was decanted and the swollen flour sediment was weighed. Swelling power is the ratio of weight of the wet sediment to the initial weight of the dry flour. A 10 ml sample was taken from the supernatant, placed in a crucible and dried in an air oven at 120 ^{o}C until constant weight. Swelling power is the ratio of weight of the wet sediment to the initial weight of the dry flour.

Determination of dispersibility

The dispersibility was measured by the method of Kulkarni *et al.* (1991). Ten gram sample was placed in a stopper measuring cylinder and distilled water was added to reach a volume of 100 ml. The mixture was stirred vigorously and allowed to settle for 3 h. Percentage dispersibility was calculated as the difference of volume of settled particles subtracted from 100.

Determination of protein solubility

Protein solubility of flour samples was determined according to the method of Elkhalifa and Bernhardt (2010) with slight modifications in terms of the pH and volume of distilled water used. A 1 g of sample was mixed with 50 ml of distilled water. The dispersion was adjusted to pH 6 with 0.1 M NaOH or HCl using a pH meter (PHS-25, TECHMEL, USA). The dispersion was shaken continuously for 1 h and centrifuged at 2000 rpm for 20 min. The supernatant was collected and the protein content of the supernatants was determined (AOAC, 2000).

Determination of gel consistency and paste clarity

The method of Elkhalifa and Bernhardt (2013) was adopted in the determination of gel consistency and paste clarity.

Determination freeze thaw stability or syneresis

Freeze thaw stability of samples was measured using 6 % (w/w) *moringa* seed flour paste following the method reported by by Eliasson and Ryang (1992) with slight modification. The flour suspension was heated at 95 ^{o}C for 15 min to form paste. A 50 mL of aliquot was placed in centrifuge tubes and capped tightly. The samples were conditioned at -10 ^{o}C for 5 days followed by thawing in a water bath for 60 min. Samples were centrifuged at 8000 x g for 10 min after which any clear supernatant liquid (syneresis) was decanted as the ratio of the weight of the liquid decanted and the total weight of the gel before centrifugation multiplied by 100.

Determination of pasting analysis

Pasting properties of rice flours were determined using rapid visco analyser (RVA) (Newport Scientific Pty Ltd., Warriewood, Australia) according to the

method of AACC (2000). A 2.5 g of flour were weighed into a dried empty canister; then 25 ml of distilled water was dispensed into the canister containing the sample. The suspension was thoroughly mixed and the canister was fitted into the rapid visco analyzer. Each suspension was kept at 50 ^{o}C for 1 min and then heated up to 95 ^{o}C at 12.2 ^{o}C /min and held for 2.5 min at 95 ^{o}C. It was then cooled to 50 ^{o}C at 11.8 ^{o}C /min and kept for 2 min at 50 ^{o}C. The RVA parameters determined include: peak viscosity (maximum paste viscosity achieved in stage 2, the heating stage of the profile), final viscosity (viscosity at the end of run), break down viscosity (difference between peak viscosity and trough), set back viscosity (difference between final viscosity and trough), pasting temperature (temperature at which starch granules begin to swell and gelatinize due to water uptake) and peak time (time at which peak viscosity was recorded) (Marston *et al*., 2016).

Statistical analysis

Data obtained from analysis of proximate composition and functional parameters were subjected to analysis of variance. Differences among mean values were compared by Tukey tests at 5 % probability level. All computations were done using statistical software (SPSS version 11)

RESULTS

The proximate composition of native and germinated *moringa* seed flour samples is presented in Table 1. The protein and ash contents increased significantly ($p<0.05$) from 35.76 to 39.41 %, and 3.85 to 4.92 %, respectively, with an increase in germination period. On the other hand, fat, crude fiber and carbohydrate contents were significantly ($p<0.05$) higher in the non-germinated *moringa* seed flour but decreased with an increase in germination time from 9.14 to 7.09 %, 5.22 to 3.10 % and 38.02 to 35.95 %, respectively.

The functional properties of native and germinated *moringa* seed flour are presented in Table 2. Water absorption capacity of *moringa* seed flour increased significantly ($p<0.05$) from 2.25 to 5.90 % after 72h germination. The native *moringa* seed flour had the lowest oil absorption capacity value (1.37 g/g) which increased with an increase in germination time. Bulk density ranged from 0.56 to 0.69 g/cm^{3}and showed no significant ($p>0.05$) difference. The foaming capacity of the flour varied significantly ($p<0.05$) from 41.09 % (non-germinated flour) to 73.25 % (at 72 h germination time). Germinated *moringa* seed flour had lower emulsion capacity value than the native *moringa* seed flour. Native *moringa* seed flour had emulsion capacity of 26.43 % which decreased significantly ($P< 0.05$) to 15.90 % after 72 h germination (Table 2). The ative *moringa* seed flour had higher dispersibility value (34.88 %) than the germinated flour. Dispersibility value decreased significantly ($p<0.05$) from 34.88 to 21.47 %) with increase in the germination time. The protein solubility value of *moringa* seed flour ranged from 32.50 to 75.52 %. The native *moringa* seed flour had lower protein solubility value (32.50 %) than the germinated flour samples (48.63 to 75.52 %).

The effect of germination on the pasting characteristics of *moringa* seed flour is presented in Table 2. The peak, trough, breakdown, final and setback viscosities decreased significantly ($p>0.05$) from 134.75 to 81.04 RVU, 83.42 to 54.38 RVU, 51.33 to 26.66 RVU, 160.56 to 94.30 RVU, and 77.14 to 39.92 RVU, respectively, with increase in germination time. The native *moringa* seed flour had the highest value while flour germinated at 72 h had the lowest peak viscosity value. Peak time

ranged from 5.04 min (for 72 h germinated *moringa* seed flour) to 5.26 min (for native *moringa* seed flour). Pasting temperature ranged between 65.93 ^{o}C (for native flour) and 69.70 ^{o}C (for 72 h germinated flour). The least gelation concentrations for germinated samples were 12, 10 and 10 % for 24, 48 and 72 h germination, respectively (Table 3). *Moringa* seed flour had lower swelling power at 60 °C than at 90 °C (Figure 1a). Freeze thaw stability of *moringa* seed flour as influenced by germination time is presented in Figure 1b. The native *moringa* seed flour had the lowest syneresis value while germinated flour had the highest value. The stability and clarity of germinated and non-germinated *moringa* seed flour pastes are s presented in Figure 1b. There were significant ($P<0.05$) differences in the paste clarity between native *moringa* seed flour and germinated flours.

Table 1 Effect of germination on the proximate composition of *moringa* seed flour

Parameter (%)	**0 h**	**24 h**	**48 h**	**72 h**
Moisture	8.01±0.04^{b}	8.77±0.10^{ab}	9.45±0.26^{a}	9.53±0.19^{a}
Protein	35.76±0.15^{c}	37.19±0.23^{b}	38.83±0.47^{a}	39.41±0.28^{a}
Fat	9.14±0.11^{a}	8.05±0.08^{b}	7.52±0.05^{bc}	7.09±0.03^{c}
Crude fiber	5.22±0.03^{a}	4.19±0.01^{b}	3.60±0.08^{bc}	3.10±0.01^{c}
Ash	3.85±0.15^{b}	4.23±0.04^{ab}	4.79±0.10^{a}	4.92±0.06^{a}
Carbohydrate)	38.02±0.65^{a}	37.57±0.73 ^{b}	35.82±0.35^{c}	35.95±0.80^{d}

Mean=± standard=deviation of three replications.
Means within a row with the same superscript were not significantly different (p>0.05).

Table 2 Effect of germination on some selected functional properties of *moringa* seed flour

Parameter	**0 h**	**24 h**	**48 h**	**72 h**
Water absorption capacity (g/g)	2.25 ± 0.04^{d}	3.38 ± 0.01^{c}	4.72 ± 0.03^{b}	5.90 ± 0.10^{a}
Oil absorption capacity (g/g)	1.37 ± 0.00^{a}	1.54 ± 0.02^{a}	1.86 ± 0.0^{a}	2.01 ± 0.01^{a}
Bulk density (g/cm^{3})	0.69 ± 0.03^{a}	0.65 ± 0.01^{a}	0.61 ± 0.01^{a}	0.56 ± 0.01^{a}
Foam capacity (%)	41.09 ± 0.84^{d}	54.39 ± 0.91^{c}	67.44 ± 0.75^{b}	73.25 ± 0.58^{a}
Emulsion capacity (%)	26.43 ± 0.07^{a}	21.16 ± 0.12^{b}	19.25 ± 0.63^{c}	15.90 ± 0.57^{d}
Dispersability (%)	34.88 ± 0.25^{a}	31.10 ± 0.39^{b}	25.03 ± 0.49^{c}	21.47 ± 0.67^{d}
Protein solubility (%)	32.50 ± 0.37^{a}	48.63 ± 0.72^{b}	63.45 ± 0.60^{c}	75.52 ± 0.84^{d}
Peak viscosity (RVU)	134.75± 0.63^{a}	125.10 ± 0.59^{b}	98.29 ± 0.70^{c}	81.04 ± 0.24^{d}
Trough viscosity (RVU)	83.42 ± 0.75^{a}	74.68 ± 0.22^{b}	66.65 ± 0.51^{c}	54.38 ± 0.72^{d}
Breakdown viscosity (RVU)	51.33 ± 0.49^{a}	50.42 ± 0.57^{b}	31.62 ± 0.30^{c}	26.66 ± 0.69^{d}
Final viscosity (RVU)	160.56 ±0.85^{a}	142.90 ± 0.90^{b}	109.77 ± 0.23^{c}	94.30 ± 0.46^{d}
Setback viscosity (RVU)	77.14 ± 0.85^{a}	68.22 ± 0.45^{b}	43.12 ± 0.55^{c}	39.92 ± 0.50^{d}
Peak time (min)	5.26 ± 0.47^{a}	5.18 ± 0.81^{a}	5.10 ± 0.09^{a}	5.04 ± 0.03^{a}
Pasting temperature (^{o}C)	69.70 ± 0.23^{a}	68.29 ± 0.97^{b}	66.93 ± 0.81^{c}	65.77 ± 0.29^{d}

Mean=and standard=deviation of three=determinations.
Mean=value with different=superscript in a row=are significantly ($P \leq 0.05$) different=from each=other.

Table 3: Effect of germination on the least gelation concentration of *moringa* seed flour

Concentration (%)	**0 h**	**24 h**	**48 h**	**72 h**
2	-	-	-	-
4	-	-	-	-
6	-	-	-	-
8	-	-	-	-
10	-	-	±	±
12	-	±	±	±
14	-	±	±	±
16	±	±	±	±
18	±	±	±	±
20	±	±	±	±

Dash (-): no gel formation; +: gel formed

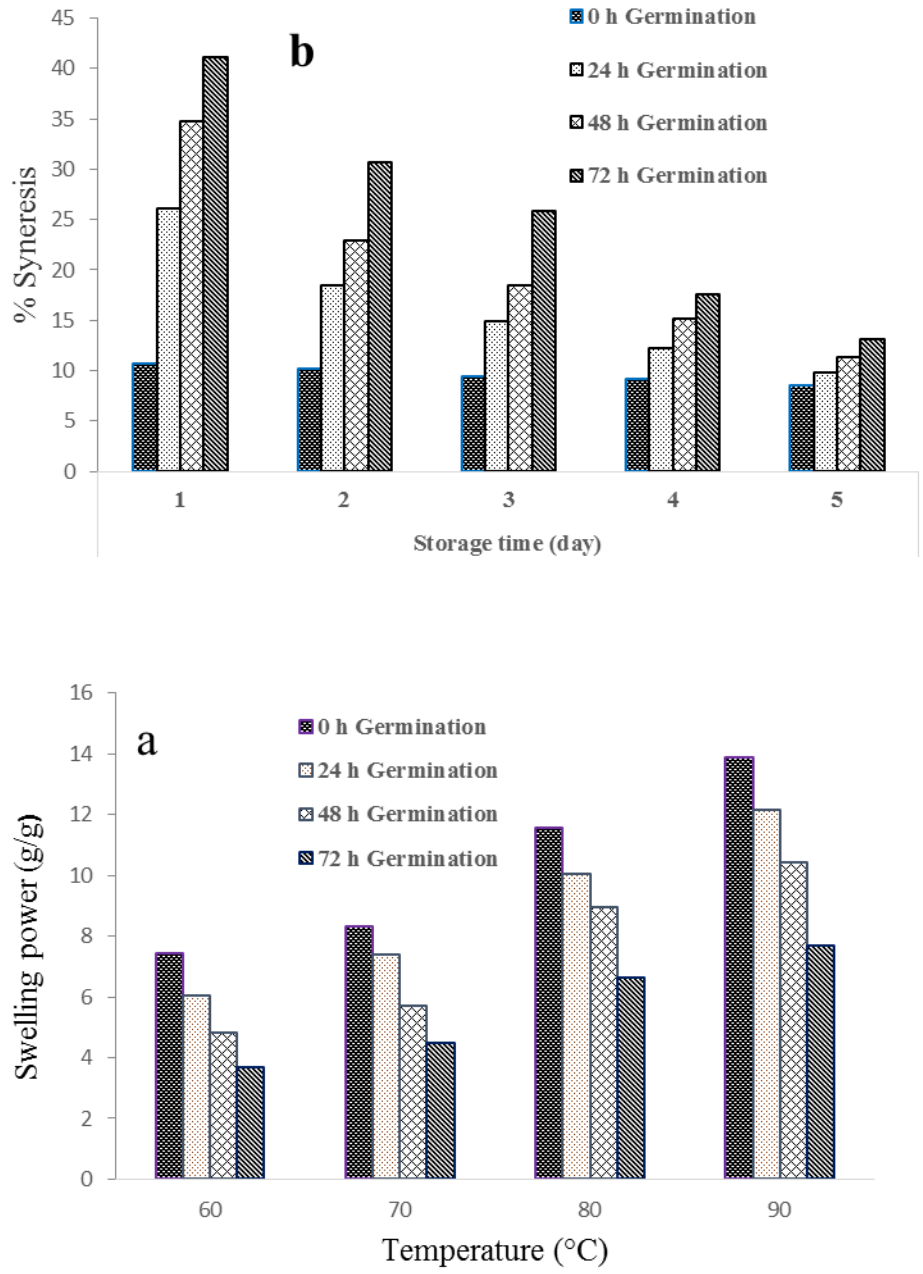

Figure 1. Swelling power (a) and freeze thaw stability (b) of native and germinated *moringa* seed flour

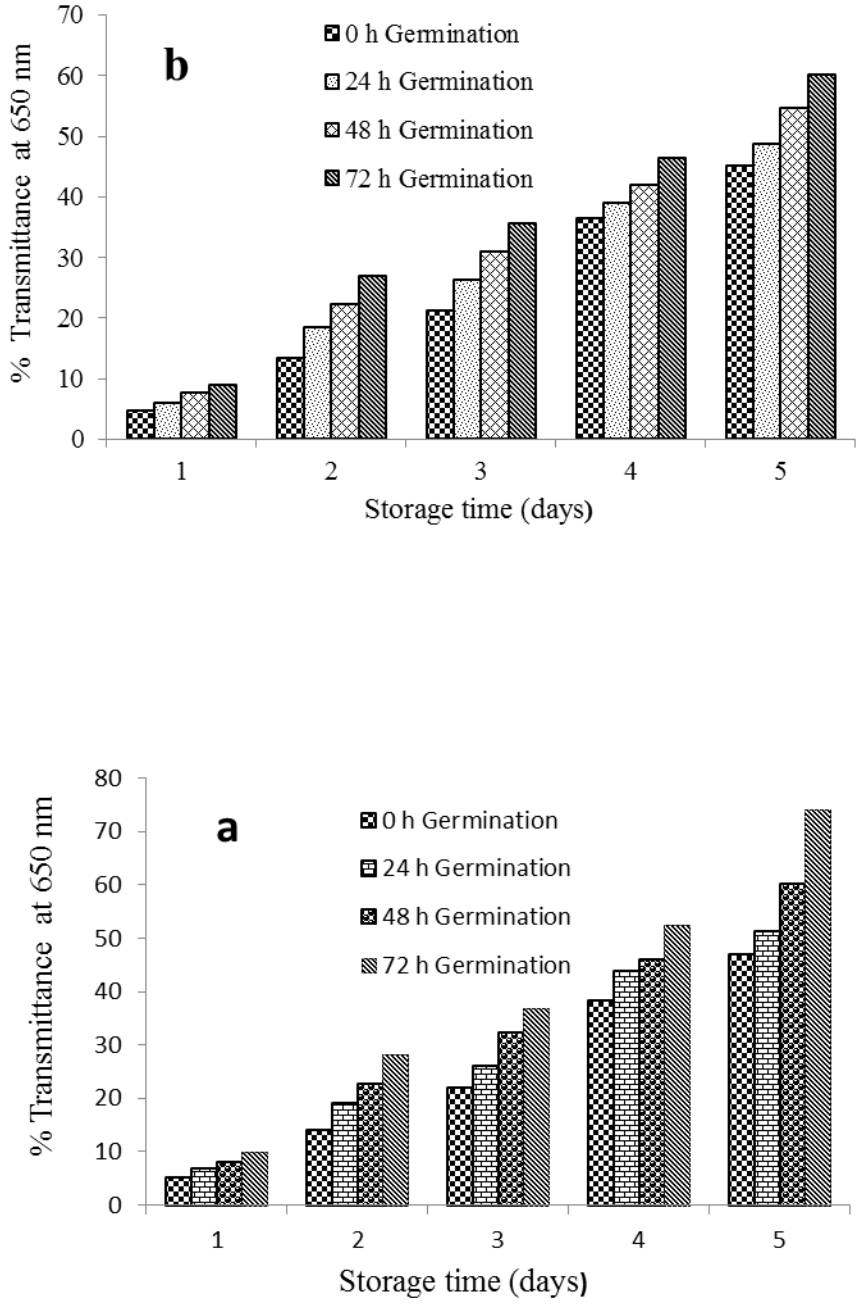

Figure 2. Clarity of starch from germinated and native *moringa* seed flour pastes (1%, w/v) stored at (a) 27 °C and at (b) 4 °C measured as percentage transmittance at 650 nm.

DISCUSSION

Proximate composition of flour plays a crucial role in determining the nutritional importance of flour (Singh *et al*., 2017). Germinated *moringa* seed flour had significantly higher ($p<0.05$) moisture value than the native *moringa* seed flour. This could be due to absorption of water by the

moringa seeds during imbibition. The significant increase in protein content as germination time increased may be attributed to increase in protease activity which results in synthesis of more proteins (Sibian *et al*., 2017; Xu *et al.*, 2017). The higher ash content of germinated *moringa* seed flour compared to the raw *moringa* seed flour could be ascribed to decrease in total soluble solids and probably due to loss of dry matter (Chinma *et al*., 2015). The decrease in fat content could be due to the use of crude fat as a source of energy during germination of the *moringa* seeds. The reduction in carbohydrate content may be attributed to the breakdown of carbohydrate into simple sugars and oligosaccharides by the f enzymes elaborated during the germination (Enujiugha *et al*., 2003). Sritongtae *et al*. (2017) reported that during the germination of rice bean, the protein and ash contents increased from 21.62 to 24.57 % and 5.44 to 6.19 %, respectively while crude fat and carbohydrate contents decreased from 1.30 to 0.55 %, and 72.37 to 68.74 %, respectively after germination for over 24 h.

Water absorption capacity of flour plays a critical role in food preparation since it affects the functional and sensory properties of food product. Water absorption capacity of *moringa* seed flour increased significantly from 2.25 to 5.90 % after 72 h germination. This may be attributed to the breakdown of polysaccharides with more hydrophilic sites. Kaur and Singh (2005) reported that legume flour containing several water-loving components such as polysaccharides; generally have high water absorption capacity. Also, the increase in water absorption capacity may be attributed to increase in low molecular weight proteins and increase in the number of polar groups on the proteins upon germination. The protein quality of flours also affects their water absorption capacity (Kaur and Singh, 2005). Ghumman *et al*. (2016) reported that during germination of pulses, water absorption capacity of non-germinated and germinated flours increased from 1.2 to 1.9 g/g and 1.1 to 2.7 g/g, respectively for lentils and 1.5 to 1.9 g/g and 1.8 to 2.6 g/g, respectively for horsegram flours over 96 h. values which were lower than the values obtained in this study. Ijarotimi *et al*. (2013) reported no change in water absorption capacity value ofnative and the 96 h germinated *moringa* seed flour n. The present study showed that germinated *moringa* seed flour had higher water absorption capacity than the native flour. The high water absorption capacity of germinated *moringa* seed flours suggests that the flours may find application in food preparations where water absorption is required. Granito *et al*. (2004) reported that water absorption capacity is considered a functional property of proteins which could be useful in viscous foods such as soups, sauces, doughs, and in baked products in which a good protein-water interaction is required.

Oil absorption capacity of *moringa* seeds flour increased by 46 % after 72 h germination period. The availability of surface hydrophobic proteins and other non-polar side chains play the main role in the binding of oil(incite ref). Germination probably increased the oil absorption capacity by unmasking the non-polar residue from the interior of protein (Benítez *et al*., 2013). The mechanism of oil absorption involves capillarity interaction which allows the absorbed oil to be retained (Du *et al*., 2014). Ghavidel and Prakash (2006) reported that oil absorption capacity increased in cowpea, green gram, lentil and bengal gram after germination. The high oil absorption capacity of germinated *moringa* seed flour suggests that the flour is

potentially useful in foods where high oil absorption capacity is desired. High oil absorption capacity of legume flour is potentially useful in food applications, especially in flavor retention, palatability improvement and extension of shelf life in meat products through reduction of moisture and fat loss (Chel-Guerrero *et al*., 2002). Oil absorption capacity of flour is important because it contributes to flavor and texture of food products

Although, no significant difference ($p \geq 0.05$) was observed between the native *moringa* seed flour and the germinated flour.There was a gradual decrease in oil absorption capacity with increase in the germination time. This could be attributed to starch modification and dispersability of flour particles probably caused by germination of the seeds. Bulk density is a measure of heaviness of flour particles which is important in packaging and depends on the structural characteristics of the product, the particle size and their distribution, and is related to other physicochemical properties (Benítez *et al*., 2013; Singh *et al*., 2017). Similar observations on low bulk density of flours caused by germination have been reported by Ghavidel and Prakash (2006) for green gram, cowpea, lentil and bengal gram. Singh *et al*. (2017) reported a reduction (f0.72 to 0.65) in bulk density after 48 h germination of sorghum flour. The low bulk density of germinated *moringa* seed flour would be of advantage in the formulation of weaning foods, where low bulk density is desirable. The bulk density of a weaning food formulation prepared from sorghum and cowpea flour blends was reduced by 12 % compared to the native flour (Malleshi *et al*., 1989).

Foaming capacity of flour samples increased with increase in germination time. Germination may have cause surface denaturation of proteins which probably lowered lower the surface tension of the molecules (Elkhalifa and Bernhardt, 2010). The increase in foaming capacity of germinated *moringa* seed flour could be attributed to the decrease in interfacial surface tension between air and water(Elkhalifa and Bernhardt, 2010). This could lead to absorption of soluble proteins thereby permitting hydrophobic interactions, and hence the good foamability. The foamability of a food material is dependent on the surface active properties of its protein (Udensi and Okoronkwo, 2006; Sathe *et al*., 1982). Studies by Ghumman *et al*. (2016) showed that germination increased foaming capacity of lentil and horsegram flours from 16.1 to 23.3 % and from 13.3 to 26.7 %, respectively. Singh et al. (2017) reported that foaming capacity increased in sorghum flour after 48 h germination. The foaming capacity value (41.09 to 73.25 %) obtained in this study was higher than the value (25.93 %) reported by Ijarotimi et al. (2013) for *moringa* seeds 96 h germination..

Germinated *moringa* seed flour had lower emulsion capacity than the native *moringa* seed flour. Sathe and Salunkhe (1981) reported that great northern beans albumin fraction was more effective in forming oil emulsion than the globulin fraction. Cserhalmi *et al*. (1998) reported that vicilin protein in the globulin fraction of peas had better emulsion properties than the albumins due to the high surface hydrophobicity of the vicilin fraction. Ghumman *et al*. (2016) reported that emulsion activity of lentil and horsegram decreased with increase in germination time. Benítez *et al*. (2013) reported that germinated legume flours showed a reduction of emulsifying activity in non-conventional legumes (*Vigna unguiculata, Canavalia ensiformis, Stizolobium niveum, Lablab purpureus*). The

high emulsion capacity of native *moringa* seed flour would be useful in foods such as comminuted meat products, salad dressings among others where emulsion property is an important consideration.

The high dispersibility v (34.88 %) of the native flour compared to germinated flour samples may be attributed to the activity of amylase enzyme which probably broke down starch into simple units (glucose). This may have resulted in reduction of viscosity of the germinated *moringa* seed flours. This also probably affected the starch solubility which decreased the flour dispersability value.

Protein solubility of *moringa* seed flour was determined at pH 6 based on the earlier reports of Ogunsina *et al*. (2010) where maximum solubility of defatted and fullfat *moringa* seed flour was observed at pH of 6. The protein solubility of *moringa* seed flour increased significantly ($p<0.05$) with increase in the germination time. The increase in protein solubility may be attributed to degradation of the storage proteins into free amino acids and short peptides due to higher proteolytic activity of protease enzymes. This probably improved the protein solubility of flour during germination (Singh and Sharma, 2017). These authors further reported that increase in protein solubility after germination results in enhancement of the nutritive value by increasing the *in vitro* protein digestibility. Elkhalifa and Bernhardt (2010) reported that the highest protein solubility value of germinated sorghum occurred at pH 6 and values obtained ranged from 46.24 to 90.69 % during 5 days germination. The high protein solubility of germinated *moringa* seed flour lends the flour for use in foods such as beverages where maximum solubility of protein is required.

Pasting properties of *moringa* seed flour was influenced by germination time. The reduction in peak viscosity, trough viscosity, breakdown viscosity, final viscosity and setback viscosity after germination may be attributed to starch degradation caused by α-amylase activity and protein hydrolysis by protease (Xu *et al*., 2017). Peak viscosity is an index of the ability of starch-based products to swell freely before their physical breakdown (Sanni *et al*., 2008). Trough viscosity is a measure of the ability of the paste to withstand breakdown during cooking and mechanical shear (Alamu *et al*., 2017). Breakdown viscosity indicates the paste stability of starch (Fernanadez de Tonella and Berry, 1989). Low breakdown value indicates that the flour could withstand heat and high mechanical shear conditions and less prone to viscosity loss upon shearing. The low viscosity value of germinated *moringa* seed flour could suggest its suitability for use in baked products. Final viscosity is an indication of re-association of starch during holding time after gelatinization and formation of gel network (Chanapamokkhot and Thongngam, 2007). Setback viscosity is an indication of how starches retrograde in flour paste during cooling and it is used to measure the staling rate of products made from such flour (Adeyemi and Idowu, 1990). The higher the setback viscosity, the lower the retrogradation of the flour pastes. Peak time, which is an indication of cooking time, decreased with increase in germination time. Peak time showed no significant difference ($P \geq 0.05$) between native and germinated *moringa* seed flour. Pasting temperature is an indication of the gelatinization time during processing (Alamu *et al.*, 2017). Pasting temperature decreased with increase in germination time. The high pasting temperature obtained from non-germinated *moringa* seed flour is an indication of the presence of starch that is highly resistant to

swelling. The pasting temperature obtained in this study is in close range with the values (63.85 to 65.08 ^{o}C) reported by Chinma *et al*. (2009) for germinated flour from yellow and brown varieties of tiger nut seeds. Ghumman *et al.* (2016) and Xu *et al*. (2017) observed a reduction in peak viscosity, trough viscosity, breakdown viscosity, final viscosity and setback viscosity with increase in germination time in lentil and horsegram flour, and adley flour, respectively.

Native *moringa* seed flour did not show good gelation capacity since it exhibited high least gelation capacity at 16 %. However, the gelation capcity was improved after germination (Table 3). Germination led to changes in protein, carbohydrate and lipids in this study which probably accounted for the variation in gel formation when compared to the native flour. Gelation property is not only a function of protein quality, but also the type of protein and its non-protein components (starch and lipids) (Sathe and Salunkhe, 1981). Ogunsina *et al*. (2010) reported a minimum gel concentration of 14 % and 16 % for defatted and fullfat *moringa* kernel flour, respectively.

Swelling power is the ability of flour to absorb water and swell under precise conditions (ref). Swelling power of flour samples were influenced by germination time, and increased with increase in temperature. This could be due to water uptake by the granule which gelatinizes the starch. As the temperature increased, intermolecular bonds between the starch granules pare broken down due to vibrational force, hence allowing hydrogen-bonding sites to engage more water molecules (Claver *et al*., 2010). The swelling power of the native *moringa* seed flour was significantly higher ($p \leq 0.05$) than that of the germinated flour at different temperatures and germination time. The swelling power of *moringa* seed flour decreased significantly ($p \leq 0.05$) with increase in germination time to reach a minimum value at 72 h. Similar observation was reported for non-conventional legume flours (Benítez *et al*., 2013). This decrease could be due to loss of starch, since swelling power is related to the level of starch (amylopectin) which probably decreased as a result of the metabolic activity during germination.

Freeze thaw stability or syneresis is the exudation of liquid from the gel at low temperature and indicates the level of starch retrogradation. The percentage syneresis of flour increased with increase in the germination time. During the first day of storage, native *moringa* seed flour had the lowest percentage syneresis value of 10.48 %, which increased significantly ($p \leq 0.05$) to a maximum value of 41.03 % after 72 h germination. The syneresis of the flour decreased significantly ($p \leq 0.05$) with increase in storage time.The high syneresis of the germinated *moringa* seed flour may be due to starch depolymerization. Starch depolymerization probaly occurred which results in more syneresis (Elkhalifa and Bernhardt, 2013; Singh *et al*., 2017). The syneresis revealed that native and germinated *moringa* seed flour would not be a useful ingredient in frozen food preparations.

Germinated *moringa* seed flour paste had higher paste clarity value than the native flour paste which suggests that native *moringa* flour can easily undergo retrogradation. Nwokocha *et al*. (2009) attributed retrogradation of starch paste to low paste clarity. The % transmittance of *moringa* seed flour paste was higher at room temperature than at lower temperature, which implies that lower temperature promoted starch retrogradation. Storage at

low temperature might have resulted in the formation of less perfect crystallites than storage at room temperature, and in higher rate of aggregation of amylose chains that led to decrease in % transmittance (Elkhalifa and Bernhardt, 2013). Germinated *moringa* seed flour had increased % transmittance compared to the native *moringa* seed flour. This observation was in agreement with the report by Elkhalifa and Bernhardt (2013) for germinated sorghum flour. Contrary to our result, Singh *et al.* (2017) reported higher % transmittance for native sorghum flour and attributed it to higher swelling power. In this study, swelling power was higher for the native *moringa* seed flour than the germinated flour.

CONCLUSION

Germination of *moringa* seed flour resulted in increased protein and ash contents while fat, crude fiber and carbohydrate contents decreased. The water and oil absorption capacities, foam capacity, protein solubility and gelation capacity of *moringa* seed flour increased significantly with increase in the germination time while bulk density, emulsion capacity, dispersibility and swelling power decreased. The percentage syneresis of the flour increased with increase in germination time. Germinated *moringa* seed flour paste had higher paste clarity than the native flour paste. The transmittance of *moringa* seed flour paste was higher at room temperature than at lower temperature. Germination of *moringa* seed flour reduced the viscosity. The improved functional properties of the germinated *moringa* seed flour could be utilized in food systems where natural modified flour is required rather than chemically or thermally modified *moringa* seed flour.

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