



Functional properties of protein concentrates and isolates produced from cashew (*Anacardium occidentale* L.) nut

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ABSTRACT

Protein isolates and concentrates were obtained from defatted cashew nut powder by two methods: alkaline extraction-isoelectric precipitation (IP) and alkaline extraction-methanol precipitation (MP). The functional properties of cashew nut protein isolates, concentrates and powder were significantly different ($p < 0.05$). Cashew nut protein isolate (CNPI) had higher water and oil absorption capacities (2.20 ml/g and 4.42 ml/g, respectively), emulsifying stability index (447%), foam capacity and stability (45% and 55%, respectively), and least gelation capacity (13.5%) than cashew nut protein concentrate (CNPC), which was also higher than that of defatted cashew nut powder (DCNP). However, emulsifying activity index (12.45%) and bulk density (0.31) of CNPI were lower than that of CNPC, which were also lower than that of DCNP. The water solubility of CNPI (95%) and CNPC (95%) was not significantly different ($p > 0.05$) among the samples, but was significantly different ($p < 0.05$) from that of DCNP (75%). The CNPI, CNPC and DCNP showed decreasing solubility with decreasing pH, with the minimum solubility being observed at a pH range of 4.0–4.5, confirming the isoelectric point of cashew proteins. However, higher water solubility, emulsifying activity, and foaming property were observed at an alkaline pH than at an acidic pH in all samples.

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1. Introduction

Cashew fruit is made up of an apple that bears fruit in which the kernel is embedded. The real fruit of the cashew is commonly a nut. It is a kidney-or-heart-shaped achene, in any normal variety. Its colour varies from bottle green (fresh fruit) to greyish-brown (dried fruit). It is attached to the end of a fleshy footstalk or peduncle, which is in fact the receptacle of the flower, that is, broadened, swollen and it forms the false fruit. The nut is composed of kernel and pericarp or shell. The kernel is slightly curved back on itself and forms two cotyledons, representing about 20–25% of the nuts weight. It is wrapped in a thin, difficult to remove peel (testa), membrane-like membrane, reddish-brown in colour, which in turn approximates to 5% of the whole nut. Cashew is of considerable economic importance because its components have numerous economic uses. The cashew kernel is of high food value with about 40–57% oil and 21% protein contents (Fetuga, Babatunde, Ekpenyong & Oyenuga, 1975). It is an important delicacy, which is mainly used in confectionery and as a desert nut. The kernel can be roasted

and consumed; it can also be used as an adjunct in chocolate and chicken feeds. The powdered milk used in the standard milk chocolate recipe was replaced with 25% roasted cashew kernel (Ogunwolu & Akinwale, 2003). In view of the increasing production of cashew globally, there is a need for an increased utilisation of the cashew nut, especially the nutritious cashew kernel.

Proteins that are utilised in food processing are of various origins, and can be roughly grouped into animal proteins (e.g. gelatine), vegetable proteins (e.g. soya protein, peanut protein and wheat protein), and animal-derivatives protein (e.g. milk proteins) (Penny, 1999). Many of the vegetable proteins require processing to provide a food material having acceptable functional properties, such as emulsification, fat and water absorption, texture modifications, colour control and whipping properties, which are attributed primarily to the protein characteristics.

In the recent years, many plants have attracted a great deal of interest as a source of low-cost protein to supplement human diets. Also, proteins are important in food processing and food product development, because they are responsible for many functional properties that influence the consumer acceptance of food products. Among the various sources of vegetable proteins considered as food ingredients are peanut and soybeans. According to Piva, Santi, and Ekpenyong (1971), a cashew kernel meal contains

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about 42% crude protein, a low content of crude fibre and 0.5% and 0.2% calcium and phosphorous, respectively. This is comparable to peanut compositions, which has been used for the production of peanut protein concentrates and isolates (Monteiro & Prakash, 1994).

Cashew kernel is therefore being considered as an additional source of protein concentrates and isolates for use in human food products.

Therefore, the objective of this study is to determine the functional properties of powder, protein concentrate, and isolate produced from cashew nut.

2. Materials and methods

2.1. Preparation of defatted cashew kernel powder

The defatted cashew nut powder was produced according to the method suggested by Sze-Tao and Sathe (2004) for the extraction of almond protein; cashew kernels were ground using pestle and mortar. The flakes were then extracted with *n*-hexane ($\times 2$), using a flake to a solvent ratio of 1:10 (w/v), with continuous magnetic stirring (1-kamag reo magnetic stirrer model, Drehzahl electronics, USA) for 1 h. The defatted flakes were then spread on a stainless tray, and were placed inside a fume cupboard for 6 h to dry and to remove the traces of the solvent used. The flakes were then ground to obtain an average particle size of 150 μm powder, packed in plastic tubes and stored at -10°C .

2.2. Extraction of cashew nut proteins

2.2.1. Method 1: aqueous-isoelectric extraction method

The method described by Wagner, Sorgentini, and Anon (2000) was used for the aqueous-isoelectric production of protein; the defatted cashew nut powder was extracted at room temperature (about 20°C) by using two different cashew powder to water ratio of 1:5 and 1:10 to obtain two different extracts. The distilled water used was also adjusted to two different pH of 7.0 and 9.0, with 0.1 N NaOH. The suspension was stirred using a magnetic stirrer for 1 h and then cold-centrifuged (using Heraeus Multifuge 1 S-R) at $1000 \times g$ for 30 min, at 4°C . The insoluble cashew protein cake was re-slurried with pH-adjusted distilled water as above, and cold-centrifuged again. The supernatants were mixed together, divided into two and adjusted to two different pH of 3.5 and 4.5 by the addition of 0.1 N HCl, allowed to stay for 2 h at 4°C , and then centrifuged again for 30 min at 4°C and $1000 \times g$. The supernatants were poured off to obtain a cashew protein slurry, which was at the bottom of the centrifuge tube. The slurry was re-suspended in water of pH 3.5 and 4.5, and the extraction was repeated as above to obtain concentrated cashew protein slurry. The cashew protein slurry was freeze-dried in a CHRIST freeze-drying system, model; ALPHA 2–4 (Martins Christ, Germany), for 12 h. The cashew proteins were then ground in a laboratory mill so as to pass through a 103-mesh screen and then packaged, and stored at -10°C . The extraction was carried out in triplicate.

2.2.2. Method 2: aqueous-methanol extraction method

This method described by Hanson (1974) was used for the alkaline extraction-methanol precipitation of cashew protein; the defatted cashew nut powder was extracted at room temperature (about 20°C) by using two different cashew nut powder to water ratio of 1:5 and 1:10 to obtain two different extracts. The distilled water used was also adjusted to two different pH of 7.0 and 9.0, using 0.1 N NaOH. The suspension was stirred using a magnetic stirrer for 1 h. Insoluble material was separated from the filtrate by filtration using a rotary vacuum filter. The insoluble cashew

protein cake was re-slurried with pH-adjusted water as above, and filtered again. The filtrates were mixed together, divided into two and mixed with two different methanol concentrations of 70% and 80%, to obtain two different extracts, allowed to stand for 2 h at 4°C , and then cold-centrifuged (using Heraeus Multifuge 1 S-R) at $1000 \times g$ at 4°C for 30 min. The supernatants were poured off to obtain a cashew slurry, which was at the bottom of the tube. The slurry was re-suspended in methanol concentration of 70% and 80%, and the extraction was repeated as above, to obtain purer cashew proteins. The alcohol was removed from the cashew protein slurry using a vacuum desolventiser. The cashew protein slurry was freeze-dried in a CHRIST freeze-drying system (Martins Christ, Germany, model; ALPHA 2–4) for 12 h. The cashew proteins were then ground in a laboratory mill so as to pass through a 103-mesh screen and then packaged and stored at -10°C . The extraction was carried out in triplicates.

2.3. Functional properties of cashew nut proteins

The following functional properties of the cashew proteins were carried out.

2.3.1. Bulk density

This was determined using the method described by Monteiro and Prakash (1994). A calibrated plastic centrifuge tube was weighed (W_1), protein samples were filled to 25 ml and the tubes were tapped to eliminate the spaces between the particles, the volume was taken as the volume of the sample. The tube was weighed again (W_2). From the difference in weight, the bulk density of the protein samples was calculated and expressed as grams per millilitre (g/ml).

2.3.2. Water absorption capacity (WAC)

This was determined using the method described by Rodriguez-Ambriz, Martinez-Ayalo, Milla, and Davila-Ortiz (2005); 100 mg of each protein samples was mixed with 1000 μl of distilled water using a stirrer. The protein suspension was then centrifuged at $1800 \times g$ for 20 min at 22°C . The supernatant was decanted, and the tube was drained at 45° angle for 10 min. Water absorption capacity was calculated by dividing the volume of water absorbed by the weight of the protein sample.

2.3.3. Fat absorption capacity (FAC)

This was determined using the method described by Lin and Zayas (1987); 100 mg of protein sample was vortex-mixed with 1000 μl of sunflower oil for 30 s. The emulsion was incubated at room temperature (about 20°C) for 30 min and then centrifuged at $13,600g$ for 10 min at 25°C . The supernatant was decanted and drained at a 45° angle for 20 min. The volume of oil absorbed was divided with the weight of the protein sample, to obtain the fat or oil absorption capacity of the sample.

2.3.4. Emulsifying properties

Emulsifying activity index (EAI) and emulsion stability index (ESI) were determined using the method described by Klompong, Benjakul, Kantachote, and Shahid (2007). Three hundred milligrams of each protein isolate samples were mixed with 30 ml of deionised water. This protein solution was mixed with 10 ml of sunflower vegetable oil, and the pH was adjusted to 2, 4, 6, 8, and 10. The mixture was homogenised at a speed of 20,000 rpm for 1 min. Fifty microlitres of the aliquot of the emulsion were transferred (using pipette) from the bottom of the container at 0 and 10 min after homogenisation, and mixed with 5 ml of 0.1% sodium dodecyl sulphate (SDS) solution. The absorbance of the diluted solution was measured at 500 nm using spectrophotometer (UVIKON 930, BIO-TEK Kontron, Germany). This was used to

calculate EAI and ESI using the method suggested by Pearce and Kinsella (1978):

$$\text{Emulsifying activity index (EAI)} (\text{m}^2/\text{g}) = \frac{2 \times 2.303 \times A_0}{0.25 \times \text{protein weight (g)}}$$

$$\text{Emulsion stability index (ESI)} (\text{min}) = \frac{A_{10} \times \Delta t}{\Delta A}$$

where A_0 is the absorbance at 0 min after homogenisation; A_{10} is the absorbance at 10 min after homogenisation; $\Delta t = 10$ min; and $\Delta A = A_0 - A_{10}$.

2.3.5. Foaming properties

Foaming capacity and stability were determined according to the method described by Sze-Tao and Sathe (2000). Two hundred and fifty milligrams of each protein sample were mixed with 250 ml of distilled water, and the pH was adjusted to 2, 4, 6, 8, and 10. This protein solution was whipped for 3 min in a stainless GS Blender (model 38 BL45 by Dynamic Corporation of America). The whipped protein solution was then poured into a 100 ml graduated cylinder. The total sample volume was taken at 0 min for foam capacity and up to 60 min for foam stability. Foam capacity and foam stability were then calculated:

$$(1) \text{Foam capacity (FC)} (\%) = \frac{(\text{Volume after whipping} - \text{volume before whipping}) \text{ ml}}{(\text{Volume before whipping}) \text{ ml}}$$

$$\text{Foam stability (FS)} (\%) = \frac{(\text{Volume after standing} - \text{volume before whipping}) \text{ ml}}{(\text{Volume before whipping}) \text{ ml}}$$

2.3.6. Least gelation concentration

This was determined using the method described by Abbey and Ibeh (1988); cashew protein samples were mixed with 5 ml of distilled water in a centrifuge tube to obtain 2%, 4%, 6%, 8%, 10%, 12%, 14%, 16%, 18%, and 20% w/v concentrations. The centrifuge tube was heated for 1 h in a boiling water bath, cooled rapidly under running tap water and further cooled for 2 h in a refrigerator at 4 °C. The least gelation concentration was regarded as the concentration at which the sample from the inverted tube did not fall or slip.

2.3.7. Protein solubility in water

This was determined by the method described by Klompong et al. (2007), 200 mg of each protein sample was dispersed in 20 ml deionised water, and the pH of the solution was adjusted to 2, 4, 6, 8, 10, and 12 with 1 or 0.1 N HCl and 1 or 0.1 N NaOH. The mixture was stirred at room temperature (about 20 °C) for 30 min, using magnetic stirrer, and then centrifuged at $7500 \times g$ for 15 min. The protein content in the supernatant was determined using the Bradford kit method (Bradford, 1976). Protein solubility was then calculated:

$$(3) \text{Solubility} (\%) = \frac{\text{Protein content of supernatant}}{\text{Total protein content of the sample}} \times 100$$

2.4. Statistical analysis

Data collected from all experiments were in triplicate, and subjected to statistical analysis, using analysis of variance (ANOVA). Differences between the treatment means were separated using Duncan's multiple range tests. All statistical procedures were carried out according to the methods of Steel and Torrie (1980), while computation was done using SAS Software package 10 (1990).

3. Results and discussion

3.1. Functional properties of defatted cashew nut powder (DCNP), cashew nut protein concentrate (CNPC) and cashew nut protein isolate (CNPI) at their natural pH

3.1.1. Water absorption capacity (WAC)

Cashew nut protein isolate was found to possess the highest water absorption capacity (WAC) of 2.20 ml H₂O/g compared with that of cashew nut protein concentrate (1.74 ml H₂O/g) and with that of defatted cashew nut powder (0.81 ml H₂O/g) (Table 1). Water absorption capacity (WAC) of DCNP, CNPC, and CNPI was significantly different ($p < 0.05$) from one another. It has been reported that the protein concentrate exhibits poor water-binding capacity compared to that of the protein isolates. This is likely due to the fact that the protein isolate has a great ability to swell, dissociate and unfold exposing additional binding sites, whereas the carbohydrates and other non-protein components of the protein concentrates may impair it (Kinsella, 1979). However, the WAC values for CNPC (1.74 ml H₂O/g) and CNPI (2.20 ml H₂O/ml) were within the range of WAC values for commercial protein concentrate and isolate (1.5–2.5 ml H₂O/g) as reported by Lin and Zayas (1987). The WAC value obtained for CNPI is comparable to what was obtained by El-Adawy, Rahma, El-Bedawey, and Gafar (2001) for bitter lupin protein isolate (2.12 ml H₂O/g), processed by the same method. Also, the WAC value of CNPC was comparable to that of Chilean hazelnut (1.34 ml H₂O/g) processed by the same method as reported by Moure, Rúa, Sineiro, and Domínguez (2001). While the WAC of the DCNP (0.8 ml H₂O/g) is lower to that of defatted peanut powder (1.45 mg H₂O/g), as reported by Monteiro and Prakash (1994). High WAC of CNPI and CNPC makes them a potential ingredient in meat, bread, and cakes industries.

3.1.2. Oil absorption capacity (OAC)

Oil absorption capacity (OAC) of cashew nut protein isolate was found to be 4.42 ml oil/g, and was higher than that of cashew nut concentrate (3.32 ml oil/g), which was also higher than that of defatted cashew nut powder (2.05 ml oil/g), and they were significantly different ($p < 0.05$) from one another (Table 1). This is in agreement with the report of Campell, Shih, and Marshall (1992) that OAC increased as protein content increased in sunflower and soya protein products. OAC of DCNP is higher than that of defatted peanut powder (1.79 ml oil/g), defatted using the same solvent (*n*-hexane) as reported by Beuchat, Cherry, and Quinn (1975), but comparable with that of defatted Niger seed (2.00 ml oil/g) as reported by Bhagya and Sastry (2003). Also, OAC of the CNPC and CNPI was higher than that of commercial soybean concentrate

Table 1

Some functional properties of defatted cashew nut powder (DCNP), cashew nut protein concentrate (CNPC) and cashew nut protein isolate (CNPI) at their natural pH.

| Functional properties | DCNP | CNPC | CNPI |
|-----------------------|--------------------------|--------------------------|--------------------------|
| WAC (ml/g) | 0.81 ± 0.01 ^c | 1.74 ± 0.01 ^b | 2.20 ± 0.01 ^a |
| OAC (ml/g) | 2.05 ± 0.02 ^c | 3.32 ± 0.02 ^b | 4.42 ± 0.01 ^a |
| EAI (%) | 24.6 ± 0.02 ^a | 13.7 ± 0.02 ^b | 12.5 ± 0.01 ^c |
| ESI (%) | 128 ± 0.03 ^c | 153 ± 0.03 ^b | 447 ± 2.00 ^a |
| FC (%) | 14.0 ± 2.00 ^c | 40.0 ± 2.00 ^b | 45.0 ± 2.00 ^a |
| FS (%) | 8.00 ± 2.00 ^c | 40.0 ± 2.00 ^b | 55.0 ± 2.00 ^a |
| Bulk density | 0.48 ± 0.02 ^a | 0.25 ± 0.01 ^b | 0.31 ± 0.01 ^c |
| LGC (%) | 6.50 ± 3.31 ^c | 10.0 ± 1.81 ^b | 13.5 ± 0.01 ^a |
| SOL (%) | 75.0 ± 2.00 ^b | 95.0 ± 1.00 ^a | 95.0 ± 1.00 ^a |

Notes: Means followed by the same alphabetic on the column are not significantly different at $p < 0.05$.

WAC: water absorption capacity; OAC: oil absorption capacity; EAI: emulsifying activity index; ESI: emulsion stability index; FC: foam capacity; FS: foam stability; and LGC: least gelation capacity; and SOL: solubility.

(ISOPRO) (1.33 ml oil/g) and commercial soybean isolate (SUPRO 670) (2.29 ml oil/g) as reported by Lin, Humbert, and Sosulski (1974) and Liadakis, Tzia, Oreopoulou, and Thomopoulos (1998), respectively. According to Kinsella (1980), the ability of protein to bind fat is very important for such applications as meat replacement and extenders, principally because it enhances flavour retention, and reputedly improves mouth feel. Also, high OAC of CNPI makes it a good ingredient for the cold meat industry, particularly for sausages, where the protein can bridge the fat and water in these products.

3.1.3. Emulsifying activity index (EAI)

At the natural pH of the samples (6.5–7.5), emulsifying activity index (EAI) of DCNP (24.63%) was the highest, and that of CNPC (13.68%) was found to be higher than that of CNPI (12.48%), although the emulsion stability index (ESI) of CNPI was the highest, while that of CNPC was higher than that of DCNP, and they were significantly different ($p < 0.05$) from one another. This is in agreement with Kinsella, Damodaran, and German (1985), who stated that the emulsifying capacity of proteins tends to decrease as protein concentration is increased, and this is also consistent with the similar reported observations on winged bean protein concentrate (Sathe, Desphande, & Salunhkhhe, 1982), and sunflower protein isolate (Lin et al., 1974). At low protein concentration, protein adsorption at the oil water interface is diffusion controlled, since it will spread over the surface before it can be adsorbed. At high protein concentration, the activation energy barrier does not allow protein migration to take place in a diffusion-dependent manner (Phillips & Beuchat, 1981), this may be partly explained why the EAI decreases with increased protein concentration. Also, Tsai, Cassens, and Briskey (1972) explained that as protein concentration is decreased, a greater degree of unfolding of polypeptides occurs during the shearing involved in the emulsifying process and this is aided by hydrophobic association of the peptide chains with the lipid droplets, so that the net result is that a much greater volume of surface area of protein is made available, and emulsifying efficiency is enhanced.

3.1.4. Foaming properties

At the natural pH of the samples, the foam capacity and stability of CNPI (45% and 55%) were higher than that of CNPC (40% and 40%), which were higher than that of DCNP (14% and 8%) (Table 1), and they were all significantly different ($p < 0.05$) from one another. Foam formation is governed by three factors; including transportation, penetration and reorganisation of the molecule at the air–water interface. Therefore, to exhibit good foaming, a protein must be capable of migrating at the air–water interface, unfolding and rearranging at the interface (Halling, 1981). According to Damodaran (1997), the foam capacity and stability were enhanced by greater protein concentration, because this increases the viscosity and facilitates the formation of a multilayer, cohesive protein film at the interface.

3.1.5. Bulk density

Table 1 also shows that the bulk density of defatted cashew nut powder (0.48 g/ml) was found to be higher than that of cashew nut protein concentrate (0.31 g/ml), which was in turn higher than that of cashew nut protein isolate (0.25 g/ml). DCNP, CNPC, and CNPI, bulk density were comparable to that of cowpea powder, protein concentrate, and isolate as reported by Ragab, Babiker, and El-Tinay (2004), but were lower than that of lentil powder, protein concentrate and isolate as reported by Suliman, Tinay, Elkhaliif, Babiker, and Elkhaliif (2006). According to Peleg and Bagley (1983), bulk density depends on the combined effects of interrelated factors such as the intensity of attractive interparticle forces, particle size, and number of contact points. However, Padmashree,

Vijayakshmi, and Puttaraj (1987) reported that higher bulk density is desirable, since it helps to reduce the paste thickness which is an important factor in convalescent and child feeding.

3.1.6. Least gelation capacity

Least gelation capacity (LGC) of the cashew nut protein isolate (13.5%) is the highest among the three samples, and that of the cashew nut protein concentrate (10.00%) was higher than that of defatted cashew nut powder (6.50%). These values are in agreement with the values reported by Okezie and Bello (1988) for soybeans powder (14%), Lqari, Vioque, Pedroche, and Millán (2002) reported that LGC of lupin protein concentrate is 12%, while Schmidt (1981) reported 7.5% for wheat protein isolate. According to Schmidt (1981), for a given type of protein, a critical concentration is required for the formation of a gel and the type of gel varies with the protein concentration. Considerably, higher protein concentration is usual required for the gelation of globular proteins.

3.1.7. Water solubility

At the natural pH, the solubility of CNPI and CNPC was not significantly different ($p > 0.05$) from one another, but was significantly higher ($p < 0.05$) than that of DCNP. The percentage solubility of CNPC (95%) and CNPI (95%) would be adequate for the use in most food formulation without adjusting the pH.

3.2. Effects of pH on water solubility of defatted cashew nut powder (DCNP), cashew nut protein concentrate (CNPC) and cashew nut protein isolate (CNPI)

Fig. 1 shows the nitrogen solubility of defatted cashew nut powder (DCNP) at different pH levels between 2 and 12. The minimum solubility of DCNP was found to be 8% at pH 4, while the solubility was 80% at pH 2. The solubility of defatted cashew nut powder increased from pH 6 to pH 12, and the maximum solubility of 85% was obtained at pH 12. The effects of pH on the solubility of cashew nut protein concentrate (CNPC) are as shown in Fig. 1. The solubility was 85% at pH 2 decreased to the minimum level of 10% at pH 4.0. The solubility thereafter increased from pH 6 to pH 12 to reach the maximum solubility of 98% at pH 12. Fig. 1 shows the effects of pH on the solubility of cashew nut protein isolate (CNPI), cashew nut protein isolate was highly soluble at both acidic and basic pH. The minimum solubility of 30% was obtained at pH 4.5, while the maximum solubility of 96% was obtained at pH 12. The solubility of DCNP, CNPC, and CNPI in water at different pH showed the same U-shaped pattern, which are typical of and similar to many such profiles reported for peanut proteins (Monteiro &

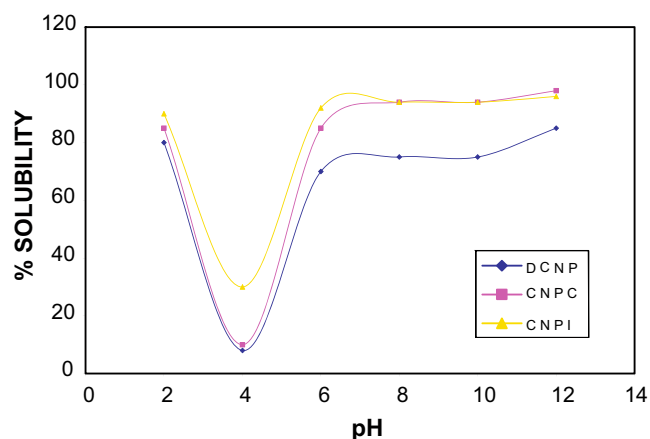


Fig. 1. Effects of pH on solubility of defatted cashew nut powder (DCNP), cashew nut protein concentrate (CNPC), and cashew nut protein isolate (CNPI).

Prakash, 1994). The cashew nut proteins showed decreasing solubility with decreasing pH, minimum solubility was observed at the pH range of 4.0–4.5. Based on this protein solubility profile, DCNP, CNPC, and CNPI were least soluble (8.0%, 10%, and 30%, respectively) at pH 4.0, 4.0, and 4.5, respectively, this indicates that cashew proteins are acidic in nature and that the isoelectric point of cashew proteins was in the range of pH 4.0–4.5. This was confirmed by the highest protein content and yield obtained from the isoelectric precipitation method of cashew protein production compared to methanol precipitation method. Also, Damodaran (1997) states that the minimum solubility occurs at about the isoelectric point (pI) of proteins, and that the majority of food proteins are acidic proteins, and thus exhibit minimum solubility at pH 4–5, and maximum solubility at alkaline pH. According to Sorgentini and Wagner (2002), the occurrence of minimum solubility near the isoelectric point is due primarily to both the net charge of peptides, which increase as pH moves away from the isoelectric point, and surface hydrophobicity that promotes the aggregation and precipitation *via* hydrophobic interactions. On either side of this pH, the protein solubility started to increase and reached a maximum value of 85%, 98%, and 96% for DCNP, CNPC and CNPI, respectively, at pH 12. These are comparable to the solubility of mustard green meal (77.9%), *Rosa mosquetta* meal (80%) as reported by Aluko, McIntosh, and Katepa-Mupondwa (2005) and Moure, Sineiro, and Domínguez (2001), respectively, solubility of bitter lupin concentrate (98.43%), and sweet lupin isolate (98.79%) as reported by El-Adawy et al. (2001). However, the CNPI solubility is higher than that of peanut protein isolate (60.5%), soya protein isolate (71.7%), and lentil protein isolate (88%) as reported by Cherry (1990), Lin et al. (1974) and Suliman et al. (2006), respectively. Cashew nut proteins showed good solubility in both acid and alkaline pH regions, and according to Idouraine, Yensen, and Weber (1991) this is an important characteristic for food formulation. However, alkaline pH was found to be slightly more effective in solubilising cashew proteins compared to acidic pH. At pH above 8, solubility did not increase significantly with an increased pH. Since extreme alkali pH is detrimental to protein quality as it destroys Lysine (Sathe, 1994), pH 7–8 is optimum to solubilise cashew nut proteins effectively. Also, Betschart and Kinsela (1973) stated that the nitrogen solubility profile over a range of pH values is being used increasingly as a guide to protein functionality, since this relates directly to many important properties, e.g. use in beverages, emulsification, foaming capacity and gelation.

3.3. The effects of pH on the emulsifying activity and emulsion stability of defatted cashew nut powder (DCNP), cashew nut protein concentrate (CNPC), and cashew nut protein isolate

The effects of pH on the emulsifying activity index (EAI) and emulsion stability index (ESI) of the defatted cashew nut powder (DCNP), cashew nut protein concentrate (CNPC), and cashew nut protein isolate (CNPI) are shown in Figs. 2 and 3. The lowest EAI and ESI of DCNP (46.3 m²/g) (20.0%), CNPC (36.8 m²/g) (10.0%), and CNPI (24.8 m²/g) (15.0%), respectively, were found around their isoelectric region (about pH 4), with coincidental decrease in solubility (Fig. 1), and increased at pH's above and below this region. As shown in Fig. 2, the highest EAI of DCNP (78.5 m²/g), CNPC (65.7 m²/g), and CNPI (57.3 m²/g) was found at pH 12. However, the highest ESI of DCNP (60.5%), CNPC (50.5%), and CNPI (95.0%) was observed at pH 8 (Fig. 3). A number of studies have shown that the pH-emulsifying properties profile of various proteins including soya protein resembles the pH-solubility profile (Aoki, Taneyama, & Inami, 1980). According to Damodaran (1997), this is because most food proteins are sparingly soluble at their isoelectric pH, poorly hydrated, and lack electrostatic repulsive forces, they are generally poor emulsifiers at this pH. According to Klompong

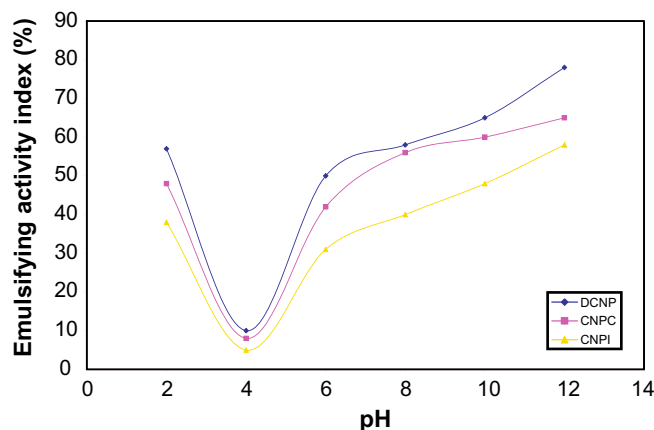


Fig. 2. Effects of pH on emulsifying activity index of defatted cashew nut powder (DCNP), cashew nut protein concentrate (CNPC), and cashew nut protein isolate (CNPI).

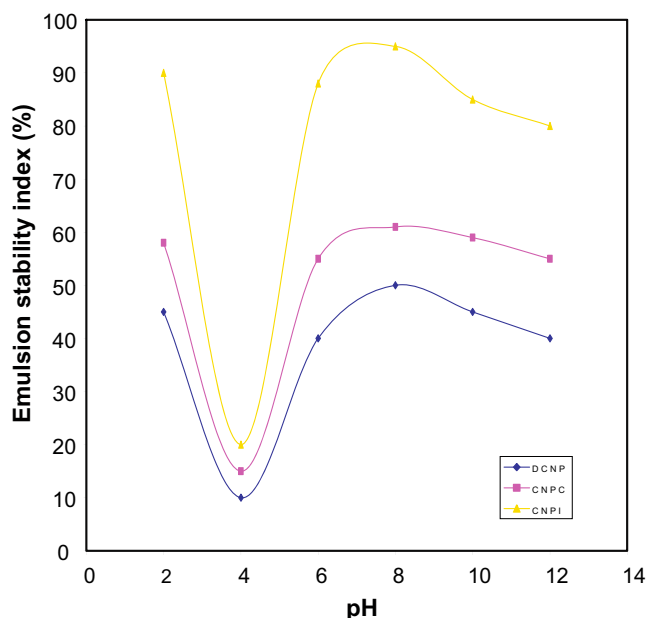


Fig. 3. Effects of pH on emulsion stability index of defatted cashew nut powder (DCNP), cashew nut protein concentrate (CNPC), and cashew nut protein isolate (CNPI).

et al. (2007), since the lowest solubility occurred at the isoelectric point, peptides could not move rapidly to the interface, and the net charge of peptide could be minimised at this pH. These proteins may, however, be effective emulsifiers when moved away from their isoelectric pH.

3.4. Effects of pH on foam properties of defatted cashew nut powder (DCNP), cashew nut protein concentrate (CNPC), and cashew nut protein isolate (CNPI)

Figs. 4 and 5 show the effects of pH on foam capacity and foam stability of defatted cashew nut powder (DCNP), cashew nut protein concentrate (CNPC), and cashew nut protein isolate (CNPI). The lowest foam capacity and foam stability of DCNP (6% and 5%), CNPC (20% and 45%), and CNPI (15% and 30%), respectively, were observed at pH 4, which was also coincident with their lowest solubility (Fig. 1), and lowest emulsifying properties (Figs. 2 and 3). The highest foam capacity and foam stability of DCNP

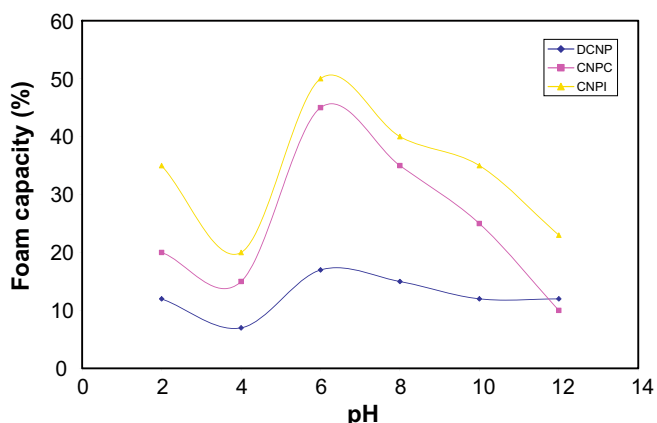


Fig. 4. Effects of pH on foam capacity of defatted cashew nut powder (DCNP), cashew nut protein concentrate (CNPC), and cashew nut protein isolate (CNPI).

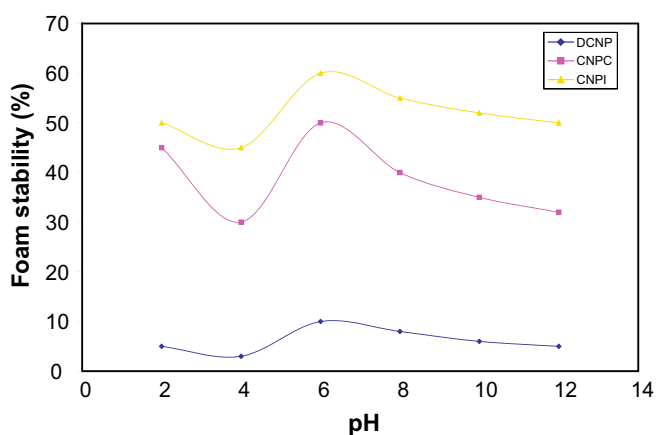


Fig. 5. Effects of pH on foam stability of defatted cashew nut powder (DCNP), cashew nut protein concentrate (CNPC), and cashew nut protein isolate (CNPI).

(16% and 10%), CNPC (50% and 60%), and CNPI (45% and 50%) were found at pH 6. This was explained by Damodaran (1997), who said that if the protein is sparingly soluble at an isoelectric point, then only the soluble protein fractions will be involved in the foam formation, and since the concentration of these soluble fractions is very low, the amount of foam formation will be less. Also, Pearson (1983) confirmed that the lowest foam properties of proteins coincided with the lowest solubility at their isoelectric point. The decreased FC and FS at very acidic and very alkaline pH were observed in all samples, this might be due to the repulsion of peptides via ionic repulsion.

4. Conclusion

The functional properties of cashew nut protein improved with the processing of cashew nut into protein concentrate and protein isolate. Cashew nut protein isolate (CNPI) has higher water and oil absorption capacity, emulsifying stability index, foam capacity and stability, and least gelation capacity than cashew nut protein concentrate (CNPC), which were also higher than defatted cashew nut powder (DCNP). However, emulsifying activity index, and bulk density of CNPI were lower than that of CNPC which were also lower than that of DCNP. pH has effects on the functionality of cashew nut protein, and higher solubility, emulsifying activity, and foaming properties were seen at the alkaline pH than at the acidic pH. Most functional properties of CNPI and CNPC were comparable with that of peanut, soybean and lupin protein isolates

and concentrates, which were already being used as the functional ingredients in many food products.

The results therefore revealed that protein isolates and concentrates of suitable functional properties could be produced from the cashew nut as a good source of a protein ingredient in food systems.

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