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Functional Properties of Cowpea (*Vigna unguiculata*) Flour preserved with Mixtures of Neem (*Azadichata Indica A.*Juss) and Moringa (*Moringa Oleifera*) Seed Oils

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Abstract: Most pesticides used in cowpea have some effects on the utilization of the grains. There is a need for a functional biopesticide that will have no adverse effect on cowpea utilisation or application in food system. This study was carried out to evaluate the functional properties of cowpea grains preserved with mixtures of neem and moringa oils. Graded mixtures and concentrations of neem and moringa seed oils (ratio 1:2/2.5µl/g, 1:2/5.0µl/g, 1.3/2.5µl/g, and 1:3/5.0µl/g) were investigated. Cowpea grains were treated with the seed oils in ratio 1:2 and 1:3 at concentrations of 2.5 and 5.0 µl/g, and stored for a period of 270 days. The functional properties (bulk density, foaming property and stability, emulsification capacity, oil and water absorption capacity, viscosity and least gelation concentration) of the differently treated grains were determined every 90 days. The data obtained was subjected to analysis of variance using SAS version 9.2 and means that were significantly different were compared using Least Significant Difference at $P \leq 0.05$. The results showed that there were no significant ($P \leq 0.05$) differences between the functional properties of the cowpea flours from grains treated with ratio 1:3/2.5µl/g and 1:3/5.0µl/g but significant differences were observed in the bulk density, emulsification capacity, foaming capacity, least gelation capacity, water absorption capacity and viscosity of the flours from cowpea grains treated with ratio 1:2/5.0µl/g and the control . There were Ssignificant ($P \leq 0.05$) reduction in the bulk density, emulsification capacity, foam capacity, oil absorption capacity, viscosity and water absorption capacity of the treated cowpea flour as storage progressed except for the gelatinization temperature that was the same throughout the period.. Preservation of cowpea grains with ratio 1:3/5.0µl/g neem-moringa seed oil retained best functional properties of the treated cowpea grains flour thus showing that it has potential to be applied for cowpea preservation without compromising the desired functional properties.

Keywords: Cowpea, functional properties, preservation, cowpea flour, neem and moringa oils

Introduction

Dry cowpea *(Vigna unguiculata L. Walp)* grains form an important component of the diet of many population groups around the world (Singh *et al.*, 1995). This food legume is readily available, inexpensive and a popular part of traditional food system. Cowpeas along with other legumes are recognized as important sources of protein (Agazounon *et al.*, 2004). The grains and leaves are the sources of carbohydrates, proteins, fats and β-carotene. The high protein content represents a major advantage in the use of cowpea in nutritional products, for infant and children's food, and to compensate for the large proportion of carbohydrates often ingested in African diets (Oyeyinka *et al.*, 2013). Cowpea is especially rich in lysine, but it is deficient in sulphur containing amino acids. Compare to other legumes, its methionine and tryptophan levels are higher. Cooked ground cowpea product makes nutrition innovation a reality. Cowpea flours, in particular, are cost-effective and versatile and can be used in nearly any application such as in snack foods, biscuit, dips and even cookies. Cowpea flour offers the same nutritional benefits as whole, prepared cowpea (Mitchell, 2009).

While nutritional quality is ultimately important in considering cowpea flour as a food ingredient, its

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successful performance depend largely on functional characteristics imparted to the final products (Mc Watters *et al.*, 1995). The versatility of cowpea flour suggests the need for a better understanding of its functional properties. However, certain percentages of cowpea produced in Nigeria are lost annually due to insect infestation. Although chemical insecticides have been the most efficient and effective means of protection of stored produce the increase in cost of chemicals, the associated environmental and health hazards, poor method of application of these chemicals and the increased demand for hygienic food supply have stimulated a search for alternative means of controlling stored product pests (Ilesanmi, 2015). Presently, research efforts are directed towards the use of biopesticides because they are believed to be safer and more environmental friendly. Ilesanmi and Gumgla (2010) preserved cowpea grains with the mixture of neem and moringa seed oils and the palatability and cookability tests indicated high acceptability by panelists. This was what informed the use of mixture of neem and moringa seed oils in various ratios of mix and concentrations in this study for the preservation of cowpea. The objective of this study was to determine changes in functional properties of stored cowpea as affected by treatment with mixtures of neem and moringa seed oils.

Methodology

Neem and moringa seed oils used in this study were extracted traditionally, using the method of Ilesanmi and Gungula, 2010. The cowpea grains sample were treated with various concentrations (2.5µl/g and 5.0µl/g) of mixture of neem and moringa seed oils in ratio 1:2 and 1:3. The treated cowpea grains were stored for a period of 270 days. During this period functional properties of the cowpeas flour were determined every 90 days.

Determination of Functional Properties of Treated and Untreated Cowpea Flours

Water and oil absorption capacity (WAC/OAC) and bulk density were determined as described by Odoemelam (2005), foam property, emulsification capacity, gelatinization temperature and viscosity were carried out using the method of Onwuka (2005) and gelation capacity was determined as described by Abbey and Ibeh (1988).

Results

Effect of the Mixture of Neem and Moringa Seed Oils on the Functional Properties of Stored Cowpea Grains Flour

The functional properties of cowpea grains treated with graded mixtures of neem and moringa seed oils are presented in Table 1. There were significant variations in the bulk density of the treated cowpea grains when compared with untreated cowpea grains (control). The control had the highest (0.91 g/ml) bulk density followed by the sample treated with ratio 1:3/5.0 µl/g neem – moringa oil, while the cowpea grains treated with ratio 1:2/2.5 µl/g had the lowest (0.80 g/ml) bulk density.

There were no significant differences ($p<0.05$) between the emulsification capacity of the treated cowpea grains and the control except for the cowpea grains treated with ratio 1:2/2.5 µl/g of neem moringa seed oils which was significantly lower in emulsification capacity when compared with the control. Cowpea grains treated with ratio 1:3/5.0 µl/g had the highest (49.14 %) emulsification capacity while the one treated with ratio 1:2/2.5 µl/g had the lowest (44.96 %) mean value.

The control sample had the highest (47.22%) foam capacity followed by sample treated with ratio 1:3/2.5 µl/g neem – moringa seed oils (42.78%) while sample treated with ratio 1:2/5.0 µl/g (38.89%) had the lowest foam capacity (Table 1). There were however no significant ($p<0.05$) variation in the percentage foam capacity of samples treated with ratio 1:3/5.0µl/g neem – moringa seed oil and the control.

There were no significant differences ($p<0.05$) in the gelatinization temperature of the treated cowpea grains and the control. The least (87.56%) gelatinisation temperature was from the cowpea grain treated with ratio 1:2/2.5 µl/g neem – moringa seed oils. There were significant differences ($p<0.05$) in the percentage least gelation capacity of cowpea grains samples treated with ratio 1:2/2.5 µl/g and 1:2/5.0 µl/g of mixture of neem and moringa seed oils compared to the control sample. The least gelation capacity of cowpea grains treated with ratio 1:3/5.0 µl/g was not significantly different ($p<0.05$) from that of the control while cowpea grains treated with ratio 1:3/2.5 µl/g had the highest (9.11%) least gelation capacity and the lowest (7.78%) least gelation capacity was from cowpea grains treated with ratio 1:2/2.5 µl/g neem moringa seed oils.

There were no significant differences $p<0.05$ in the oil absorption capacity of the treated samples and the control except for the sample treated with ratio 1:2/2.5 µl/g that significantly increased in oil absorption when compared with control. Cowpea samples treated with ratio 1:3/2.5 µl/g however had the best (1.06 ml/g) oil absorption capacity while samples treated with ratio 1:2/2.5 µl/g had the least. There were significant differences ($p<0.05$) in the viscosity of the treated samples and control. The treated samples significantly ($p<0.05$) reduced in viscosity. Those cowpea grain samples treated with ratio 1:3 mixture of neem and moringa seed oils were better in viscosity than those treated with ratio 1:2. The control sample had the highest viscosity (1183.80 cP) followed by 1:3/2.5 µl/g treatment (1076 cP) and the lowest (708 cP) in viscosity was the one treated with 1:2/2.5µl/g neem – moringa seed oil.

There were significance differences ($p<0.05$) in the water absorption capacity of untreated cowpea grains flour and the treated cowpea grains flour samples except for the water absorption capacity of samples treated with ratio 1:2/2.5 µl/g neem moringa seed oils which favourably compared with the control (Table 1). The sample treated with ratio 1:2/2.5 µl/g neem – moringa oil had the highest (2.37 ml/g) water absorption capacity while the least (1.60 ml/g) was from the sample treated with ratio 1:3 mixture of neem and moringa seed oil. Generally, samples treated with ratio1:3 mixture of neem –moringa seed oil performed better than those treated with 1:2 mixture of the oil in terms of functional properties.

Table 1: Effects of different Concentrations of Mixtures of Neem and Moringa Seed Oils on the Functional Properties of Stored Cowpea Flour

Treatment	Bulk density (g/ml)	Emulsification capacity (%)	Foam capacity (%)	Gelatinization temperature (ºC)	Least gelation capacity (%)	Oil absorption capacity (ml/g)	Viscosity (cP)	Water absorption capacity (ml/g)
Control	0.91	47.48	47.22	87.78	8.67	1.08	1183.80	2.12
1:2/2.5µl/g	0.80	44.96	39.44	87.56	7.78	1.35	708.00	2.21
1:2/5.0µl/g	0.82	47.43	38.89	87.78	8.00	1.09	951.20	2.37
1:3/2.5µl/g	0.88	46.78	42.78	87.78	9.11	1.06	1073.50	1.89
1:3/5.0µl/g	0.88	49.14	41.67	87.67	8.67	1.19	1046.70	1.89
Mean	0.86	47.16	42.00	87.71	8.44	1.15	992.70	2.10
LSD at 0.05	0.02	1.74	5.36	1.09	0.41	0.11	58.02	0.15
Prob. of F	<0.001	<0.001	0.027	0.990	<0.001	<0.001	<0.001	<0.001

Effect of Storage Period on the Functional Properties of Cowpea Treated with Neem and Moringa Seed Oils

The bulk density of the treated and untreated cowpea flour varied with storage period as shown on Table 2. There were significant differences (p<0.05) in the bulk density of the cowpea flour samples within the periods with value ranging from 0.789 g/ml – 0.911 g/ml. The bulk density significantly (p<0.05) decreased as storage period progressed. In the same vein, there was a significant (p<0.05) decrease in the emulsification capacity of the cowpea flours as storage period progressed with values ranging from 52.29% to 40.47% from 90 – 270 days respectively. There were significant differences (p<0.05) in the foam capacity of cowpea stored for 90 days and those stored for 180 and 270 days but there were no significant differences (p>0.05) in the gelatinization temperature within those periods of storage. The percentage least gelation capacity significantly (p<0.05) increases as the storage period progresses with values ranging from 7.60% - 9.33% at the end of 90 days and 270 days respectively.

The oil absorption capacity of cowpea at various storage periods was highest at 1.245 ml/g at the end of 90 days followed by samples stored for 270 days but the values significantly (p<0.05) dropped at the end of 180 days of storage. The water absorption capacity was highest (2.33 ml/g) at the end of 90 days but there was no significant difference (p<0.05) in the water absorption capacity of the stored cowpea at the end of 180 days and 270 days of storage. At the end of 90 days of storage, the viscosity reduced to 1126.6 cP. This value significantly (p<0.05) dropped (725.4 cP) at 180 days and later picked up (1126.0 cP) at the end of 270 days of storage.

Interaction between Storage Period and Mixture of Neem and Moringa Seed Oils on the Functional Properties of Stored Cowpea Flour

Results of the interaction between storage period; mixture of neem and moringa seed oils on the functional properties of stored cowpea grains are presented in Table 3. At 90 days of storage, cowpea grains treated with ratio 1:3/5.0 µl/g neem – moringa oils recorded the highest bulk density (0.93 g/ml) followed by the cowpea grains treated with ratio 1:3/2.5 µl/g and 1:2/5.0 µl/g that recorded 0.90 and 0.90 g/ml bulk density respectively. Cowpea grains treated with ratio 1:2/2.5 µl/g however had the least bulk density (0.89 g/ml). At 180 days of storage, cowpea grains treated with ratio 1:3/2.5 µl/g recorded the highest bulk density compared with cowpea grains samples treated with ratio 1:3/5.0 µl/g, 1:2/5.0 µl/g which

Table 2: Mean Effect of Storage Period on the Functional Properties of Cowpea Flour Treated with mixture of Neem and Moringa Seed Oils

Period in days	Bulk density (g/ml)	Emulsification capacity (%)	Foam capacity (%)	Gelatinization temperature (ºC)	Least gelation capacity (%)	Oil absorption capacity (ml/g)	Viscosity (cP)	Water absorption capacity (ml/g)
90	0.91	52.29	47.00	88.00	7.60	1.25	1126.60	2.33
180	0.87	48.71	37.67	87.67	8.40	0.99	725.40	1.95
270	0.79	40.47	41.33	87.47	9.33	1.23	1126.00	2.01
Mean	0.86	47.16	42.00	87.71	8.44	1.15	992.70	2.10
LSD at 0.05	0.02	1.35	4.15	0.84	0.32	0.08	44.94	0.12
Prob. of F	<0.001	<0.001	0.027	0.434	<0.001	<0.001	<0.001	<0.001

recorded 0.88 g/ml and 0.86 g/ml bulk density. The least bulk density at that period was from the cowpea treated with ratio 1:2/2.5 µl/g neem – moringa seed oils. Similar trends were observed at 270 days ofstorage.

The combination of 90 days storage period and treatment of cowpea grains samples with neem – moringa oils in the ratio of 1:2/2.5, 1:3/2.5 and 1:3/5.0 µl/g recorded the same values for least gelation capacity (8.0%). The same trend was observed at 180 days in storage while at 270 days ofstorage, cowpea grains treated with ratio 1:3/2.5 µl/g recorded the highest gelation capacity (11.33%) followed by cowpea grains treated with ratio 1:3/5.0 µl/g. The least gelation capacity (7.33%) was however from the cowpea grains treated with ratio 1:2/2.5 µl/g neem – moringa oils.

At 90 days in storage, cowpea grains flour treated with ratio 1:2/2.5 µl/g recorded the highest oil absorption capacity (1.89 ml/g) followed by the cowpea treated cowpea grains flour with ratio 1:3/5.0 µl/g. The least oil absorption capacity (0.86 ml/g) was however recorded from ratio 1:3/2.5 µl/g neem – moringa oils. As storage progressed to 180 days, treated cowpea grains flour with ratio 1:3/2.5 µl/g had the highest oil absorption capacity (1.10 ml/g) compared to the oil absorption capacity from the remaining treated cowpea. The treated cowpea grains flour at 270 days in storage recorded the same value for oil absorption capacity (1.22 ml/g).

At 90 days in storage, storage period interaction with ratio1:2/5.0 µl/g treated cowpea grains recorded the highest viscosity (1277.9 cP) compared to other interactions. The lowest (835.0 cP) was recorded from cowpea grains flour treated with ratio 1:2/2.5µl/g neem – moringa oils. Ratio 1:3/2.5 µl/g treated cowpea grains flour however had higher viscosity (827.2 cP) compared with other treated cowpea samples at the end of 180 days in storage. At 270 days in storage ratio 1:3/5.0 µl/g treated cowpea grains flour had the highest viscosity (1623.0 cP) followed by ratio 1:3/2.5µl/g treated cowpea grains flour with a viscosity value of 1283.9 cP while the least viscosity was from ratio 1:2/2.5 µl/g treated cowpea grains flour.

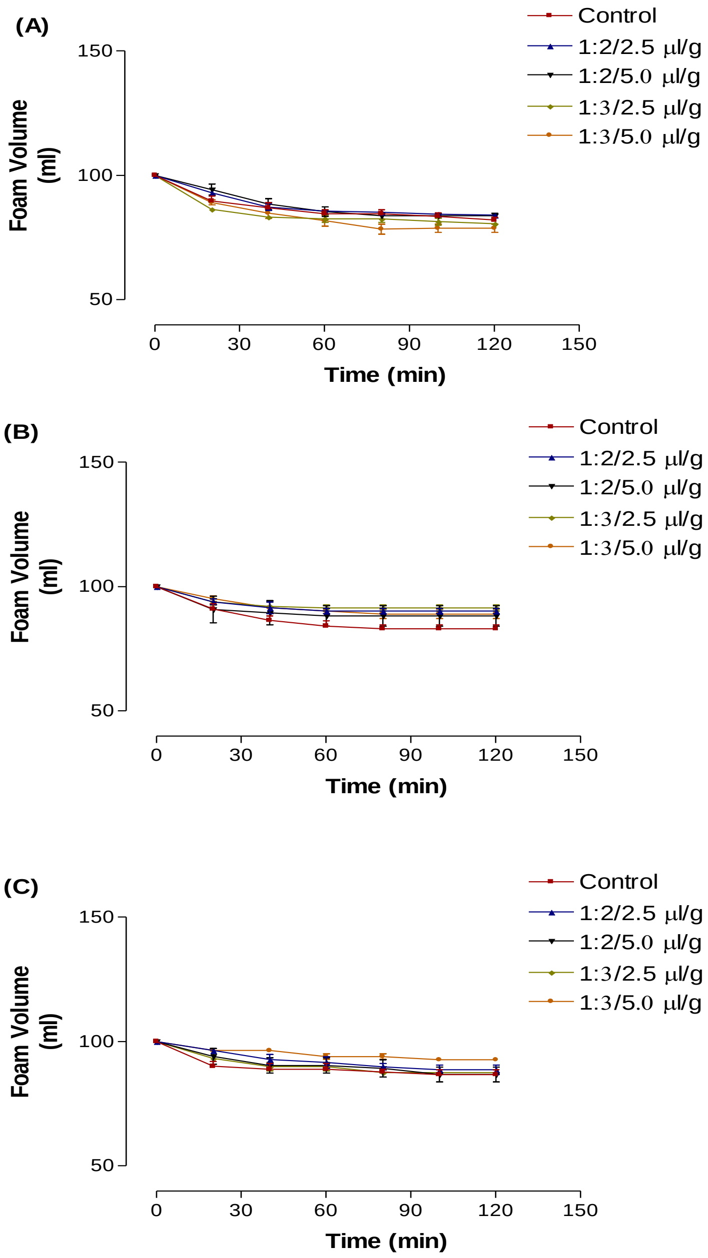
Also, cowpea grains flour treated with ratio 1:2/5.0 µl/g recorded the highest water absorption capacity (2.43 ml/g) followed by ratio 1:3/5.0µl/g treated cowpea grains flour with water absorption capacity of 2.40 ml/g and the least water absorption capacity (2.23 ml/g) was from the ratio 1:2/2.5 µl/g neem – moringa seed oils at the end of 90 days of storage. As storage progressed to 180 days, ratio 1:3/2.5 µl/g treated cowpea grains flour recorded the lowest water absorption capacity (1.60 ml/g) followed by ratio 1:3/5.0 µl/g that had 1.73 ml/g, and at 270 days in storage, ratio 1:3/5.0 µl/g treated cowpea flour absorbed the least quantity of water (1.5 ml/g) followed by ratio 1:3/2.5 µl/g treated cowpea flour with water absorption capacity of 1.80 ml/g. Ratio 1:2/5.0 µl/g treated cowpea grains flour however recorded the highest water absorption capacity (2.53 ml/g).

Table 3: Interaction of Storage Periods and Neem and Moringa Seed Oil Mixtures on the Functional Properties of Cowpea Flour

Period in days	Control	Oil concentration 1:2/2.5µl/g	1:2/5.0µl/g	1:3/2.5µl/g	1:3/5.0µl/g	Mean	LSD at 0.05	Prob. of F
			Bulk density (g/ml)					
90	0.94	0.89	0.90	0.90	0.93			
180	0.93	0.80	0.86	0.89	0.88			
270	0.85	0.71	0.72	0.85	0.82	0.86	0.03	<0.001
			Least gelation capacity (%)					
90	6.00	8.00	8.00	8.00	8.00			
180	10.00	8.00	8.00	8.00	8.00			
270	10.00	7.33	8.00	11.33	10.00	8.44	0.71	<0.001
			Oil absorption capacity (ml/g)					
90	1.07	1.89	1.01	0.86	1.39			
180	0.89	0.95	1.04	1.10	0.95			
270	1.28	1.22	1.22	1.22	1.22	1.15	0.18	<0.001
			Viscosity (cP)					
90	1447.80	835.00	1277.90	1109.50	962.60			
180	969.40	514.00	762.00	827.20	554.40			
270	1134.40	775.00	813.70	1283.90	1623.00	992.70	100.49	<0.001

			Water absorption capacity (ml/g)					
90	2.33	2.23	2.43	2.27	2.40			
180	2.13	2.13	2.13	1.60	1.73			
270	1.90	2.27	2.53	1.80	1.53	2.10	0.27	<0.001

The effect of mixture of neem and moringa seed oils on the foam stability of treated and untreated cowpea flours are as shown in Figure 1 the highest (94.41%) mean foam stability was found in the cowpea flour treated with ratio 1:2/5.0 µl/g neem and moringa seed oils at 20 mins after whipping and the least (83.99%) was found in the cowpea sample treated with ratio 1:2/2.5 µl/g mixture of neem and moringa seed oils at 20 min after whipping. There were however no significant differences ($p<0.05$) at various time of settling in the foam stability of all the cowpea flours at various period of storage. The foam stability



Values are mean ± SEM with n = 3. (Make the graphs bolder and clearer)

Figure 1: Effects of Mixture of Neem and Moringa Seed Oils on Foam Stability of Cowpea Stored for (A) 90, (B) 180 and (C) 270 Days improved as storage period progresses and also the foam stability decreases as the settling time progresses. The percentage foam stability was however highest at every given time for those treated and untreated samples that were stored for 270 days. Percentage foam stability was also higher at every given time for those samples treated with ratio 1:2/5.0 µl/g of mixture of neem and moringa seed oils.

Discussion

Bulk density is an indication of the porosity of a product. The reduction in bulk density of treated and untreated cowpea as storage period progressed is in agreement with the work of Oyeyinka *et al.* (2013) as related to quality attributes of weevil infested cowpea products. The range in values from 0.71g/ml to 0.94g/ml is at par with the report of Oyeyinka *et al.* (2013). Lower bulk density was reported by Falade and Kolawole (2011) and Olapade *et al.* (2004). The different in the bulk density could be attributed to the difference in the particle size of the cowpea flour (Perez, 1997) whereas it was obvious that the bulk density of those treated with ratio 1:2/2.5 µl/g reduced significantly when compared with the control, that of grains treated with 1:3/5.0 µl/g of neem and moringa seed oils favourably compared with the control samples. Based on this finding, it appeared that the inability of this lower concentration (ratio 1:2/2.5 µl/g) of the oils to properly preserve the cowpea sample which lead to infestation of the sample, affected the bulk density as the endosperm of the cowpea grains have been consumed by cowpea bruchid. (Ilesanmi and Gungula, 2010) Also because 1:3/5.0 µl/g neem – moringa seed oil preserved the sample against infestation, the bulk density was not affected.

The fact that there was no significant different between the emulsification capacity of the treated and untreated cowpea flour in this study suggest that treatment with oil does not affect the emulsion properties of the cowpea flour. Only the sample treated with ratio 1:2/2.5 µl/g has its emulsification capacity significantly decreased probably due to its infestation by cowpea weevils. Ojimelukwe *et al.* (1999) in their work on effect of infestation on the nutrient content and physiochemical properties of two cowpea affirmed that infestation by insect pests reduced the emulsification properties of cowpea flour.

The least gelation capacity of the treated and untreated (control) cowpea flour ranging from 6.0% - 11.33% was within the range of 5.5 % – 16% reported for raw cowpea flour by Enwere and Ngoddy (1986); Abbey and Ibeh (1988) and Olaofe *et al.* (1993). Gelation takes place more readily at higher protein concentration because of the greater intermolecular contacts during heating. Since cowpea contains high protein and starch, the least gelation capacity of flours is influenced by physical competition for water between protein gelation and starch gelatinization. The gelling capacity of flour has been attributed to denaturation, aggregation and thermal degradation of starch (Enwere and Ngoddy, 1986). The low gelation capacity therefore observed from cowpea samples treated with ratios 1:2 mixture of neem and moringa seed oils at the end of 270 days of storage showed that the starch granules of the cowpea samples were not affected and this may also be attributed to total available carbohydrate (Odoelemam, 2005)

The water absorption capacity (WAC) of treated and untreated cowpea flour ranges between 1.6 g/ml – 2.53 g/ml. This is similar to the range reported by Falade and Kolawole (2011), Enwere and Ngoddy (1986) for cowpea flours and Adebowale *et al*, (2005) for mucuna beans flour. Water absorption in flour correlates positively with the analysed content and also particle size of the cowpea flour (Adeyemi and Beckley, 1986). Water absorption capacity is an indication of the extent to which protein can be incorporated into food formulation. Increase in water absorption capacity implies high digestibility of the starch and high yield. The water characteristic represent the ability of a product to associate with water under condition where water is limiting, in order to improve its handling characteristics and dough making potentials (Iwe and Onalope 2001). The variation in water absorption capacity within the storage periods may be attributed to variation in the relative humidity within the periods.

The Oil Absorption Capacity (OAC) of treated and untreated cowpea varied with storage periods but were all within the range 0.86 g/ml to 1.27 g/ml reported by Oyeyinka *et al.* (2013) and is also similar to those reported by Falade and Kolawole (2011). These values suggest that the native proteins in the cowpea flours have not been altered. The mechanism of oil absorption involves the physical entrapment of oil by food component and affinity of nonpolar protein side chains for lipids (Kinsella, 1982; Sathe *et al.*, 1982) the OAC of flours is important for the development of new food products as well as their storage stability, particularly for flavour binding and in the development of oxidative rancidity. Generally, the oil and water absorption capacity of cowpea flour is also very important for the determination of the texture of 'moimoi' and the sogginess of 'Akara', which translates to the acceptability and their economic value. The low OAC by these samples are highly desirable as far as flour products are concerned. This functional property determines the amount of flour to make good dough. These findings are in agreement with Adebowale *et al.* (2005) who opined that 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 characteristic of foods and food products.

The foaming capacity of treated and untreated cowpea sample ranged between 37.67% – 47.22%. This is consistent with the report of Abbey and Ibeh (1988) and Odedeji and Oyeleke (2011). At the end of 90 days of storage, there was no significant difference ($p < 0.05$) between the foaming capacity of the treated cowpea and the untreated cowpea; but the foaming capacity of the untreated cowpea flours samples increased as storage progressed to 270 days. The foaming capacity of the treated cowpea flour samples decline at 180 days and remain stable till 270 days, the findings is consistent with the one reported by Adebowale *et al.* (2005) who discovered that the foaming capacity of full fat mucuna beans is lower (between 9.6% – 19.2%) than those of defatted mucuna beans (50% – 84%). Abbey and Ibey (1988) recorded 40% foaming capacity of defatted cowpea flour and lower values for full fat cowpea flour. It was reported that that foamability is related to the rate of decrease of the surface tension of the air/water interface caused by absorption of protein molecules (Sathe *et al.*, 1982). The oil can also increase surface tension which will eventually reduce the foaming capacity of the treated cowpea flour. Graham and Philips (1976) linked good foamability with flexible protein molecules, which reduce surface tension. Low foamability according to Adebowale *et al.* (2005) can be related to highly ordered globular proteins which resist surface denaturation. The basic requirements of proteins as good foaming agents as Adebowale *et al.* (2005) said are the ability to:

i. adsorb rapidly at air - water interface during bubbling
ii. undergo rapid conformational change and re-arrangement at the interface, and
iii. form a cohesive viscoelastic film via intermolecular interactions.

The first two factors according to Adebowale *et al.* (2005) are essential for better foamability whereas the third is important for the stability of the foam. The foaming capacity as recorded from 37.67% to 46.67% for the treated samples showed that the treatment might not have adversely effected the cowpea samples especially in the first 90 days of storage and the result at the end of 180 – 270 days can also be compared favourably with the control even though the oil caused slight reduction in the foam capacity of the treated samples.

The gelatinisation temperature of both treated and untreated cowpea within the periods of storage ranged between 86.67 ºC and 88 ºC, and was similar to those (84 ºC – 88 ºC) reported by Kerr *et al.* (2000) and (79.33 ºC – 84.83 ºC) reported by Ajeigbe *et al.* (2008). The least (86 ºC) gelatinisation temperature was found among those cowpea grains sample treated with lower concentration of the oils. This slight reduction may be due to infestation by cowpea weevils which might have affected the gelling properties of the flour starch granules. Unlike pure starch, cowpea contain 35% – 53% starch and ~ 24% protein (Okechukwu and Rao, 1997) Based on the findings from this study, the treatment with the mixture of neem and moringa seed oils might not have had any adverse effect on the gelatinization temperature of the treated cowpea flour.

The viscosity of treated and untreated cowpea samples within the storage period ranged between 514 cP and 1623 cP. The result showed that as the water absorption capacity decreased at the end of 180 days of storage, the viscosity decreased and as the water absorption capacity picked up at the end of 270 days of storage the viscosity also picked up. It was also observed that the moisture content of the treated cowpea dropped significantly at the end of 180 days of storage and later picked up at the end of 270 days due to variation in relative humidity within the storage period. Odedeji and Oyeleke (2011) reported the same trend of water absorption/viscosity relationship.

Those cowpea grains samples treated with ratio 1:2/2.5 µl/g however recorded the least (514 cP) viscosity while cowpea grains sample treated with ratio 1:3/5.0 µl/g and the highest (16223 cP) throughout the period of storage. This may be due to infestation by cowpea weevils which might have lead to weakness of intermolecular network which might have in turn caused the flour granules to fall apart when gelatinized in hot water thus forming a paste of relatively low viscosity. It might also be due to changes in flour protein interaction (Ohr, 2004). The difference in viscosity may also be due to reduction in protein as a result of carbohydrate and protein interaction (Cherry and McWaters, 1981) as a result of the infestation by cowpea weevils. Ojimelukwe *et al.* (1999) affirmed that infestation of cowpea by weevils reduces its viscosity. The findings revealed that the application of mixture of neem and moringa seed oils may not have any adverse effects on the viscosity of the treated cowpea flour samples.

Foam stability (FS) described the ability of protein to form a strong cohesive film around air vacuole, which resists air diffusion from vacuole. The result of the foam stability of both treated and untreated cowpea flour in this study ranged between 83.91% and 94.41%. This was in the range 83.2% – 98.41% reported by Aremu *et al.* (2008) for bambara groundnut flour and kersting groundnut flour. It is also comparable to 91.0% reported for raw cowpea flour by Padmashrre *et al.* (1987) and 90% for the same raw cowpea flour reported by Ahmed *et al.* (2012). The values of foam stability at the end of 120 minutes for all the samples range between 86% and 87% except the sample treated with ratio 1:2/2.5 µl/g that was 83%. This may mean that the treatment with mixture of neem and moringa seed oils does not adversely affect the foam stability of the treated cowpea flour. Foam stability is important since success of a whipping agent depends on its ability to maintain the whip as long as possible. As evident in this study, the high foam stability of these samples may be the reason behind the high acceptability in terms of sponginess of the Akara and texture of moimoi prepared from these treated samples, as foam stability according to Ngoddy *et al.* (1986) is essential for akara preparation as stable foam according to Oyeyinka (2012) contributes to desired spongy texture which invariably will translate to higher demand of such product by the consumer and will improve the economic value of cowpea preserved with neem and moringa seed oils.

Conclusion

The study concludes that:

i. The preservation of cowpea grains with mixtures of neem and moringa seed oils in ratio 1:2 and 1:3 and at a concentration of 2.5µl/g and 5.0µl/g does not affect the native protein in the cowpea grains as it does not altered the oil absorption capacity, foam capacity and gelation capacity.
ii. The mixture of these oils has no adverse effect on the functional properties, rather the treatment improved most of the functional properties of the treated cowpea flour.

Recommendation

The study recommends preservation of cowpea grains with ratio 1:3 mixture of neem and moringa seed oils for maximum functional benefits of its flour.

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