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SOLUBILITY, EMULSION AND FOAMING PROPERTIES OF COCONUT (*COCOS NUCIFERA*) PROTEIN CONCENTRATES

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ABSTRACT

Full-fat and defatted coconut protein concentrates containing 27.80% and 30.20% proteins (on a dry weight basis), respectively, were prepared from freeze-dried coconut meal samples. Selected functional properties such as: nitrogen solubility, emulsion and foaming properties were determined. Nitrogen solubility was measured in the range of P^H 2.0-12.0 in three dispersion media including water, 0.1M NaCl (low salt) and 1.0M NaCl (high salt). The emulsion properties of the protein concentrates were measured at varying P^H values (2.0-10.0) and sample concentrations.

Foaming properties were determined using same parameters including the use of additives (NaCl solutions and carbohydrates). Below and above the isoelectric P^H (4.0-5.0) the nitrogen solubility increased. The coconut protein samples showed a fairly high solubility (more than 54.0% and 53.0%) for full-fat coconut protein concentrate (FFC-PC) and defatted coconut protein concentrate (DFC-PC), respectively at pH 2.0. FFC-PC sample had maximum solubility (more than 73%) at 10.5 and minimum solubility (13.2%) at P^H 4.0. On the alkaline P^H scale, FFC-PC sample had maximum solubility of more than 43% at P^H 10.5 in high salt (1.0M NaCl) solution while DFC-PC sample had maximum solubility of 50.2% in 1.0M NaCl solution and more than 80% in low salt (0.1M NaCl) dispersion medium.

The emulsions prepared had good stability. A maximum of 92.5ml/g protein of emulsification capacity, at P^H 10.0 and minimum of 45.3ml/g protein at P^H 4.0 were obtained for FFC-PC while DFC-PC had a maximum EC of 86.4ml/g protein. FFC-PC samples produced significantly ($P \leq 0.05$) higher emulsion capacities than DFC-PC samples at all the dispersion P^H and sample concentrations investigated. The FFC-PC samples had a significantly low foaming capacity than the DFC-PC samples at all the tested P^H values. Similarly, the foaming capacities of FFC-PC and DFC-PC decreased with increasing P^H of the sample medium. Both FFC-PC and DFC-PC foams collapsed completely, after 3hr standing at ambient temperature. Foaming was concentration dependent. The FFC-PC and DFC-PC foams increased sharply at 0.2% NaCl content of the sample slurries and progressed steadily to a peak of 92.0% and 113% in FFC-PC and DFC-PC samples respectively in 0.8% NaCl solution and then declined gradually with increased salt concentration. Addition of polymeric carbohydrates (sucrose, corn starch, gum acacia and pectins) significantly improved foaming properties of the protein concentrates but the foam stabilities were not significantly affected.

Key words: Coconut, Protein, Solubility, Foaming, Emulsion

INTRODUCTION

The advent of modern technology in processing of oil-bearing materials for extraction of oil has brought in a variety of oil-free residues, which are rich in protein. Coconuts, though abundant in the Niger Delta region and hinterland of southern Nigeria, are rarely processed but eaten raw as fresh fruits. Coconuts contain in good measure, excellent proteins, carbohydrates and minerals beside a good supply of edible oil [1].

After oil extraction the residual cake is generally unfit for human consumption and is used for animal feed or fertilizer [2]. Special attention is now being devoted to concentration and isolation of proteins from oil seeds. Such protein concentrates/isolates offer greater opportunity for incorporation of and /or supplementation of a broad variety of food and may probably fit the needs of infants whose needs are critical.

To be useful and successful in food applications, proteins should have satisfactory intrinsic properties such as: nutritional properties and organoleptic attributes. Besides, the proteins should have several desirable characteristics referred to as functional properties, such as solubility under varying conditions, emulsifying and foaming capacity. Emulsifying capacity (EC) is an important protein functionality trait related to their ability to lower the tension at the interface of water and oil. Emulsifying properties of protein are affected by source of protein, protein concentrations, medium P^H incubation temperature and mechanical force [3].

Use of plant proteins in emulsified foods systems could promote fat binding to reduce cooking losses, improve EC and maintain stability of the emulsion system [4]. Similarly, various proteins could be used as foaming agents because their surface properties are mainly responsible for foam development [5]. Protein foams are important in many processes in the beverage and food industries and this has stimulated interest in their formation and stability. Foams are used to improve texture, consistency and appearance of food and are commonly encountered in baked, confectionery and other goods.

Protein functionality is governed by their structural characteristics, which are themselves influenced by many factors of their environment. Although the behaviour of a protein is influenced by its solubility characteristics, the correlations between the two have been crude [6]. The present investigation were undertaken to evaluate the functional properties of coconut protein concentrate with the objective to compare full fat and defatted coconut protein concentrates for nitrogen solubility, emulsification and foaming properties in various dispersion media.

MATERIALS AND METHODS

Sample source and preparation

Matured ripe coconuts (the West African Tall variety) were collected from the Integrated Agriculture Project Farms, Kaani, Khalga, and Rivers State. Preparation of protein concentrate was as described in a previous study [7].

Test of functional properties

Nitrogen solubility of both full- fat coconut protein concentrate (FFC –PC) and defatted coconut protein concentrate (DFC-PC) samples in various dispersion media were determined by a modified method of Betschart [8].

Two hundred mg samples each were dispersed with distilled water, 0.1M NaCl (low salt) and 1.0M NaCl (high salt) solution. The media were adjusted to different P^H levels (2.0 –12.0) with 1M NaOH or 1M HCl. The dispersed samples were shaken for 30min and centrifuged at 1000 x G for 20 min.

Duplicate aliquots of supernatant were analyzed for nitrogen contents by micro-Kjeldahl. The percentage nitrogen solubility was calculated based on total nitrogen in the supernatant to total nitrogen in the sample. AOAC [9] methods were used to determine the moisture (7.003), protein (7.080) fat (14.019), crude fiber (7.061), and ash (dry ashing method) content of FFC-PC and DFC-PC. Carbohydrate was determined by difference of the constituents from 100.

Emulsion properties

Emulsions were prepared according to the method of Beuchat [10]. The sample (2g) was blended in a Moulinex electric blender with 5.0ml of oil in 100ml distilled water for 30seconds at high speed. Oil was added in 5 ml portions continuing blending. The drop in consistency (from a maximum), judged by a decrease in resistance to blending (subjectively) was considered to be the point of discontinuation of oil addition. The amount of oil added up to this point was interpreted as the emulsifying capacity of the sample. The emulsion so prepared was then allowed to stand in a graduated cylinder and volume of water separated and time noted in each case to study the emulsion stability. All experiments were conducted in duplicate and at room temperature (30 $\pm$ 1C). Effects of P^H on emulsion capacity were evaluated using 2% (w/v) slurries and adjusting the P^H to a desired value (P^H 2.0- 10.0) with IN HCL or IN NaOH.

Effect of sample concentration

Effects of concentration on emulsion capacity were evaluated at concentrations of 2, 4, 6, 8 and 10 (w/v).

Foaming properties

Foaming capacity and stability were studied according to the method of Coffmann and Garcia [11]. A 2g sample was whipped with 100ml distilled water for 5mins in a Moulinex electrical blender at high speed and was poured into a 250ml-graduated cylinder. The total volume at time intervals: 0.0, 0.5, 1.0, 1.5, 2.0, 3.0 and 4.0 hrs were noted. Volume increase (%) was calculated according to the following equation.

Effects of P^H on foaming properties
Effects of P^H on foaming capacity were studied on 2% (w/v) slurries by adjusting the P^H to the desired value (P^H 2.0 –10.0) before whipping.

Effects of concentration on foaming capacity
Effects of concentration on foaming capacity were evaluated by whipping 2,4,6,8, and 10% (w/v) slurries as described above. Salt (NaCl) concentrations of .0.2, 0.4, 0.6, 0.8, 1.0, 1.5, 2.0% (w/v) slurries were employed to study the effects of salt on foaming capacity.

Effect of certain carbohydrates on foaming properties
The effects of certain carbohydrates on foaming properties of coconut protein concentrates were evaluated. Galactose, sucrose (all from BDH chemicals, England), Gum acacia, pectins and corn starch (from Hopkins and Williams Laboratory Reagents, Essex, England) were used. Samples (0.25g of each carbohydrate per gram of protein concentrate) were blended in 100 ml of distilled water for 5mins. Samples were then transferred into 250ml graduated cylinders and examined for volume increase as described above. All experiments were conducted at room temperature, in duplicates and means reported.

Statistical Analysis
All data were examined statistically by analysis of variance [12] and adopting the least significance difference (LSD) as the test for significance

RESULTS

Mean values for the proximate composition of full fat (FFC-PC) and defatted (DFC-PC) coconut protein concentrates are presented in Table 1.The FFC-PC and DFC-PC contained 27.80% and 30.20% proteins, respectively. The lipid, carbohydrate, crude fiber and ash contents differed significantly ($P \leq 0.05$).

Nitrogen solubility
Nitrogen solubility profiles of FFC- PC and DFC-PC as a function of P^H and ionic/salt concentrations are shown in Fig 1 and Fig 2. Generally, the nitrogen solubility response of the samples to changing levels of P^H in water and low salt dispersion differed from that of the high salt suspension. The Full-fat coconut protein concentrate and DFC-PC samples showed minimum solubility between P^H 4.0 –5.0 and maximum solubility in the range of P^H 9.0 – 10.5.

The FFC-PC sample had maximum solubility (more than 73.0%) at P^H 10.5 and minimum solubility (13.2%) at P^H 4.0-5.0 (Fig1). The coconut protein showed fairly high solubility at P^H 2.0 (about 54.6% and 53.2%) in FFC-PC and DFC-PC, respectively, Fig 1. However, at P^H 4.0 –5.0, protein extraction increased with increasing concentration of salt. DFC-PC samples were less soluble than their unextracted counterpart in this P^H range. Whereas the

reverse was the case beyond the isoelectric P^H, on the alkaline side there was a steep increase in solubility.

At high (1.0M) NaCl concentration, the solubility decreased drastically, while at the lower (0.1M) NaCl concentration, solubility increased at all the P^H levels. FFC-PC samples had a maximum solubility of more than 43% at P^H 10.5 in 1.0M NaCl solution.

Similarly, the DFC-PC samples had maximum solubility of about 50.2% in 1.0M NaCl solution and more than 80% in 0.1M NaCl dispersion medium. At the lower salt (0.1M NaCl) concentration, the solubility of both FFC-PC and DFC –PC samples increased slightly in the P^H range 8.0- 10.5 indicating the "salting-in" effect while at higher salt concentration (1.0M NaCl), the solubility decreased which revealed the "salting-out" effect on the complex protein system.

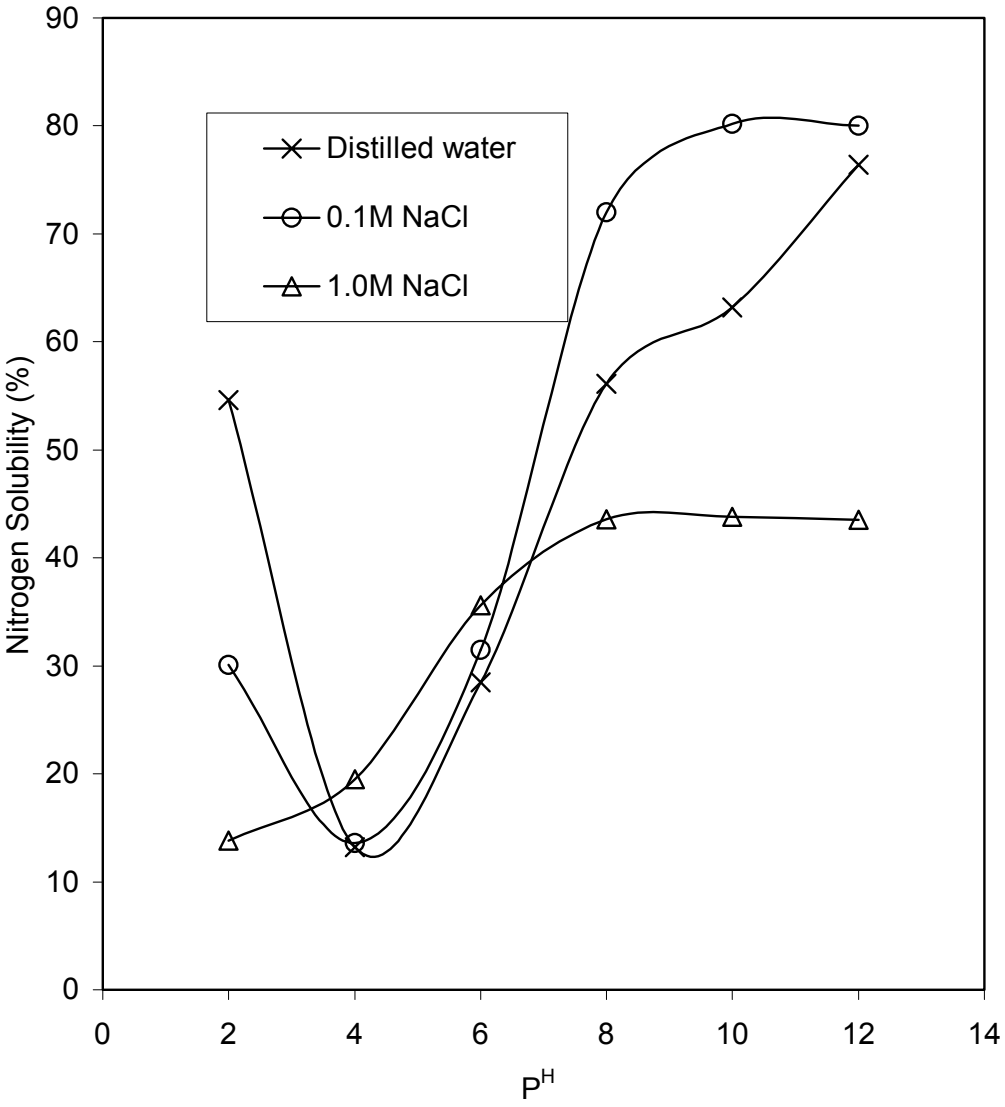

Fig 1. Effect of P^H on nitrogen solubility of fullfat Coconut protein concentrate (FFC-PC) at different salt concentrations (%)

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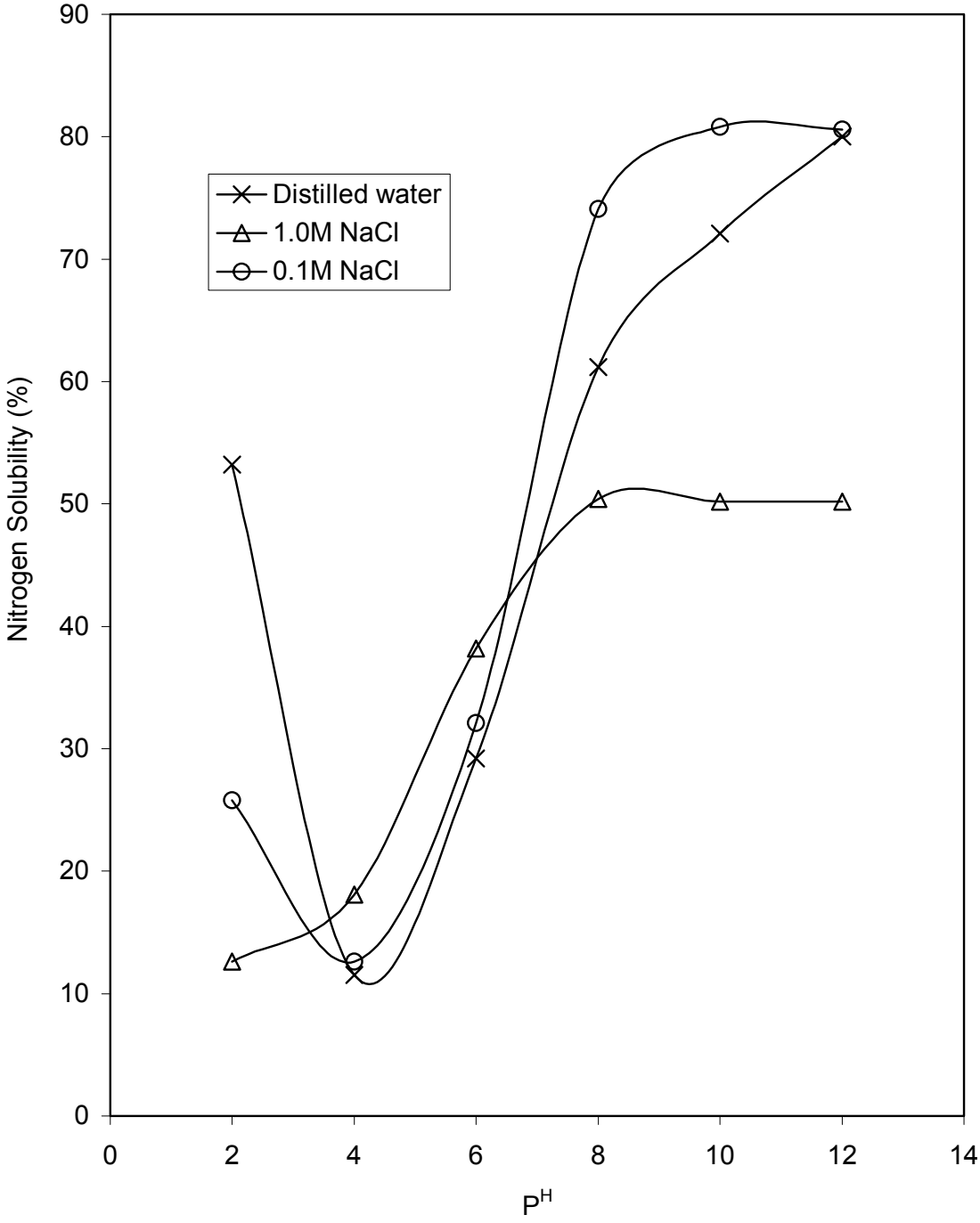

Fig 2 Effect of P^H on nitrogen solubility of defatted Coconut protein concentrate (DFC-PC) at different salt concentrations (%)

Emulsion properties: Effect of P^H

The emulsion capacities of FFC-PC and DFC-PC over a range of P^H (2.0 –10) are shown in Table 2. The Emulsion capacity (EC) of coconut protein concentrate suspensions was markedly improved by adjusting the P^H from 2.0 to 10.0. Alkaline P^H improved the EC more than the acid P^H A maximum value of 92.5ml/g protein of emulsification capacity at P^H 10.0 and a minimum value of 45.3ml/g protein at P^H 4.0 were observed for FFC-PC, while DFC-PC had a maximum EC of 86.4ml/g protein at P^H 10.0. Both samples showed positive correlation with P^H and nitrogen solubility. Emulsion capacity of the protein suspensions was greatest at the two extreme P^H levels (2.0 and 10.0) and least at P^H 4.0. Removal of lipids with *n*-hexane significantly ($P \leq 0.05$) reduced the EC of DFC-PC when compared with FFC – PC.

Emulsion stability

Table 3 shows the emulsion stabilities of FFC-PC and DFC-FFC samples held for various times at ambient temperature. The emulsions prepared from FFC-PC and DFC-PC had good emulsion stabilities. First phase separation occurred after 36hrs and 48hrs for DFC-PC and FFC-PC, respectively when held at ambient temperature.

Effect of sample concentration

The effects of concentration on emulsion capacity of the protein concentrate are summarized in Table 4. In comparing the emulsion capacities of FFC-PC and DFC-PC samples, quantities of oil emulsified increased as sample concentration increased, though not proportionately. However, when expressed on a unit protein basis, emulsion capacity actually decreased with increased sample concentration.

Foaming properties

Data in Table 2 show the effect of P^H on the foaming capacities of FFC-PC and DFC-PC samples. FFC-PC samples had a significantly ($P<0.05$) lower foaming capacity than the DFC-PC samples at all the tested P^H values. Similarly, the foaming capacities of FFC-PC and DFC-PC decreased with increasing P^H of the dispersion medium. A maximum volume increase of 26.4% for (FFC-PC) and 41.2% (DFC-PC) at P^H 2.0 and a minimum volume increase of 16.4% and 28.4% at P^H 10.0 were obtained for FFC-PC and DFC-PC samples, respectively.

Data in Table 3 show the foam stabilities of FFC-PC and DFC-PC samples. Both FFC-PC and DFC-PC foams had low stability. In both samples, foam volume reduced drastically after 30mins then stabilized for about 1hr before a gradual decline for 1.5hrs and collapsed after 4hrs. Full-fat coconut protein concentrate maintained a significantly higher foam volume than DFC –FC for up to 2.5hrs.

Effect of sample concentration

Data in Table 4 show the effects of concentration on foaming capacities of FFC-PC and DFC-PC. Foaming was concentration dependent and increased with increasing concentrations of protein concentrate. There was a rapid increase in foam volume up to 6(w/v)% solids concentration with a maximum at 10(w/v)% solids concentration. The Defatted coconut protein concentrate had a significantly higher foaming capacity than FFC-PC samples.

Effect of salt concentration on formability

The effect of salt additions on the foaming capacities of FFC-PC and DFC-PC are presented in Table 5. Addition of salt (NaCl) significantly ($p \leq 0.05$) improved the foamability of FFC-PC and DFC-PC. In both samples foam volume increased sharply at 0.2% NaCl content of the slurries then improved steadily to a peak of 92.0 % and 113% in FFC-PC and DFC-PC samples respectively at 0.8(w/v)% salt solution then declined gradually with increased salt concentration.

Table 6a and Table 6b present the effect of carbohydrates on foaming properties of FFC-PC and DFC-PC respectively. Addition of carbohydrates other than galactose at levels of 0.25g/g protein concentrate significantly ($P \leq 0.05$) increased the foaming capacity over that of the control. Higher foam volumes were obtained in samples treated with pectins, gum acacia and corn starch.

Similar observations were made with DFC-PC (Table 6b). However foam volume was higher in DFC-PC than in FFC-PC for all treatments with carbohydrates.

DISCUSSION

Defatted coconut protein concentrate had a significantly higher protein but lower lipid content than full fat coconut protein concentrate. These differences in the proximate composition of these proteins could reflect differences in their conformation, molecular flexibility and physiochemical properties [5, 13]

Test of functional properties: Nitrogen Solubility

As depicted in Fig 1 and Fig 2, nitrogen solubility was P^H dependent. The nature of the nitrogen solubility curve of coconut protein concentrates resembles the nitrogen solubility curve of many oilseeds (14-16). Similar to other oilseeds, the minimum solubility for coconut proteins was at P^H 4.0-5.0. Gbenle and Onyekachi [16] observed that the minimum solubilities for groundnut, soya bean and melon seed were at P^H 4.0-6.0. Similarly, they reported that groundnut and C.*edulis* proteins showed fairly high solubilities of about 56% and 44% respectively at P^H 2.0.

The high solubilities of coconut proteins at acid P^H suggest that they may be used in acid foods and beverage [14]. Kwon *et al*. [17] also reported increased protein extraction at the isoelectric P^H with increasing concentration of salts. At this P^H (isoelectric) protein extraction is least extractable in water [18]. Similar to other oilseed proteins, coconut protein demonstrated higher solubilities at alkaline P^H. Available results [14-16] indicate that the nitrogen solubilities of oilseed protein isolates at their maximal P^H of solubility were 88% for groundnut, 82% for the C. *citrullus* and 77% soyabean. The change of solubility profile of DFC-PC resulting from lipid removal may indicate the modification (alteration of ionic charges) on the protein structure as suggested by Wang and Kinsella [18].

Emulsion properties

Data in Table 2 show that the emulsion capacities of FFC-PC and DFC-PC were dependent on P^H Similar P^H dependence of emulsifying capacities of proteins has been reported [19-21]. The emulsifying capacities of soluble proteins depend upon the hydrophilic-lipid balance, which is affected by P^H. The net charge at the interface may impede or facilitate emulsifying activity of proteins.

Our observations on increased E C. in the alkaline P^H are in agreement with the findings of Bera and Mukherjee [6]. The DFC-PC samples contained more carbohydrate (40.68%) than FFC-PC samples (36.21%). Poor emulsion properties of DFC-PC samples were due to presence of carbohydrates. The lipid content of FFC-PC might have influenced the hydrophilic-lipid balance of proteins to more favourable level and hence had higher EC. Similarly, the emulsions prepared from FFC-PC were more stable than those from DFC-PC samples (Table 3). This was expected because the lipid content of FFC-PC influenced EC and ES [5].

The emulsion capacity of FFC-PC and DFC-PC samples decreased with increasing sample concentration (Table 4). Lin *et al*.[22] similarly reported decreased EC of sunflower and soybean flours and protein concentrates/isolates as sample concentration was increased. Phillips [23] explained the dependence of EC on protein concentration on the basis of absorption kinetics at a low protein concentration, the rate of adsorption is diffusion controlled but at high protein concentration, there is an activation barrier to absorption. Under the latter conditions the ability of the protein molecules to create space in the existing film and to penetrate and rearrange on the surface is rate determining.

Foam properties

The FFC-PC samples had significantly poor foaming capacities than the DFC-PC samples at all the tested P^H values (Table 2). The poor foaming capacity of FFC-PC may be due to presence of lipids. Wang and Kinsella [18] observed that bound lipids in alfalfa leaf protein preparation depressed foaming. The FFC-PC sample contained more than 12.0% fat that may be responsible for poor foaming in comparison to the DFC-PC samples.

The stability of FFC-PC and DFC-FC foams was low (Table 3). DFC-PC foams collapsed completely after 48hrs at 30C. Foamability is related to the rate of decrease of surface tension of the air /water interface caused by adsorption of protein molecules. According to Grahams and Phillips [24] flexible protein molecules like (β-casein which can rapidly reduce surface tension give good foamability, whereas a highly ordered globular molecule such as lysozyme, which is relatively difficult to denature give lower foaming properties.

Foaming properties of all samples increased with an increase in protein concentration (Table 4). The effect may be explained to be similar to that of P^H as more proteins become available to foam and to stabilize the foam., Canella. [25] reported maximum foam expansion of acid-butanol treated sunflower seed flour and sunflower seed protein isolate and soya protein isolate at 1% level. On the other hand, Huffman *et al.* [26] observed an increase in foam expansion up to 8%, concentration of sunflower seed flour at P^H 9.0. From the above observation it appears that foaming properties may increase with increase in protein

concentration up to a certain level, presumably, due to saturation point of protein solubility under the experimental conditions.

The effect of additives on the foaming properties was variable. NaCl addition (Table 5) increased foaming properties perhaps by increasing the protein solubility through partial denaturation [27]. Kinsella [28] reported formation of high capacity low stability foams when salt was added to protein suspensions. Similar variable results were obtained with the addition of carbohydrates (Table 6a and 6b). Our results with the incorporation of carbohydrates on foam volume and stabilities are in accord with Sathe *et al.* [29] ; Gujska and Khan [30].

CONCLUSION

Full fat coconut protein concentrate and Defatted coconut protein concentrate containing 27.80% and 30.20% protein respectively (on a dry weight basis) were prepared from the West African tall coconuts. Both FFC-PC and DFC-PC samples showed minimum nitrogen solubility between P^H 4.0–5.0 and maximum solubility in the range of P^H 9 -10.5.

In low salt solutions (0.1 M NaCl), the solubility of both FFC-PC and DFC-PC samples increased slightly in the range of P^H 8.0-12.0, while at higher salt concentration solubility decreased indicating the "salting out" effect on the complex protein system. Emulsion properties of the protein concentrate were P^H dependent. The protein concentrate emulsion had good stability (36-48 hrs). Foaming properties were P^H dependent with a maximum within the acid range. Coconut protein had poor foaming capacity and could be improved by increasing sample concentration as well as adding NaCl. Although carbohydrates other than galactose improved foam volume increase, foam stabilities were not significantly ($p \geq 0.05$) affected.

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Table 1: Proximate composition of full-fat and defatted coconut protein concentrates

Sample†	Moisture (%)	Protein (%)	Lipid (%)	Crude fibre (%)	Ash (%)	Carbohydrate (by difference) %
FFC-PC	7.65 [a]	27.80 [a]	12.40 [b]	4.20*[a]	1.74 [a]	36.21[a]
DFC-PC	8.32 [a]	30.20 [b]	11. 58 [a]	6.40 [b]	2.82[b]	40.68[b]
LSD$^{\Delta}$ = 0.72						

† FFC-PC = Full-fat coconut protein concentrate, DFC-PC =Defatted coconut protein concentrate.
$^{\Delta}$Least significant difference at $p \leq 0.05$.
*Means in the same columns followed by different superscripts differ significantly ($p \leq 0.05$).

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Table 2: Effect of P^H on emulsion and foaming capacities of full-fat and defatted coconut protein concentrates*

P^H †	*FFC-PC		DFC-PC	
	Emulsion capacity G oil/ g sample	Foaming capacity % Vol. Increase	Emulsion capacity g oil/ g sample	Foaming capacity % Vol. Increase
2	74.9^c	26.4^c	70.3^c	42.1^d
4	45.3^a	21.5^b	41.1^a	37.8^c
6	62.6^b	18.4^{ab}	56.7^b	32.6^b
5	78.4^d	18.2^{ab}	73.2^d	32.3^b
10	92.5^e	16.4^a	85.4^e	28.4^a
LSD^Δ = 2.2				

FFC-PC = Full-fat coconut protein concentrate, DFC-PC =Defatted coconut protein concentrate.
*Mean of duplicate determinations.
†A 2% (W/V) Slurry was employed at different P^H levels.
$^\Delta$Least significant difference at $p \leq 0.05$. Means in the same columns not followed by the same superscripts are significant different ($p \leq 0.05$).

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Table 3: Foam and emulsion stabilities of full-fat and defatted coconut protein concentrate*

Time	Foam stability†		Time	Emulsion stability††	
(hr)	FFC-PC	DFC-PC	(hr)	FFC-PC	DFC-PC
0.0	138	150	0	0	0
0.5	122	134	8	0	0
1.0	122	134	12	0	0
1.5	114	124	16	0	0
2.5	112	116	20	0	0
3.0	110	112	36	0	2
4.0	110	100	48	2	2

LSD^{Δ} = 0.3

FFC-PC = Full-fat coconut protein concentrate, DFC-PC =Defatted coconut protein concentrate.
*Mean of duplicate determinations.
† Volume (ml) at ambient temperature (30 + 1°C) of a 2% (w/v) Slurry.
†† Volume of water (ml) separated at ambient temperature (30 + 1°C).
$^{\Delta}$Least significant difference at $p \leq 0.05$. = 0.3. Means of samples in the same columns exceeding this value are significantly different ($p \leq 0.05$)

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Table 4: Effect of sample concentration on the Emulsion and foaming Properties of full-fat and defatted coconut protein concentrates*

Concentration†	*FFC-PC		DFC-PC	
	Emulsion stability ml oil/ g sample	Foaming stability % Vol. Increase	Emulsion stability ml oil/ g sample	Foaming stability % Vol. Increase
2	96.1^{e}	38.2^{a}	90.2^{d}	50.3^{a}
4	64.2^{d}	43.4^{b}	58.6^{c}	65.1^{b}
6	52.3^{C}	49.5^{c}	46.1^{b}	73.4^{c}
8	44.1^{b}	54.1^{d}	36.8^{a}	78.3^{d}
10	40.5^{a}	56.4^{d}	34.4^{a}	81.2^{e}
LSD$^{\Delta}$ = 3.2				

FFC-PC = Full-fat coconut protein concentrate, DFC-PC =Defatted coconut protein concentrate.
*Mean of duplicate determinations.
†A 2% (w/v) slurry was employed at different sample concentration level.
$^{\Delta}$Least significant difference at $p \leq 0.05$. Means in the same columns followed by different superscripts differ significantly ($p \leq 0.05$)

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Table 5: Effect of salt concentration on formability of full-fat and defatted coconut protein concentrates*

Salt concentration† % (w/v)	FFC-PC		DFC-PC	
	Total vol (ml)	Vol. Increase %	Total vol (ml)	Vol. Increase %
0	138[a]	38[a]	150[a]	50[a]
0.2	174[b]	74[b]	195[b]	95[b]
0.4	180[c]	80[c]	203[c]	103[d]
0.6	184[d]	84[d]	208[d]	108[e]
0.8	192[g]	92[g]	213[f]	113[g]
1.0	188[f]	88[f]	210[e]	110[f]
1.5	188[f]	88[f]	210[e]	110[f]
2.0	185[e]	85[e]	195[b]	98[c]
LSD[Δ] = 0.7				

FFC-PC = Full-fat coconut protein concentrate, DFC-PC =Defatted coconut protein concentrate.
*Mean of duplicate determinations.
† A 2% (w/v) aqueous suspension was employed.
[Δ]Least significant difference at $p < 0.05$. Means in the same columns not followed by the same superscripts are significantly different ($p \leq 0.05$)

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Table 6a: Effect of carbohydrates on foaming properties of full-fat coconut protein concentrates (FFC-PC)

Carbohydrate	Volume after whipping (ml)	Volume increase %	Volume (ml) at room temp. (30^0C) after time (hr)							
			0.5	1.0	1.5	2.0	2.5	3.0	4.0	12.0
Control	138	38	126	116	110	108	106	104	102	100
Galactose	138	38	126	116	108	108	106	104	100	100
Sucrose	140	40	128	118	112	110	108	106	104	100
Corn starch	142	42	130	120	114	112	110	108	106	100
Gum acacia	146	44	134	124	116	114	112	110	108	102
Pectins	148	48	136	126	118	116	114	112	110	102
LSD^{Δ} = 2.5										

*Mean of duplicate determinations. Volume (ml) at room temp. (30^0C) after time (hr)
†A 2% (w/v) slurry was employed to study the effects of carbohydrates (0.25g/g protein conc.) on foaming properties
$^{\Delta}$Least significant difference at $p \leq 0.05$. = 2.5. Means of any two carbohydrates exceeding this value are significant different ($p \leq 0.05$)

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Table 6b: Effect of carbohydrates on foaming properties of defatted coconut protein concentrates (DFC-PC)

Carbohydrate†	Volume after whipping (ml)	Volume increase %	Volume (ml) at room temp. (30C) after time (hr)							
			0.5	1.0	1.5	2.0	2.5	3.0	4.0	12.0
Control	150	50	144	142	140	140	136	132	122	100
Galactose	152	52	146	144	142	142	134	130	120	100
Sucrose	154	54	144	134	126	122	120	110	105	100
Corn starch	156	56	148	138	136	132	124	120	110	100
Gum acacia	158	58	150	142	134	126	122	116	110	102
Pectins	160	60	156	152	148	144	140	132	122	102
LSD$^{\Delta}$ = 2.5										

*Mean of duplicate determinations.
†A 2% (W/V) slurry was employed to study the effects of carbohydrates (0.25g/g protein con.) on foaming properties
$^{\Delta}$Least significant difference at P< 0.05. 2.5. Means of any two carbohydrates exceeding this value are significant different ($p \leq 0.05$)

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