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Foaming, Water Absorption, Emulsification and Gelation Properties of Kersting's Groundnut (*Kerstingiella geocarpa*) and Bambara Groundnut (*Vigna subterranean*) Flours as Influenced by Neutral Salts and Their Concentrations

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Abstract: Foaming capacity and stability, water absorption capacity; emulsion capacity and stability; and least gelation concentration of kersting's and bambara groundnut flours as influenced by types of salt (NaCl, $NaNO_3$, $NaNO_2$, CH_3COONa and Na_2SO_4) and their concentrations were investigated using standard techniques. The results showed that the highest foaming capacity was recorded for CH_3COONa at 15.0% (w/v) salt concentration in kesting's groundnut while lowest was $NaNO_2$ at 0.5% (w/v) in bambara groundnut flour. Foaming stability values after 8h were types of salt and salt concentrations dependent. The water absorption capacity decreased at various salt concentrations compared with value in distilled deionized water. The best salts for water absorption capacity were $NaNO_2$, CH_3COONa and Na_2SO_4 particularly at 0.5% (w/v) salt concentration. The oil emulsion capacity depended mostly on salt concentration and the type of salt under consideration while oil emulsion stability is better at higher salt concentrations between 5.0-15% (w/v) than lower salt concentrations for the two studied samples. Likewise the least gelation concentration of 12.0% (kersting's groundnut flour) and 14.0% (bambara groundnut flour) in free salt solutions were improved to between 6.0-10% and 8.0-12.0%, respectively in the presence of the salts used.

Key words: Bambara groundnut, functional properties, influence, kersting's groundnut, salt concentrations

Introduction

Many plant proteins usually in the form of protein extracts or seed flours are being investigated and tested for new products such as low cost formulated foods which are nutritious, attractive and acceptable to consumers just like conventional foods from meat, fish and dairy products (Lawhom and Cater, 1971; Lin *et al.*, 1974; McWatters and Cherry, 1977).

Research attention that has been directed towards increasing utilization of plant protein sources for food use includes lima bean (Oshodi and Adeladun, 1993; Chel-Guerrero *et al.*, 2002), cowpea (Olaofe *et al.*, 1993; Aletor and Aladetimi, 1989; Agunbiade and Longe, 1999; Aremu *et al.*, 2005), pigeon pea (Akintayo *et al.*, 1999; Oshodi and Ekperigin, 1989), peanut (Khan *et al.*, 1975; McWatters *et al.*, 1976), sunflower (Huflman *et al*, 1975), African yam bean (Oshodi *et al.*, 1995; Adeyeye, 1997; Akintayo *et al.*, 1998), fluted pumpkin (Fagbemi *et al.*, 2006), scarlet runner bean (Aremu *et al.*, 2006a), chick pea (Liu and Hung, 1998), gila bean (Siddhuraju *et al.*, 2001), faba bean (Kranse *et al.*, 1996) and cashew nut (Fagbemi *et al.*, 2004; Aremu *et al.*, 2006b).

The ultimate success of utilizing plant proteins as ingredients depend largely upon the beneficial qualities they impact to foods which depend largely on their functional properties (Aluko and Yada, 1995). The functionality of plant protein has been reported to be dependent upon the chemical characteristics influence on the functional properties of proteins; these include moisture, temperature, pH, salt concentration, enzymes, chemical additives, mechanical processing, quantity, sequence, rate and time of addition of the ingredients (Johnson, 1970).

In our earlier work, we have presented the origin, the nutritional composition and oil characteristics of kersting's groundnut (*Kerstingiella geocarpa*) and bambara groundnut (*Vigna subterranean*) seeds' flours (Aremu *et al*., 2006c, d, e). Therefore in continuation of our studies on these under-utilized tropical legumes, this article considers the effects of salt types and their concentrations on some functional properties of kersting's and bambara groundnut flours. This would provide useful information to industrialists and others alike on the subsequent incorporation of the studied samples into food products to producing natural, cheap and adaptable functional foods.

Materials and Methods

Collection and treatment of sample: Kersting's and bambara groundnuts were purchased from Nasarawa market in Nasarawa State, Nigeria. The seeds were screened to remove bad ones and stones. Warm water was added to the good seeds and left overnight, manually dehulled, dried in an oven at 45°C, then drymilled to a fine powder. The powdered samples were stored in polythene bags and kept in refrigerator at 4°C prior use. The samples were identified as Kersting's Groundnut Flour (KSGF) and Bambara Groundnut Flour (BBGF). All chemicals used were of analytical grade.

Determination of foaming properties: The foaming capacity and stability were studied by the method of Coffman and Garcia (1977). A known weight of the sample was dispersed in 100 mL distilled water. The resulting solution was homogenized for 5 min at high speed. The volume of foam separated was noted. The total volume remaining at interval of 0.00, 0.50, 1, 2, 3, 4 up to 24th was noted for the study of foaming stability.

$$\text{Foaming capacity (\%)} = \frac{\text{Vol. after homogenization} - \text{Vol. before homogenization}}{\text{Vol. before homogenization}} \frac{x}{1}$$

$$\text{Foaming capacity (\%)} = \frac{\text{Foam volume after time(t)} \times 100}{\text{Initial foam volume} \quad 1}$$

The effect of salt concentration on foaming properties was carried out by replacing distilled and deionized water with various salt concentrations.

Determination of water absorption properties: Water absorption capacity was determined using the method of Sathe and Salunkhe, (1981) as modified by Adebowale *et al*. (2005). Ten milliliter of distilled and deionized water was added to 1.0 g of the sample in a beaker. The suspension was stirred using a magnetic stirrer for 5min. The suspension obtained was thereafter centrifuged at 3500 rpm for 30 min and the supernatant measured in a 10 mL graduated cylinder. The density of water was taken as $1.0gcm^{-3}$. Water absorbed was calculated as the difference between the initial volumes of water added to the sample and the volume of the supernatant. The effects of salts were studied by replacing distilled and deionized water with various salt concentrations. The salts used were $NaNO_3$, NaCl, $NaNO_2$, Na_2SO_4 and CH_3COONa, all British Drug Houses products. The concentration of the various salt solutions used were prepared by weighing 0.5, 1.0, 2.0, 5.0, 10.0 and 15.0 g of the salts which were dissolved in 99.5, 99.0, 98.0, 95.0, 90.0 and 85.0 mL of distilled and deionized water, respectively.

Determination of emulsification properties: Emulsion was prepared using Beuchat (1977) procedure. One gram of sample was blended in a Kenwood major blender with 50 mL distilled and deionized water for 60sec at maximum speed. Executive Chef vegetable oil was added in 5 mL portions with continued blending. A drop in consistency was considered to be the point, at which oil addition was discontinued. The emulsion so prepared was then allowed to stand in a graduated cylinder and the volume of water separated at 1, 2 and 24 h were recorded in mL g^{-1} as emulsion stabilities. The salt effect was studied by replacing distilled and deionized water with various salt concentrations.

Determination of least gelation concentration: Gelation property was investigated using the method described by Coffman and Garcia (1977). Sample suspensions of 2-20% were prepared in distilled water. Ten milliliter of each of the prepared dispersions was transferred into a test tube. It was heated in a boiling water bath for 1 h, followed by rapid cooling in a bath of cold water. The test tubes were further cooled at 4°C for 2 h. The least gelation concentration was determined as the concentration when the sample from the inverted test tube did not slip or fall. The salt effect was studied by replacing distilled and deionized water with various salt concentrations. All the results were mean of triplicate determinations.

Statistical evaluation: The statistical calculations included percentage value, grand mean, standard deviation and coefficient of variation percent.

Results and Discussion

Effect of salt concentrations on foaming property: Effect of salt concentrations on foaming capacity of Kersting's Groundnut Flour (KSGF) and Bambara Groundnut Flour (BBGF) is presented in Table 1. Low Foaming Capacity (FC) variation existed within salt concentrations as depicted by the CV%. The values of FC ranged from 7.8% in BBGF to 32.1% in KSGF (NaCl); 9.6% in BBGF to 26.4% in KSGF ($NaNO_3$); 7.6% in BBGF to 34.0% in KSGF ($NaNO_2$); 15.3% in BBGF to 42.3% in KSGF (CH_3COONa) and 13.5% in BBGF to 41.5% in KSGF (Na_2SO_4). While the highest FC was reported for Na_2SO_4 at 15.0% (w/v) salt concentration found in KSGF and lowest FC was recorded for $NaSO_2$ at 0.5% (w/v) salt concentration in BBGF. Some of the FC values investigated under different salt concentrations are comparable to values reported for varieties of dehulled African yam bean (21.34-48.44%) (Adeyeye and Aye, 1998) and some oil seeds (40-50%) (Olaofe *et al.*, 1994). However, effect of salt on FC was concentration-dependent, as high concentrations of different salt solutions were found to depress foaming. The beneficial effects of low concentration of salt enhance protein solubility whereas high concentrations decrease it (Narayana and Narasinga 1984; Akintayo *et al.*, 1999). Since foam capacity appears to be due to solubilised protein, the differing effects of salt concentrations may be explained on this basis. The high foaming capacity under selective salt concentration will enhance its functionality in its uses for the production of cakes (Johnson *et al.*, 1979; Lee *et al.*, 1993) and whipping

Table 1: Foaming capacity (%) of the seeds flours in various salt solutions

Salt concentration	NaCl		$NaNO_3$		$NaNO_2$		CH_3COONa		Na_2SO_4	
	KSGF	BBGF	KSGF	BBGF	KSGF	BBGF	KSGF	BBGF	KSGF	BBGF
0.0	23.1	15.4	23.1	15.4	23.1	15.4	23.1	15.4	23.1	15.4
0.5	19.2	9.6	26.4	13.5	25.0	7.6	30.8	13.2	36.5	18.9
1.0	32.1	9.6	23.1	13.7	34.0	11.5	30.8	15.3	35.8	13.5
2.0	18.9	13.2	24.1	13.0	26.9	13.2	35.8	17.0	28.8	19.2
5.0	19.2	15.4	22.6	11.8	28.9	11.5	39.6	17.0	35.8	26.2
10.0	26.9	7.8	24.1	9.6	27.5	19.2	22.6	15.4	34.6	32.7
15.0	30.2	9.8	17.0	11.5	28.8	17.6	42.3	17.3	41.5	34.0
Mean	24.2	11.5	22.9	12.7	27.7	13.7	32.1	15.8	33.7	22.8
SD	5.6	3.1	2.9	1.9	3.5	4.0	7.6	1.4	6.0	8.2
CV%	23.1	27.0	12.7	15.0	12.6	29.2	23.6	8.9	17.0	36.0

(%)[a]: w/v; SD: Standard Deviation; CV%: Coefficient of variation percent; KSGF: Kersting's Groundnut Flour, BBGF: Bambara Groundnut Flour

Table 2: Foaming stability (%) after 8 h of the seeds flours in various salt solutions

Salt concentration	NaCl		$NaNO_3$		$NaNO_2$		CH_3COONa		Na_2SO_4	
	KSGF	BBGF	KSGF	BBGF	KSGF	BBGF	KSGF	BBGF	KSGF	BBGF
0.0	91.2	98.4	91.2	98.4	91.2	98.4	91.2	98.4	91.2	98.4
0.5	88.7	93.0	94.7	88.1	86.2	91.6	82.4	91.7	81.7	85.7
1.0	88.6	91.2	82.8	87.9	80.3	91.4	80.9	90.0	83.3	91.5
2.0	85.7	88.3	80.6	87.9	81.8	90.0	79.2	87.1	85.1	87.1
5.0	83.9	83.3	80.0	89.5	79.1	89.7	83.8	87.1	80.1	86.2
10.0	86.4	90.9	83.8	91.2	81.5	83.9	89.2	88.3	80.0	61.4
15.0	76.8	91.1	87.1	89.7	82.1	88.3	83.1	88.5	76.0	76.1
Mean	85.9	90.9	85.7	90.4	83.2	90.5	84.3	90.2	82.5	83.8
SD	4.7	4.6	5.5	3.7	4.2	4.6	4.4	3.9	4.8	11.9
CV%	5.5	5.1	6.4	4.1	5.0	5.1	5.2	4.3	5.8	14.2

(%)[a]: w/v; SD: Standard Deviation; CV%: Coefficient of variation percent; KSGF: Kersting's Groundnut Flour, BBGF: Bambara Groundnut Flour

toppings where foaming is an important property (Kinsella, 1976a,b).

Foaming Stability (FS) values after a period of 8 h are shown in Table 2. Results showed that CV% range values among salt concentrations were close, an indication that they were not seriously varied. The values of FS at the end of two hours periods had been reported in literature for some legumes. The FS for hulled African yam bean seeds ranged between 42.5-43.3% (Adeyeye and Aye, 1989), soy flour (14.6%) and sunflower flour (9.0%) (Lin *et al.*, 1974) and pigeon pea (2.0%) (Oshodi and Ekperigin, 1989), most of our results were greater than these quoted values; and comparable with 91.0% reported for raw cowpea flour (Padmashrre *et al*., 1987) for the same interval. 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 Table 2, the type of salt and their concentrations have a lot of influence on the foam stability of legume flours under study.

Effect of salt concentration on water absorption capacity: Table 3 depicts variation in Water Absorption Capacity (WAC) at different salt concentrations and among various salts. WAC of $NaNO_3$ solution in BBGF is most highly varied with CV, 33.6% while $NaNO_2$ in KSGF recorded lowest variation of CV, 9.8%. Generally all the coefficient of variations (CV%) were low. The best salts for the WAC property were $NaNO_2$, CH_3COONa and Na_2SO_4 particularly at 0.5% (w/v) salt concentration. The values compare favourably with WAC of 130% reported for sunflower flour (Lin *et al.*, 1974), 138% for pigeon pea (Oshodi and Ekperigin, 1989), 100-266% for defatted flours of oil seeds (Ige *et al.*, 1984), 212% for cowpea flour (Olaofe *et al.*, 1993) and 182.0% for benniseed (Oshodi *et al.*, 1999). Liquid retention is an index of the ability of proteins to absorb and retain water which in turn influences the texture and mouth feel characteristics of foods and food products like comminuted meats, extenders or analogues and baked products (Adeyeye and Aye, 1998; Cheftel *et al.*, 1985; Okezie and Bello, 1988).

Effect of salt concentration on emulsion capacity and activities: Different salts and their concentrations affect emulsion capacity (Table 4) and emulsion activities of the seed flours (Table 5-7). The results showed that Emulsion Capacity (EC) depended mostly on salt concentration and the type of the salt under consideration; for instance in this study CH_3COONa and Na_2SO_4 favoured good emulsion capacity while $NaNO_3$ with overall mean values varying from 159.9-173.5%

Table 3: Water absorption capacity (%) of the seeds flours in various salt solutions

Salt concentration	$NaCl$ KSGF	$NaCl$ BBGF	$NaNO_3$ KSGF	$NaNO_3$ BBGF	$NaNO_2$ KSGF	$NaNO_2$ BBGF	CH_3COONa KSGF	CH_3COONa BBGF	Na_2SO_4 KSGF	Na_2SO_4 BBGF
0.0	230.0	240.0	230.0	240.0	230.0	240.0	230.0	240.0	230.0	240.0
0.5	160.0	120.0	180.0	140.0	180.0	120.0	200.0	140.0	210.0	150.0
1.0	1600.0	140.0	160.0	120.0	200.0	180.0	200.0	120.0	210.0	120.0
2.0	180.0	120.0	170.0	100.0	200.0	200.0	200.0	140.0	190.0	150.0
5.0	160.0	140.0	160.0	130.0	170.0	120.0	200.0	100.0	180.0	190.0
10.0	160.0	120.0	160.0	100.0	200.0	140.0	160.0	120.0	180.0	180.0
15.0	150.0	120.0	150.0	110.0	190.0	140.0	140.0	140.0	180.0	160.0
Mean	171.5	142.9	172.9	141.4	195.8	162.9	190.1	142.9	197.2	170.0
SD	26.3	43.9	27.0	51.8	19.2	45.4	30.1	45.4	19.9	38.3
CV%	15.3	30.7	15.6	36.6	9.8	27.9	15.8	31.8	10.1	22.5

(%)[a]: w/v; SD: Standard Deviation; CV%: Coefficient of variation percent; KSGF: Kersting's Groundnut Flour, BBGF: Bambara Groundnut Flour

Table 4: Emulsion capacity (%) of the seeds flours in various salt solutions

Salt concentration	$NaCl$ KSGF	$NaCl$ BBGF	$NaNO_3$ KSGF	$NaNO_3$ BBGF	$NaNO_2$ KSGF	$NaNO_2$ BBGF	CH_3COONa KSGF	CH_3COONa BBGF	Na_2SO_4 KSGF	Na_2SO_4 BBGF
0.0	218.1	210.0	218.1	210.0	218.1	210.0	218.1	210.0	218.1	210.0
0.5	145.3	124.6	186.9	186.9	145.3	186.9	186.9	206.6	145.3	166.1
1.0	124.6	124.6	145.3	124.6	186.9	186.9	206.6	228.4	166.1	206.6
2.0	145.3	124.6	166.1	186.9	206.6	166.1	206.6	206.6	186.9	206.6
5.0	124.6	124.6	145.3	145.3	145.3	145.3	228.4	228.4	145.3	186.9
10.0	145.3	124.6	166.1	145.3	124.6	145.3	206.6	249.2	166.1	186.9
15.0	145.3	145.3	186.9	166.1	145.3	145.3	186.9	228.4	206.6	166.1
Mean	149.8	139.7	173.5	166.4	167.5	169.4	205.7	222.5	176.4	186.9
SD	31.7	31.9	26.0	29.9	36.0	25.8	15.2	15.7	28.6	18.8
CV%	21.2	22.8	15.0	18.0	21.5	15.2	7.4	7.1	16.2	9.9

(%)[a]: w/v; SD: sTandard Deviation; CV%: Coefficient of variation percent; KSGF: Kersting's Groundnut Flour, BBGF: Bambara Groundnut Flour

Table 5: Emulsion stability (mL g^{-1}) after 1 h of the seeds flours in various salt solutions (volume of water separated at room temperature, 26±2.5°C)

Salt concentration	$NaCl$ KSGF	$NaCl$ BBGF	$NaNO_3$ KSGF	$NaNO_3$ BBGF	$NaNO_2$ KSGF	$NaNO_2$ BBGF	CH_3COONa KSGF	CH_3COONa BBGF	Na_2SO_4 KSGF	Na_2SO_4 BBGF
0.0	18.5	19.0	18.5	19.0	18.5	19.0	18.5	19.0	18.5	19.0
0.5	19.0	29.0	31.0	19.0	31.0	25.0	31.5	18.0	28.0	31.0
1.0	22.0	28.0	24.0	21.0	24.0	27.0	26.0	15.0	32.0	31.0
2.0	25.0	27.0	36.0	30.0	36.0	32.0	18.0	15.0	33.0	29.0
5.0	26.0	30.0	34.0	36.0	34.0	14.0	17.0	26.0	33.5	35.0
10.0	19.0	29.5	36.0	34.0	36.0	16.0	36.0	26.0	35.0	15.0
15.0	27.0	29.5	23.0	37.0	23.0	32.0	34.5	17.5	22.0	35.0
Mean	22.4	27.3	28.9	28.0	28.9	23.6	25.9	19.5	28.9	27.9
SD	3.6	3.8	7.1	8.1	7.1	7.4	8.2	4.7	6.3	7.8
CV%	16.1	13.9	24.6	28.9	24.6	31.4	31.7	24.1	21.8	28.0

(%)[a]: w/v; SD: Standard Deviation; CV%: Coefficient of variation percent; KSGF: Kersting's Groundnut Flour, BBGF: Bambara Groundnut Flour

inhibit emulsification property. Generally EC of seed flours decreased as salt concentrations increased in all the samples investigated. Since hydrodynamics of protein molecules in food system is greatly influenced by prevalent ionic strength and concentration. It is then reasonable that observation in the result predicated on the perturbations of structure by the various salts. The solubility is a function of the ionic strength, which is readily calculated from the molar concentrations of the ions and their charges using the expression.

$$I = \frac{1}{2}\sum_{i=1}^{n} MiZi^2$$

Where: I is the ionic strength, M the molarity, Z the charge of the ion, the $\sum_{i=1}^{n}$ denotes that the MZ^2 terms are added for each of the ions (White *et al*., 1973). This shows that the samples were generally more soluble between 0.5-5% (w/v) of salt concentrations. Until the point of saturation is reached, increase in ionic strength of the protein solution enhances its solubility. Increase in solubility is facilitated by improved ionic interactions,

Table 6: Emulsion stability (mL g^{-1}) after 2 h of the seeds flours in various salt solutions (volume of water separated at room temperature, 26±2.5°C)

Salt	NaCl		$NaNO_3$		$NaNO_2$		CH_3COONa		Na_2SO_4	
concentration	KSGF	BBGF	KSGF	BBGF	KSGF	BBGF	KSGF	BBGF	KSGF	BBGF
0.0	30.0	22.5	30.0	22.5	30.0	22.5	30.0	22.5	30.0	22.5
0.5	26.0	31.0	34.5	27.0	33.0	28.0	25.0	22.0	30.0	33.0
1.0	30.0	31.0	26.0	29.0	30.0	30.0	27.0	19.0	34.0	33.0
2.0	29.0	29.0	37.0	31.0	22.0	35.0	34.0	18.0	36.0	31.0
5.0	35.5	33.5	35.0	37.0	19.0	16.0	22.0	30.0	35.0	37.0
10.0	22.5	32.0	37.0	35.5	37.0	19.0	15.0	28.0	36.0	16.0
15.0	29.5	31.0	27.5	38.0	35.5	34.0	28.0	21.0	26.0	37.0
Mean	28.2	30.0	32.4	31.4	29.5	26.4	25.9	22.9	32.4	29.9
SD	3.6	3.8	4.6	5.7	5.3	7.4	6.1	4.5	3.8	7.8
CV%	12.8	12.7	41.2	18.2	18.0	28.0	23.6	19.7	11.7	26.1

(%)[a]: w/v; SD: Standard Deviation; CV%: Coefficient of variation percent; KSGF: Kersting's Groundnut Flour, BBGF: Bambara Groundnut Flour

Table 7: Emulsion stability (mL g^{-1}) after 24 h of the seeds flours in various salt solutions (volume of water separated at room temperature, 26±2.5°C)

Salt	NaCl		$NaNO_3$		$NaNO_2$		CH_3COONa		Na_2SO_4	
concentration	KSGF	BBGF	KSGF	BBGF	KSGF	BBGF	KSGF	BBGF	KSGF	BBGF
0.0	35.0	30.0	35.0	30.0	35.0	30.0	35.0	30.0	35.0	30.0
0.5	34.0	38.0	36.5	28.0	37.0	32.0	31.0	25.0	35.0	35.0
1.0	37.5	38.0	26.0	29.5	35.0	34.0	30.0	21.0	36.0	36.0
2.0	35.0	36.0	38.0	31.5	34.0	38.0	39.0	34.0	38.0	34.0
5.0	36.0	38.0	36.0	37.0	23.0	18.0	33.0	36.0	39.0	40.0
10.0	28.0	34.0	39.0	37.5	38.5	20.0	32.0	33.0	40.0	31.0
15.0	34.0	35.0	32.0	39.5	38.0	37.0	39.5	39.0	32.0	38.5
Mean	34.2	35.6	34.6	33.3	34.2	29.9	34.2	31.1	36.4	34.9
SD	3.0	2.9	4.4	4.6	5.3	7.9	3.8	6.3	2.8	3.7
CV%	8.8	8.1	12.7	13.8	13.5	26.4	11.1	20.3	7.7	10.6

(%)[a]: w/v; SD: Standard Deviation; CV%: Coefficient of variation percent; KSGF: Kersting's Groundnut Flour, BBGF: Bambara Groundnut Flour

which promote protein-water solubility. In this sense improved solubility increases the emulsifying capacity of the seed flours. Di-and trivalent ions are more effective than univalent ions. This is evident in the results of Na_2SO_4. However, improved result recorded for CH_3COONa, with a univalent ion, CH_3COO^- might be due to the hydrophobic interactions. Table 4 also shows slight variation according to CV% indicating there were no significant different in the reported values. However, the current report was better than some reported values for legumes in the literature (Lin *et al.*, 1974; Sathe and Salunkhe, 1981) hence the studied samples might be useful in the production of sausages, soups and cakes (Altschul and Wilcke, 1985). The Oil Emulsion Stability (OES) of the flours are shown in Table 5 (after 2 h), 6 (after 2 h) and 7 (after 24 h). The CV% after period of 1h ranged between 13.9% in BBGF and 49.2% in KSGF amongst various salt concentrations. Volume of water separated generally increased at 0.5% (w/v) to 2.0% (w/v) salt concentrations except CH_3COONa and Na_2SO_4 which showed variation at these levels. At higher salt concentrations, water separated decreased except in $NaNO_2$. The same trend was observed after periods of 2 and 24 h, indicating that the degree of water separation varies from salt to salt. Three separate mechanisms that appear to be involved in the formation of stable emulsion may be (I) reduction of interfacial tension (ii) formation of a rigid interfacial film and (iii) electrical charge (Mcwatters and Cherry, 1977). The surfactancy of proteins is related to their ability to lower the interfacial tension between water and oil in the emulsion (Oshodi and Ojokan, 1997). The surface activity is a function of the ease with which protein can migrate to, adsorb at, unfold and rearrange at an interface and presumably salts reduce the surface activity of the studied flours and thereby increase the interfacial tension which leads to decrease in emulsion capacity, salts may also reduce charge repulsion between the proteins and enhance hydrophilic association at the interface (Kinsella *et al.*, 1985). The decrease in emulsion stability as noticed in Tables 5-7 may be due to increased contact leading to coalescence which thereby reduces stability (Parker, 1987).

Effect of salt concentrations on gelation property: Result of salt concentrations effect on Least Gelation Concentration (LGC) is presented in Table 8. LGC in distilled and deionized water varied between 12.0-

Table 8: Least gelation concentration (%) of the seeds flours in various salt solutions

Salt concentration	NaCl KSGF	NaCl BBGF	$NaNO_3$ KSGF	$NaNO_3$ BBGF	$NaNO_2$ KSGF	$NaNO_2$ BBGF	CH_3COONa KSGF	CH_3COONa BBGF	Na_2SO_4 KSGF	Na_2SO_4 BBGF
0.0	12.0	14.0	12.0	14.0	12.0	14.0	12.0	14.0	12.0	14.0
0.5	8.0	12.0	6.0	8.0	8.0	8.0	6.0	10.0	10.0	12.0
1.0	6.0	12.0	6.0	8.0	8.0	8.0	6.0	10.0	10.0	12.0
2.0	6.0	10.0	8.0	10.0	6.0	10.0	8.0	10.0	8.0	12.0
5.0	6.0	12.0	10.0	8.0	10.0	12.0	6.0	12.0	10.0	10.0
10.0	8.0	14.0	10.0	8.0	8.0	12.0	6.0	8.0	8.0	10.0
15.0	6.0	16.0	12.0	10.0	10.0	14.0	8.0	12.0	12.0	14.0
Mean	7.4	12.9	9.1	9.4	8.9	11.1	7.4	10.9	10.0	12.0
SD	2.2	2.0	2.5	2.2	2.0	2.5	2.2	2.0	1.6	1.6
CV%	30.0	17.7	27.8	30.0	22.0	27.8	30.0	22.0	16.3	16.3

(%)[a]: w/v; Sd: Standard Deviation; CV%: Coefficient of variation percent; KSGF: Kersting's Groundnut Flour, BBGF: Bambara Groundnut Flour

14.0% among the samples while the various salt concentration values ranged from 6.0-16.0% (NaCl), 6.0- 12.0% ($NaNO_3$), 6.0-14.0% ($NaNO_2$), 6.0-12.0% (CH_3COONa) and 8.0-14.0% (Na_2SO_4) showing that the best salt concentrations (w/v) were 0.5, 1.0, 5.0 and 10.0% in most of the salts used. Addition of various salt solutions up to 5% (w/v) salt concentration generally improved gelation property of the flours by lowering the LGC. Lowering of the LGC by the addition of salt at appropriate salt concentration have been reported for lupin seed (England, 1975), cashew nut flour (Fagbemi *et al.*, 2004), *T. durum* flour (Adeyeye and Aye, 2005), winged bean (Sathe *et al.*, 1982), pigeon pea protein concentrate (Akintayo *et al*., 1999) and mucuna species (Adebowale *et al*., 2005). It has been reported that electrostatic interaction due to electrostatic shielding of charges at low salt concentrations above 5-10%, there may be denaturation of the seed protein and probable neutralization of the charges stabilizing gel formation which resulted in high LGC (Giami and Bekebain, 1992). KSGF and BBGF in slurry of 2.0-5.0% (w/v) salt concentrations may be recommended where they are to be used as thickener in food system. The CV% of LGC ranged between 16.3-30.0% among the salt concentrations indicating the results were not seriously varied.

Conclusions

The results revealed that flours of kersting's and bambara groundnuts prepared with various concentrations of NaCl, $NaNO_3$, $NaNO_2$, CH_3COONa and Na_2SO_4 improved the gelation property by lowering the least gelation concentration compared with least gelation concentration in distilled deionized water. The seeds flours could be a useful replacement in viscous food formulation such as soups and baked goods due to high values of water absorption and oil emulsion capacities. The results further showed that water absorption capacity, emulsion capacity/stability and foaming capacity/stability of the studied samples were affected by salts and these effects depend on the types of salt and their concentrations. Therefore, salts may be selectively used to improve or inhibit the functional properties of kersting's and bambara groundnut flours.

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