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EFFECTS OF SALTS ON THE FUNCTIONAL PROPERTIES OF *Daniellia oliveri* SEEDS FLOUR

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Abstract: The effects of salts, NaCl, $CaCl_2$, KCl, CH_3COONa and $NaNO_3$ on some of the functional properties of *Daniellia oliveri* seed flour were investigated. Results showed that the least gelatin concentration of 6.06 ± 0.2% in distilled water was improved to between 2.0 and 4.0% in the presence of salts used. The water absorption capacity decreased from 413 ± 0.4 to between 292 ± 0.2 and 392 ± 0.4 depending on the type and concentration of the salt. The foaming capacity increased from 6.9 ± 0.2% without salt to between 9.6 ± 0.3% and 42.6 ± 0.4% with salt. A progressive decrease in emulsion capacity was observed with increase in salt concentrations generally up to 1% salt, after the value increased up to 5% salt. For the emulsion stability in the presence of NaCl, KCl and $CaCl_2$ the oil separation is less than that of CH_3COONa and $NaNO_3$. The pH of minimum solubility changes from 5 without salt to 4 in the presence of 0.5 to 10% NaCl and also 0.5% and 1.0% of CH_3COONa. The pH also changes from 5 to 6 for 0.5 to 10% $CaCl_2$. Also there is a sharp drop in protein as concentration of salts increase from 5% to 10%.

Keywords: Functional properties, *Daniellia oliveri*, seed flour

Introduction

Daniellia oliveri is called "Rolfe" in English, "Samein" in Arabic and "Iya" in Yoruba. According to Balogun and Adebayo (2009), *Daniellia oliveri* is in amazon region of South America. It produces liquid oleoresin which has been used as medicines by indigenous people for more than 400 years (Gentry, 1993). The oleoresin produced in the trunk, stem and leaves consists of large but varying amount of volatile oils, non-volatile resinous substances and small quantities of acids. Modern scientific studies have authenticated some of these medicinal uses of oleoresin such as its effectiveness as an antibacterial, anti-inflammatory and anti oxidant agent (Verpoorate and Dahl, 1997; Basile *et al.*, 1998).

However, there are information about the tree, trunk and leaves but the information about the seed is not available. So the purpose of this work is to know the effect of salts concentration on some functional properties of *Daniellia oliveri* seed flour. Such information may expand the scope of knowledge on the processing condition necessary to enhance the use of the seed flours as functional ingredients in food system (Fagbemi *et al.*, 2004). The functional properties are the physcio-chemical characteristics which may affect the behaviour of food systems during processing and storage e.g. solubility, foaming ability, gelation and emulsification properties (Oshodi and Ekperigin, 1999).

The presence of salt may increase the total water content of the protein system at specific water activity values, although it may reduce the preferential binding of water to the protein (Sathe and Salunkhe, 1998). These effects are markedly dependent on the nature of the anion and cation components (Sathe and Salunkhe, 1998; Altschul and Wilks, 2002). The effect of salt is significant because in many foods, salts concentration are approximately 0.2 – 0.3M, (Altschul and Wilks, 2002). This work aimed to know the effects of some selected salts like NaCl, $CaCl_2$, KCl, CH_3COONa and $NaNO_3$ on the functional properties of *Daniellia oliveri* seed flour.

Material and Methods

The *Daniellia oliveri* (*Caesalpiniaceae*) has a variety of vernacular names in Nigeria "Iya" in Yoruba, "Maje" in Hausa, Samein in Arabic and Rolfe in English. The seeds were harvested from trees abundantly in and around Ahmadu Bello University Zaria and University of Agriculture Markudi all in the northern part of Nigeria. It was indentified at Plant Science Department of Ekiti State University, Ado Ekiti. Ekiti State. The samples were sun - dried, de -shelled, powdered, packaged in polythene bags and stored at 4^0C until used.

The salts used were NaCl, $CaCl_2$, KCl, CH_3COONa and $NaNO_3$; all chemicals used were of analytical grades. The concentrations of the different salts used were 0.5, 1.0, 2.0, 5.0, 10.0, 15.0 and 20.0% w/v, respectively. The dependence of protein solubility with pH of *Daniellia oliveri* seed flour in various salt solutions was determined by mixing for 5 min, 1 g of the flour with 50 cm^3 of prepared salt solution in a magnetic stirrer at room temperature (25^0C).

The pH of the resulting solution was adjusted to the desired value using either 0.1M HCl or 0.1M NaOH; samples were centrifuged for 30 min and the protein content of the supernatant was determined by micro-kjeldahl method (AOAC, 1990).

Foaming capacity and foaming stability were determined by the method of Coffmann and Garcia (1997). 1.0 g of the sample flour was weighed and dispersed in 100 ml of various salt solutions were homogenized for 1 min in a KW 10 Kenwood food blender at maximum speed and the content were immediately poured into 100 cm^3 graduated cylinder. Foaming capacity was the foam volume immediately after mixing. Foaming stability was determined as the volume of foam that remained after 0, 30, 60, 90, 120, 150, 180 and 300 min. Expressed as a percentage of the initial foam volume.

Determination of emulsion capacity

Emulsion capacity and emulsion stability were determined using the method of Akintayo *et al*. (1998). Emulsions were formed inside a 600 ml beaker by use of continuous stirring apparatus. This apparatus consisted of a regulated/stabilized 6V power supply, a burette, stirrer, beaker with emulsion and a digital milliammeter. The stirrer consisted of a stain-less rod holding a perspex bridge fixed to a 6V d.c motor spindle by means of a plastic adaptor. The motor itself was driven by a regulated and stabilized 6V d.c power supply. An unloaded motor has free run maximum speed for the given voltage. When loaded, the speed tends to be dragged down and in order to maintain its speed, more current is drawn from the source.

This principle was utilized in this work, where increase in motor current was observed over increasing viscosity during emulsification process. At the inversion point of the emulsion, a sudden breakdown in viscosity occurs and a sharp fall in motor current was observed. This sharp fall is a precision determinant of the inversion point of the emulsion. The motor current was observed using a digital milliameter. The stirrer has an added advantage in that while the Perspex bridged stirrer vigorously the content of the beaker, the emulsion mixture is also bombarded by the vertical steel rods and this enables a food blending process to occur.

1 g of sample flour was dissolved in 25 ml various salt solutions. The mixture was stirred for 30 min in order to disperse the sample. Oil was then added at a rate of 1.0 ml/sec from a burette until emulsion collapsed indicated by a sharp fall in motor current. The volume of oil added up to inversion point was noted and the emulsion capacity expressed as ml of oil per g of sample.

Determination of emulsion stability

The emulsion stability was determined according to Akintayo *et al*. (1998) following the procedure used for the emulsion capacity, except that 100 ml oil was added rather than addition of oil until emulsion break point. 2% slurry of the protein sample as prepared by dissolving 0.5 g of sample in 25 ml of various salt solution and 100 ml of oil was added, the mixture as then stirred for 30 min. A 50 ml of aliquot of resultant emulsion (RE) was measured in to a 50 ml graduated cylinder and allowed to stand at room temperature. The amount of oil separated noted at time intervals within the range of 0 to 336 h.

Results and Discussion

The values for the lowest gelation concentration (LGC) are shown in Table 1 for all the salts. The salt free was 6%. The addition of salts resulted in a decreased in the least gelation concentration that depended on the concentration and type of salt under consideration and values obtained varies between 2% and 6%. It was observed that the gel-forming property of *Daniellia oliveri* seed improved at high concentration and much better in the presence of KCl. Similar observations have been reported by Sathe *et al.* (1982a, 1982b) for lupin seed and winged been respectively and Akintayo *et al.* (1999) for pigeon pea protein concentrates. It was observed that *Daniellia oliveri* had high binding ability despite the fact that its protein content was low and the low value of lowest gelation concentration for *Daniellia oliveri* will render it useful in the production of curd or as additive to other materials for gel forming in food products.

Table 2 presents the water absorption capacity of *Daniellia oliveri* seed flour in different salt concentrations. The water absorption capacity in distilled water is found to be 413% which is higher than that of Albizia lebbeck 169.60% (Adubiaro *et al.*, 2009), Triticum durum flour 140.63% (Adeyeye and Aye, 2005), Abenopus breviflorus beint seed flour 201% (Oshodi, 1992) and cowpea flour 246% (Olaofe *et al.*, 1993).

Table 1: Lowest gelation concentration of *Daniellia oliveri* seed flour in various salt concentrations

Conc. Salt used %	Lowest gelation concentration (%)				
	NaCl	$CaCl_2$	KCl	CH_3COONa	$NaNO_3$
0.0	6	6	6	6	6
0.5	6	4	3	4	6
1.0	4	4	3	4	6
2.0	4	4	2	3	4
5.0	3	2	2	3	3
10.0	3	2	2	3	3
15.0	4	3	4	4	4
20.0	4	3	4	4	4

Table 2: Water absorption capacity of *Daniellia oliveri* seed flour in various salt concentrations

Conc. of Salt used %	Water absorption capacities (%)				
	NaCl	$CaCl_2$	KCl	CH_3COONa	$NaNO_3$
0.0	413±1.5	413±1.5	413±1.5	413±1.5	413±1.5
0.5	360±0.5	354±2.0	322±0.7	392±0.4	372±0.0
1.0	348±0.5	322±1.0	308±0.5	390±0.5	364±0.6
2.0	344±1.5	312±0.0	324±0.5	350±1.0	352±0.5
5.0	328±1.5	302±0.6	310±0.5	312±1.5	350±1.0
10.0	320±1.0	284±2.5	292±0.5	310±0.5	410±0.6
15.0	380±1.0	342±2.0	352±0.3	368±1.5	422±1.5
20.0	562±1.5	408±1.5	368±1.5	412±2.0	518±1.0

Table 2 further shows a progressive decrease in water absorptivity with increase in salt concentration generally up to 10% salt, after which the water absorptivity starts to increase. The percentage of decrease or increase in water absorption capacity varies with the type of salt. This may be due to the fact that the effects of salts vary with the cation and anion species involved (Kinsella *et al.*, 1995).

The values for the foaming capacity are shown in Table 3 for all the salts. Low foaming capacity existed between salts and within salts concentration. The values of foaming capacity range from 12.6% - 36.6% (NaCl), 10.4 – 24.2% ($CaCl_2$), 15.8-64.6% (KCl), 9.6-22.4% (CH_3COONa) and 14.6-32.4% ($NaNO_3$). The highest foaming capacity was reported for KCl at 15.0% w/v salt concentration, lowest value was recorded for CH_3COONa at 0.5% w/v salt solution. Table 3 still shows that the foaming capacity depends on the type of salt under consideration. For all the salts used there is an increase in the foaming capacity with increase in concentration of salt from 0.5 to 15.0%. The foaming capacity values are higher in the presence of NaCl and KCl salts which will improve the functionality of *Daniellia oliveri* seed flour in its uses for the production of cakes and whipped toppings where foaming is an important property (Kinsella, 1999).

Table 3: Foaming capacity at zero hour

Conc. of Salt used %	NaCl	$CaCl_2$	KCl	CH_3COONa	$NaNO_3$
0.0	6.9±0.5	6.9±0.5	6.9±0.5	6.9±0.5	6.9±0.5
0.5	12.6±0.4	10.4±1.0	15.8±1.2	9.6±1.7	14.6±1.0
1.0	15.2±0.7	12.6±1.4	17.4±1.5	10.2±0.5	16.8±2.1
2.0	18.8±0.9	14.8±0.6	22.8±1.1	12.8±1.3	20.2±1.1
5.0	20.4±0.8	18.2±0.5	26.8±0.7	14.6±0.6	22.4±0.3
10.0	42.6±0.5	24.8±1.0	48.2±0.5	20.2±1.0	26.8±1.5
15.0	43.4±0.3	26.8±1.5	56.4±0.3	28.6±0.5	38.2±1.5
20.0	36.6±1.5	24.2±1.5	42.6±1.5	22.4±1.5	32.4±2.0

Table 4: Foaming stability % of *Daniellia oliveri* in different solutions of NaCl

Time (min)/ Salts conc. (%)	0.0	0.5	1.0	2.0	5.0	10.0	15.0	20.0
0.0	100	100	100	100	100	100	100	100
30	80.4	82.4	82.6	84.0	86.2	86.2	88.0	88.4
60	78.8	80.8	80.8	82.2	84.6	84.6	86.2	86.2
90	70.4	72.8	72.8	74.6	76.4	76.8	78.8	78.2
120	68.8	70.2	72.6	72.8	74.0	76.2	76.2	76.2
150	60.2	62.4	64.8	64.8	66.2	66.8	70.8	72.4
180	50.4	52.8	54.6	56.2	58.4	58.8	60.2	60.8
300	50.0	52.6	52.8	54.6	54.6	54.8	56.8	60.2
Mean	69.9	71.8	72.6	73.7	75.1	75.7	76.9	77.8
SD	16.8	161	15.6	15.2	15.1	14.8	14.5	13.7
CV%	24	22	21	21	20	20	19	18
Rate/min	0.17	0.16	0.16	0.15	0.15	0.15	0.14	0.13

Table 5: % Foaming stability of *Daniella olivieri* in different solutions of KCl

Time (min)/ Salts conc. (%)	0.0	0.5	1.0	2.0	5.0	10.0	15.0	20.0
0.0	100	100	100	100	100	100	100	100
30	80.4	74.8	76.2	76.8	78.4	78.4	80.2	80.0
60	78.8	70.2	70.8	74.4	74.6	74.8	76.2	78.4
90	70.4	62.4	62.8	64.0	64.2	66.8	66.6	68.4
120	68.8	60.2	60.8	62.4	62.8	64.4	64.8	66.2
150	60.2	56.8	58.4	60.2	62.6	62.8	64.6	64.8
180	50.4	56.4	56.8	58.2	58.6	60.0	60.2	60.8
300	50.0	52.0	54.2	54.8	56.8	56.8	58.4	58.8
Mean	69.9	66.6	67.5	68.6	69.8	70.5	71.4	72.2
SD	16.8	15.4	15.0	14.6	14.3	13.9	13.8	13.6
CV%	24	23	22	21	20	20	19	19
Rate/min	0.17	0.16	0.15	0.15	0.14	0.14	0.14	0.14

Table 6: % Foaming stability of *Daniellia oliveri* in different solutions of $CaCl_2$

Time (min)/ Salts conc. (%)	0.0	0.5	1.0	2.0	5.0	10.0	15.0	20.0
0.0	100	100	100	100	100	100	100	100
30	80.4	70.8	72.4	72.8	74.2	74.6	74.8	78.2
60	78.8	68.4	68.8	70.0	70.2	72.4	74.6	76.2
90	70.4	64.8	66.2	66.8	68.4	8.8	70.0	70.8
120	68.8	62.4	64.4	64.6	66.8	66.8	68.2	68.0
150	60.2	60.8	60.8	62.2	62.8	64.0	64.8	66.2
180	50.4	58.8	58.8	60.2	60.8	62.4	64.6	66.0
300	50.0	58.8	58.8	58.6	60.2	60.8	60.4	60.2
Mean	69.9	13.6	13.5	13.3	12.9	12.6	12.3	12.0
SD	16.8	13.6	13.5	13.3	12.9	12.6	12.3	12.0
CV%	24	20	20	19	18	18	17	16
Rate/min	0.17	10.4	0.14	0.14	0.13	0.13	0.13	0.13

Table 7: % Foaming stability of *Daniellia olivieri* in different solutions of CH_3COONa

Time (min)/ Salts conc. (%)	0.0	0.5	1.0	2.0	5.0	10.0	15.0	20.0
0.0	100	100	100	100	100	100	100	100
30	80.4	48.3	49.0	52.3	52.8	52.8	60.0	60.2
60	78.8	42.8	43.0	48.4	48.8	48.8	50.0	502
90	70.4	40.6	40.8	42.4	44.2	46.40	346.80	48.2
120	68.80	38.40	38.8	40.2	40.8	42.2	42.6	42.8
150	60.2	38.6	38.6	40.0	40.0	40.0	42.2	42.8
180	50.4	34.4	34.8	34.8	38.2	38.8	40.0	40.6
300	50.0	32.6	32.8	31.8	38.2	38.2	40.0	40.2
Mean	69.9	47.0	47.2	48.7	50.4	50.9	52.7	53.1
SD	16.8	22.0	22.0	21.8	20.7	20.5	20.2	20.1
CV %	24	47	47	45	41	40	38	38
Rate / Min	0.17	022	0.22	0.23	0.21	0.21.	0.20	0.20

The foaming stability values are shown in Tables 4 to 8. The order of decreasing foaming stability in the presence of salts were NaCl; rate = 0.13 to 0.17 $min^{-1,}$ KCl; rate is 0.14 to 0.16 min^{-1} $CaCl_2$: rate is 0.13 to 0.14 min^{-1} $NaNO_3$: 0.24 to 0.27 min^{-1} and CH_3COONa: rate is 0.20 to 0.23 min^{-1}. The rate at which the foam ruptures for *Daniellia oliveri* seed flour in all the salts was low but the values were better in the presence of $CaCl_2$ with the rate of 0.13 to 0.14 min^{-1}, KCl of 0.14 to 0.16 min^{-1} and that of NaCl of 0.13 to 0.17 min^{-1}. The foaming stability of the seed flour after 2 h without salt is 68.8%. This value is higher than that of soy flour 14.6% (Lin *et al.*, 2004), pigeon pea 20.0% (Oshodi and Ekperigin, 1989), hulled African yam bean seed flour 43.3-42.5% (Adeyeye and Aye, 1998) but lower than that of cowpea flour 91.0% (Padmashree *et al.*, 1997) for the same time interval. Since the foam stability is important and the success of a whipping agents depends on the ability to maintain the whip as long as possible, so *Daniellia oliveri* has ability to maintain the whip as long as possible in the presence and absence of salts and this suggests that this seed flour would be suitable for food formulation where there is need for better foaming stability.

Table 8: % Foaming stability of *Daniellia olivieri* in different solutions of $CaNO_3$

Time (min)/ Salts Conc. (%)	0.0	0.5	1.0	2.0	5.0	10.0	15.0	20.0
0.0	100	100	100	100	100	100	100	100
30	80.4	78.2	68.6	60.4	21.6	24.8	19.8	21.8
60	78.8	40.4	42.8	60.4	21.6	24.8	19.8	21.8
90	70.4	38.8	42.8	32.4	21.6	24.8	19.8	21.8
120	68.8	26.8	42.8	31.4	21.6	24.8	19.8	21.8
150	60.2	26.8	24.2	32.4	21.6	24.8	19.8	21.8
180	50.4	26.8	21.2	22.4	21.6	24.8	19.8	21.8
300	50.0	26.8	24.2	22.2	21.6	24.8	19.8	21.8
Mean	69.9	45.6	46.2	45.3	31.3	35.2	30.1	31.6
SD	16.8	28.1	26.4	26.8	27.7	26.3	28.3	27. 6
CV %	24	62	57	59	88	75	94	87
Rate/ min	0.17	0.24	0.25	0.26	0.26	0.26	0.27	0.27

Table 9: Effects of salts on emulsion capacity of *Daniellia oliveri* seed flour

Conc. Salt used (%)	Emulsion capacity (ml of oil per g)				
	NaCl	$CaCl_2$	KCl	CH_3COONa	$NaNO_3$
0.0	188.8±4.2	188.8±3.4	188.8±4.2	188.8±5.2	188.8±4.6
0.5	160.10±6.3	148.1±3.2	158.4±3.4	136.8±4.2	142.4±4.0
1.0	153.5±3.5	145.0±4.2	148.0±2.5	130.2±4.0	138.3±3.6
2.0	155.0±5.2	146.5±4.6	154.6±3.5	134.6±3.5	140.4±2.0
5.0	156.2±5.0	148.3±4.6	156.4±6.2	136.4±2.2	140.8±3.2
10.0	103.5±4.5	98.6±2.1	100.2±4.0	80.2±4.3	93.2±4.0
15.0	100.8±4.0	84.2±2.0	98.4±3.2	80.6±2.6	88.6±3.1
20.0	98.4±3.2	77.1±2.6	96.2±4.1	78.8±4.0	82.4±4.2

Table 10: Stirrer current drawn at the inversion of *Daniellia oliveri* emulsions

Conc. Salt used(%)	NaCl (mA)	$CaCl_2$ (mA)	KCl (mA)	CH_3COONa (mA)	$NaNO_3$ (mA)
0.0	620±3.6	620±3.2	620±3.2	620±3.2	620±4.0
0.5	550±6.2	504±4.0	408±4.2	491±4.6	522±2.0
1.0	438±4.8	422±4.2	332±4.0	420±4.8	501±2.0
2.0	440±4.2	428±4.8	340±3.2	440±6.0	508±3.6
5.0	442±4.0	430±4.2	360±4.6	424±3.4	512±4.0
10.0	104±3.4	102±4.6	93±2.0	68±4.0	122±4.2
15.0	84±2.0	100±2.3	80±2.2	60±2.2	100±2.3
20.0	82±1.2	100±2.2	78±2.1	58±2.3	98±2.2

Emulsion capacity

The results obtained for emulsion capacity and the current drawn are presented in the Tables 9 and 10, respectively. The emulsion capacity and the current drawn depend on the salt concentration and the types of salts under consideration. A progressive decrease in emulsion capacity was observed with increased in salt concentrations generally up to 1% salt, after which emulsion capacity then increased with 5% salt solution but the values were lower than in the absence of salts. At high concentration of salts, 10 to 20%, the values of emulsion capacity for all the salts used were lower compared to the values obtained for low concentration of salts (0.0, 0.5, 1.0, 2.0 and 5%). The same observation has been made for benniseed flour (Ogungbenle *et al.*, 2002) and for bovine plasma protein concentrate (Oshodi and Ojokan, 1997).

It was observed that the current drawn decreased between 0.0 and 1% salt concentration and later decreased again as the salt concentration increased above 5% salt concentration.

Emulsion stability

The oil emulsion stability (OES) ml of *Daniellia oliveri* with different salts are shown in Figs. 1 to 5 for salt concentrations between 0.5 and 20%. It has been observed that the capacity of protein to aid the formation and stabilization of emulsions is important for many applications in cake batters, coffee whiteners, milks, mayonnaise, salad dressings, comminuted meats and frozen desserts (Kinsella *et al*., 1995). For *Daniellia oliveri,* the volume of oil separated increased with increase in time which resulted in reduction of oil emulsion stability. In the present study, it was observed that the oil emulsion stability is at its best in the presence of CH_3COONa and $NaNO_3$. The decrease in emulsion stability as time increased has been explained to have been due to increased contact leading to coalescence which thereby reduced stability (Parker, 1997).

The degree of oil separation varied from salt to salt. In the presence of NaCl, KCl and $CaCl_2$ the oil separation is less than that of $CH_3CHOONa$ and $NaNO_3$. Three separate mechanisms that appear to be involved in the formation of stable emulsion in NaCl, KCl and $CaCl_2$ may be due to (i) reduction of interfacial tension and (ii) electrical charge (Mcwatters & Cherry, 1981).

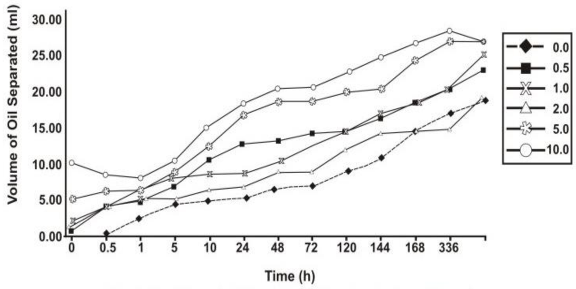

Fig. 1: Emulsion stability of *Daniellia oliveri* using different concentrations of NaCl solution

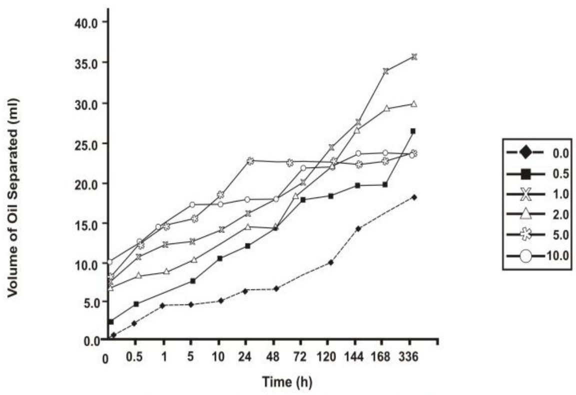

Fig. 2: Emulsion stability of *Daniellia oliveri* using different concentrations of $CaCl_2$ Solution

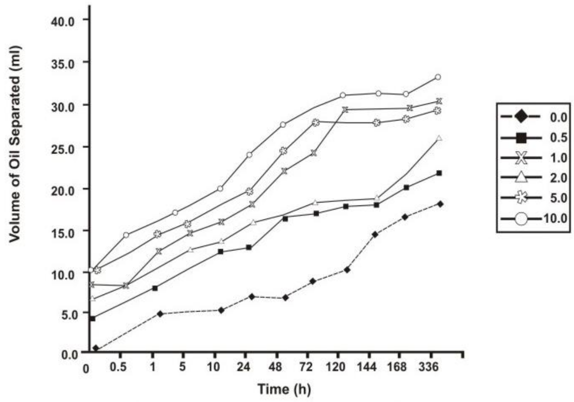

Fig. 3: Emulsion stability of *Daniellia oliveri* using different concentrations of KCl Solution

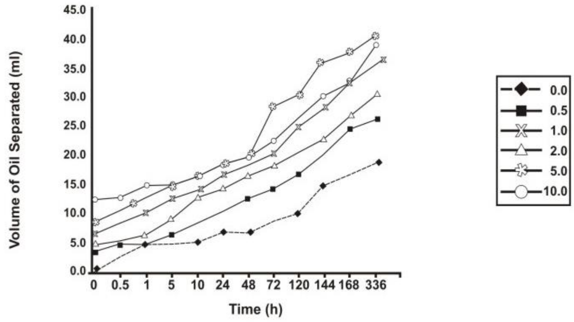

Fig. 4: Emulsion stability of *Daniellia oliveri* using different concentrations of CH_3COONa Solution

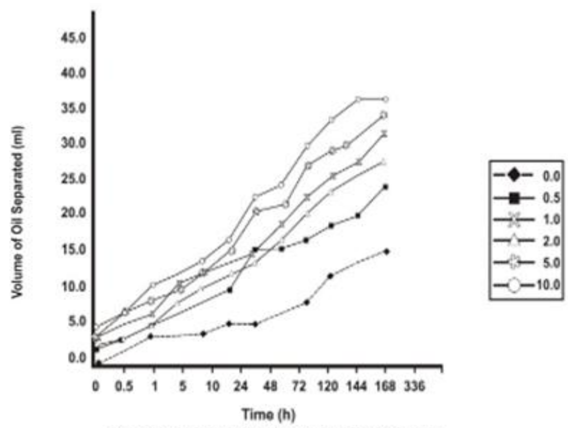

Fig. 5: Emulsion stability of *Daniellia oliveri* using different concentrations of $NaNO_3$ Solution

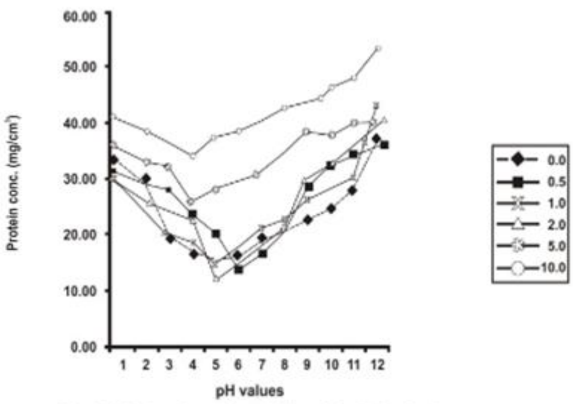

Fig. 6: Variation of protein solubility of *Daniellia oliveri* with pH in various concentrations of NaCl Solution

The variation of protein solubility with pH in the presence and absence of salts are shown in Figs. 6 to 10. For the seed flour in the absence of salts the solubility curve shows a minimum at about pH of 5. In the presence of 0.5 to 10% NaCl the minimum solubility appeared at about pH 4. In the presence of $CaCl_2$ the minimum stability changed to pH 6 for 0.5 to 10%. The effect of different concentrations of KCl on the protein solubility also presented in Fig. 8. These curves also depict that the pH of 5.0 observed at zero concentration of KCl was also shifted to pH 4 for 1% and 2.0% salt concentrations. Fig. 9 presents the effect of CH_3COONa on *Daniellia oliveri* seed flour. The minimum pH at about 5 in the absence of CH_3COONa was changed to pH 4 at 0.5% and 1.0% also in the presence of $NaNO_3$ (Fig. 10) the minimum solubility at pH 5 without salt was changed to pH 6 which means the seed will be more stable in the acidic medium.

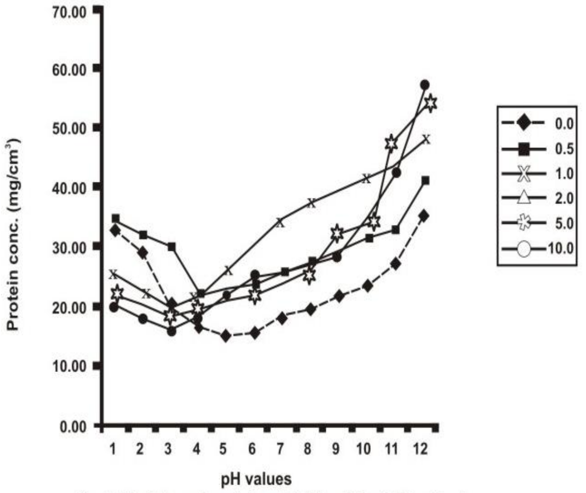

Fig. 7: Variation of protein solubility of *Daniellia oliveri* with pH in various concentrations of $CaCl_2$ Solution

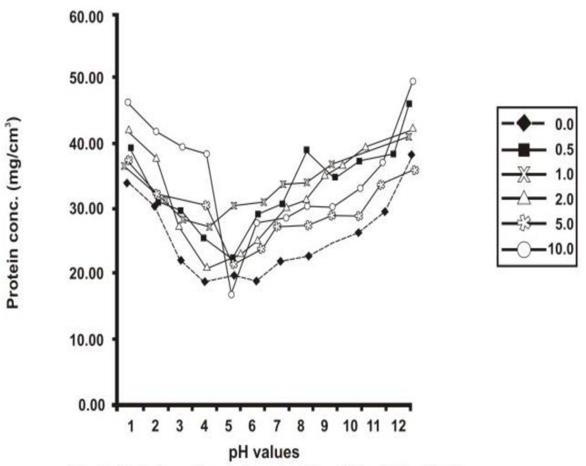

Fig. 8: Variation of protein solubility of *Daniellia oliveri* with pH in various concentrations of NaCl Solution

It is observed generally that for all the five salts used in these studies, the protein of the seed was more soluble in the acid region of pH than in the absence of these salts, whereas in the basic region, the solubilities were less compared to those obtained in the absence of the salts. This observation agree with that of bovine plasma protein concentrate, Pigeon pea and bennised flour (Oshodi and Ojokan, 1997), (Oshodi and Aasa, 1993) and (Ogungbenle *et al.*, 2002), respectively. The solubility of protein depends on hydration and the degree of hydrophobicity of the protein molecules (Sathe and Salunkhe, 1998). Denaturation process may cause reduction in hydration of the protein, exposing more hydrophobic groups and thereby reducing the solubility of the protein in the lower pH region. Perutz (1997) observed that the ionization of non polar groups (that lie in the interior of the molecule) by alkali leads these groups to attract hydration shells which are misfits in the native structure thus shifting the equilibrium towards the unfolded form. In addition, Perutz (1997) emphasized that the electrostatic interactions (ionization of interior non-polar groups) are more important in hydration of proteins than the surface charge. So, for all the functional properties, salts may be selectively used to improve or inhibit these properties in *Daniellia olivieri* seeds.

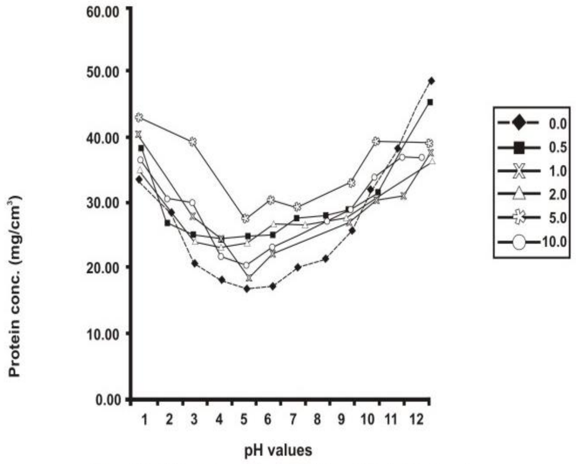

Fig. 9: Variation of protein solubility of *Daniellia oliveri* with pH in various concentrations of CH_3COONa Solution

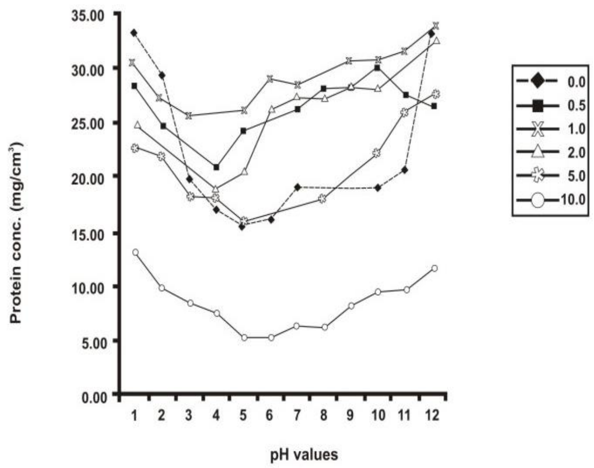

Fig. 10: Variation of protein solubility of *Daniellia oliveri* with pH in various concentrations of $NaNo_3$ Solution

Conclusion

The above results show that the gelation, water absorption, foaming capacity/stability, emulsion capacity, stability and protein solubility of *Daniellia oliveri* seed flour are affected by salts and that these effects depend on the types of salt and their concentrations. Therefore salts may be selectively used to improve or inhibit these functional properties of *Daniellia oliveri* seeds.

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