The Annals of the University *Dunarea de Jos* of Galati
Fascicle VI – Food Technology, New Series Year III (XXXIII)
Paper presented at the International Symposium *Euro - aliment 2009*, 9th – 10th of October 2009, Galati – ROMANIA

CHEMICAL AND FUNCTIONAL CHARACTERIZATION OF CHICKPEA PROTEIN DERIVATES

IONESCU AURELIA[1], APRODU IULIANA[1], DARABĂ AURA[1], GURĂU GABRIELA[2], BACIU CRISTINA[1], NICHITA ANDREI[1]

[1] *University "Dunărea de Jos" Galați, Faculty of Food Science and Engineering*
[2] *University "Dunărea de Jos" Galați, Faculty of Medicine and Pharmacy*

aurelia.ionescu@ugal.ro

Received 4 June 2009
Revised 12 August 2009

Whole flour, defatted flour and freeze dried protein concentrate were obtained from chickpea. Protein solubility, water and oil absorption capacity, emulsifying capacity and emulsion stability, foaming capacity and foam stability were used to evaluate the chickpea protein derivates from a chemical and functional standpoint. The chickpea protein concentrate, obtained by alkaline solubilization (pH 10.5) followed by isoelectric precipitation at pH= 4.5 and freeze drying, displayed the highest protein content and the best functional properties. The profiles of the solubility curves corresponding to the chickpea protein concentrate indicate a minimum solubility at pH ranging from 4 to 5 (i.e., protein solubility of 12.5% in the case of chickpea protein concentrate) and two domains of maximum solubility at pH 1.8 and 11.8 (i.e., protein solubility of 53.2% and 85.7%, respectively, in the case of chickpea protein concentrate). The profiles of protein solubility curves are similar with the profiles of the emulsifying capacity vs. pH curves. The foaming capacity increased with the increase of chickpea protein concentration. After 120 hours of storage the foam stability was higher than 90%. The experimental data show that the chickpea protein concentrate can be successfully used as food ingredient due to its chemical composition and functional properties.

Keywords: chickpea, whole flour, defatted flour, protein concentrate, functional properties

1. Introduction

Chickpea (*Cicer arientum L.*) is considered the 5th valuable legume in terms of worldwide economical standpoint. Chickpea is planted in Southern and Western areas of Asia and Mediterrana. India is the principal, high quality chickpea provider, realizing 75% of the world gross production (Grelda et al., 1997). Chickpea is considered a good source of proteins and carbohydrates. Like other legumes, chickpea's globulins and albumins represent the two major fractions found in beans. In legumes, the globulins, represented mainly by legumin and vicinin, reach up to 60-80% out of the extractable proteins of the beans whereas the albumin fraction, less abundant, represents up to 15-25% out of the beans' proteins (Singh et al., 2008). Albumins play an important role in chickpea beans since they contain most of the enzymes and proteins with metabolic significance. In addition, they display a higher nutritive value compared to the globulins due to their high content in lysine and sulfur aminoacids.

The increased demands for food products and functional, pharmaceutical and cosmetic ingredients, obtained from vegetal sources, determined the interest increment for the production of purified protein derivates of vegetal origin, such as concentrates, isolates and hydrolysates (Pawar and Ingle, 1988; Tharanathan and Mahadevamma, 2003). Numerous researchers have been preoccupied with the obtaining of protein concentrates and isolates from vegetal, animal or microbial sources as well as with the characterization from these products' functional standpoint (Aluko and Yada, 1993; Burgess and Kelly, 1979; Sathe and Salunkhe, 1981; Sathe et al., 1982a; Sathe et al., 1982b; Sanchez-Vioque *et al*., 1999).

In order to obtain food-grade protein isolates, the high molecular weight oligomeric storage proteins from seeds are generally separated by alkaline solubilization followed by isoelectric precipitation (Derbyshire et al., 1976; Sanchez-Vioque et al., 1999).

The chickpea proteins are better appreciated compared to the proteins from pigmelion peas, blackgram and greengram (Kaur and Singh, 2007) due to their high biological value, high biodisponibility, well-balanced aminoacids content and low content in antinutritional factors (Friedmen et al., 1996 and Santiago et al., 2001). The low fat content combined with the special characteristics of chickpea beans justify the nowadays concerns for chickpea protein isolates and concentrates obtaining and their functional characterization. Sanchez-Vioque et al. (1999) investigated the protein recovery yield in different experimental conditions, functional properties and the composition of chickpea protein isolates in direct relations with the possibility of using these isolates in food industry. According to their findings, the protein isolates characterized by a high absorption capacity of water and oil are adequate for obtaining cheese, bakery and meat products. On the other hand, the isolates with a good emulsifying capacity can be successfully used for obtaining products such as frankfurter and cream-like products. Very few scientific data regarding the lyophilized chickpea protein concentrate obtaining and characterization, from a chemical and functional standpoint are reported. Therefore, the objectives of the present study were to obtain whole and defatted chickpea flours and freeze dried protein concentrate and to characterize these products from the chemical and functional properties standpoint. Concerning the functional properties of the chickpea proteins, the water and oil absorption capacity, protein solubility profile and emulsifying capacity for different pH values, emulsions stability, foaming capacity and foam stability were investigated.

2. Materials and methods

2.1. Materials

The chickpea beans, purchased from a local store specialized in selling vegetable products were used to obtain the protein derivates: whole flour, defatted flour and lyophilized concentrate.

Analytically pure reagents were used for the chemical tests and treatments. For testing the emulsifying capacity, the commercial sunflower oil was used.

2.2. Obtaining the whole chickpea flour

After drying, the chickpea beans were milled using a WZ-2 (Sadkiewicz, Polonia) cereal mill. With the aim to remove the impurities and to obtain an uniform product, the whole flour was passed through a 312 mesh sieve.

2.3. Obtaining the defatted chickpea flour

The defatted chickpea flour was obtained after the removal of fats by extraction with ethanol, at 22ºC. The whole flour-ethanol blend (1:5 w/v) was periodically mixed, during the extraction process. The total removal of fats was achieved after four extraction cycles of four hours each. In order to remove all ethanol, the chickpea flour was dried at 43ºC, for 36 hours, in hot air flow.

2.4. Obtaining the lyophilized chickpea protein concentrate

The lyophilized protein concentrate was obtained from defatted chickpea flour. Because the chickpea proteins display a higher solubility for pH > 9.0, the pH of the defatted flour dispersion prepared in water was adjusted, by using 2N NaOH, to 10.5. Fiber and starch fractions were removed from the alkaline

dispersion by centrifugation at 3000 rpm, for 20 min (temperature of 4ºC). Solubilized proteins were collected as supernatant which subsequently was used for the protein fraction recovery by isoelectric precipitation (pH 4.5). For pH adjustment, a 2N HCl solution was used. After precipitation, the proteins were separated by centrifugation at 3000 rpm, for 20 min. (temperature of 4ºC). The precipitate was washed with distilled water (pH 7.0) for three times, to achieve a complete removal of any existing contaminant. The lyophilization of the resulted protein concentrate was performed with Alpha 1-4 LD Plus freezer. The samples were first frozen for 42 hours at – 48ºC using a Platinum 500 ultra-freezer. The lyophilization conditions were: heating of the pump for 20 min; main drying for 2 hours at 1 mbar and -20ºC followed by a final drying for 20 min.

2.5. Proximate chemical composition

Protein, fat and ash contents were determined using the A.O.A.C. methods (1990). The contents in crude fibers and carbohydrates were estimated by subtracting the sum of ash, fat and protein from the dry weight of the samples. pH values were recorded with a pH-meter (model Hanna) on a 10 % aqueous protein dispersion (w/v) at 22 ± 1ºC.

2.6. Determination of the chickpea protein derivates functional properties

Proteins solubility. Proteins solubility of the chickpea protein derivates was studied at pH values ranging from 1.8 to 11.8. Initially, suspensions with 5% protein derivate in 0.1 N NaOH, were obtained. For a better solubilization, the suspensions were stirred for 2 hours, at room temperature, using a magnetic stirrer. Aliquot parts from the suspension were sampled for the determination of protein solubility at different pH values achieved after the adjustment with a 2M HCl solution and 1 hour agitation. Before mineralization, the samples were centrifuged at 3000 rpm, for 30 min. The mineralization has been performed into a Trade Raypa type installation. From the resulted supernatant, the total nitrogen was determined according to the semimicro Kjeldahl method. Protein solubility curves were constructed by using the average values obtained for each considered pH value.

Water and oil absorption. Water absorption capacity was determined by centrifugation, according to the method described by Sathe et al. (1982a) which was slightly modified. The samples (3 g of protein derivates) were first dried for 24 hours at 104ºC and afterwards placed into pre-weighed centrifuge tubes and dispersed into 25 ml of distilled water. The obtained dispersions were occasionally stirred. After 30 min of storage at 22 ± 1ºC, the samples were centrifuged for 30 min at 3500 rpm. The supernatant was removed and the moisture excess was released by drying for 25 min at 50ºC. The tubes containing the samples were reweighed. The water absorption capacity was determined for a genuine pH of the protein suspension and expressed as ml absorbed water/g of protein derivate.

Oil absorption was determined according to the method of Lin et al. (1974). The protein derivate (0.5 g) was homogenized with 6 ml of sunflower oil into a pre-weighed centrifuge tube. Aiming for a better proteins dispersion in oil, the content of the tubes was stirred for 1 min, afterwards, the samples were centrifuged at 3000 rpm, for 25 min, 30 min later the oil separated being removed. Oil absorption capacity was expressed as ml oil/g of protein derivate.

Emulsifying capacity. In order to study the effect of pH on the emulsifying capacity of the chickpea protein derivates, 1% (w/v) protein dispersions were obtained. Subsequently, the protein dispersions were stirred with a magnetic stirrer and the pH adjustments, from 1.8 to 11.8, were made by adding 2M NaOH or 2M HCl solutions.

For the determination of emulsifying capacity, 50 g of protein suspension were transferred into a blender vat and the sunflower oil was added, under continuous mixing until the emulsion was destroyed (Beuchat, 1977). Measurements were performed at 22 ± 1ºC and the emulsifying capacity was expressed as ml of oil used for the emulsification of 1 g of chickpea protein derivate.

Emulsions preparation. The oil/water emulsions, stabilized with chickpea proteins (whole flour or protein concentrate), were prepared from 50 g of 1% aqueous protein suspension and 30 ml of sunflower oil by vigorous stirring for 3 min using a Braun mixer at 22ºC. The temperature control was made by immersing the samples in a water-ice mixture bath. Each emulsion obtained was immediately assessed from the physical appearance and texture standpoint.

Emulsion stability during centrifugation. Stability of emulsion was evaluated by measuring the quantity of released water from the emulsion, after centrifugation, according to the method described by Johnson and Brekke (1983). The emulsion was centrifuged at 3000 rpm, for 10 min. Emulsion stability, expressed in terms of percents of water released from emulsion, after centrifugation, was calculated using the following formula:

$$\% \text{ Released water} = B/A \cdot 100,$$

where A is the total volume of the emulsion (ml) and B is the volume of aqueous phase released from emulsion, after centrifugation (ml)

Foaming capacity and foam stability. Foaming capacity and foam stability were determined according to the method described by Lin et al. (1974), slightly modified. 100 ml of 1% (w/v) aqueous chickpea protein dispersion was homogenized using a Braun blender for 3 min. Dispersion volume was recorded before and after foaming.

Foaming capacity was expressed as percentage of volume increase after stirring. The foam stability was recorded at 30, 60, 90, 120, and 150 min storage at room temperature.

2.7. Statistical analysis

Sigma Plot 2001 Software was used for the statistical analysis of the experimental data. Each experiment was performed in triplicate and the results were expressed as average values. The standard deviations were smaller than 5%.

3. Results and discussions

3.1. Approximate chemical composition

The chemical composition of the chickpea protein derivates: whole and defatted flour, and lyophilized concentrate is depicted in Table 1. The protein content of whole flour was 23.08 ± 1.23%, which corresponds to Kabuli biotype chickpea, with 22.8 ÷ 24.9% protein content.

By fat removal from the chickpea flour, the proteins content slightly increased up to 23.53 ± 1.31% whereas fat content decreased from 6.65 ± 0.28% to 0.66 ± 0.02%. The fat content was lower than the one reported by Sanchez-Vioque et al. (1999), respectively 1.5%. The remaining lipids, mainly nonpolar, play an important role in the product aromas and they interact with proteins (Kikugawa et al., 1981; Sánchez-Vioque et al., 1998; Rackis et al., 1979).

The total carbohydrates, mainly represented by starch and fibers, are the major constituents of the chickpea flour. The recorded level of the total carbohydrates was 57.88% for whole flour, and 62.17% for defatted flour. These findings are in agreement with the carbohydrates levels reported by Kaur and Singh (2007) for the Kabuli type chickpea, respectively 60.2 ± 2%. The total starch content was 42.5 ± 1.96%, for the defatted flour. According to Meares et al. (2004), for the chickpea Desi and Kabuli type, amylose represents 26.1 and 26.4%, respectively, out of the total content of starch which could represent 45.2 and 42.1%, respectively.

Ash content, represented 3.21 ± 0.11% of the whole chickpea flour, was higher than the levels of 2.72÷2.91%, reported by Sanchez-Vioque et al. (1999), and than the levels of 2.71÷2.91%, reported by

Kaur and Singh (2007). For the defatted flour, the ash content was slightly higher than that of whole flour, respectively 3.53 ± 0.15%.

Lyophilized protein concentrate was characterized by a protein content of 81.54 ± 3.87%, and low contents in fats, respectively 1.25 ± 0.04%, and in ash, represented by 2.85 ± 0.09%. The ash content was superior to the content of 0.71%, reported by Sathe et al. (1982b) for the lyophilized lupine protein concentrate. By refinement, the total carbohydrates level was substantially diminished to 10.33%, level which is characteristic to the protein concentrates with similar content in proteins (higher than 75%).

Table 1. Chemical composition of chickpea flours and lyophilized protein concentrate

	Whole flour	Defatted flour	Protein concentrate
Moisture, g%	9.18 ± 0.38	10.11 ± 0.43	4.03 ± 0.15
Total proteins, g%	23.08 ± 1.23	23.53 ± 1.31	81.54 ± 3.87
Fats, g%	6.65 ± 0.2 8	0.66 ± 0.2	1.25 ± 0.04
Ash, g%	3.21 ± 0.11	3.53 ± 0.15	2.85 ± 0.09
Carbohydrates, g%	57.88	62.17	10.33

3.2. Proteins solubility

Proteins solubility at different pH values represents a performance indicator of protein flours, concentrates and isolates when used in different food systems, and gives indications about protein denaturation degree during chemical and thermal treatments Horax et al. (2004). The proteins solubility profiles, corresponding to the chickpea flour and protein concentrate, presented in Figure 1, indicate a minimum of solubility for pH values of 4.0 to 5.0 and two zones of maximum solubility for the extreme pH values. According to Vani and Zayas (1995), the isoelectric pH of most of vegetal origin proteins corresponds to values between 4.0 and 5.0. Therefore, the lack of electrical charge for pH = 4.5, influenced negatively the water binding and the solubility of proteins. Under these conditions, the whole chickpea flour displayed a protein solubility of 25.84% and the chickpea protein solubility was 12.5%. For extreme pH values, the net electrical charges are high, and allow rejection forces between the protein chains and the protein solubility increase. In case of pH = 11.8, the protein solubility was 91.25%, for the whole flour, and 85.7%, for the protein concentrate, while in the case of pH = 1.8, the proteins solubility was 58.9%, for the whole flour, and 53.2%, for the protein concentrate. Kinsella (1979), Hermansson (1979) and Lillford (1983) reported that the reduction in solubility, at very low pH values, is due to the protein denaturation and insolubilization processes.

The profiles of solubility curves obtained based on our experimental data are in agreement with other findings regarding soy (Achouri et al., 1998), lentil (Bora, 2002), chickpea (Sanchez-Viogue et al., 1999; Kaur and Singh, 2007) and rapeseed (Goncalves et al., 1997). The decrease of protein solubility in the protein concentrate compared to the chickpea flour is the result of protein denaturation during fat removal, chemical treatments applied for protein purification, and during the lyophilization process.

3.3. Functional properties

3.3.1. Water absorption capacity

Whole flour and protein concentrate from chickpea showed a water absorption capacity of 126±5.83 ml H_2O/100 g and 176±7.25 ml H_2O/100 g product, respectively. Water binding properties of proteins are determined by their degree of interaction with water.

Water retention capacity of proteins depends on some parameters such as: particle size, steric factors, conformational characteristics, hydrophilic/hydrophobic balance of aminoacids and presence of lipids,

sugars and tannins associated with proteins (Han and Khan, 1990), in greater quantities in flours and concentrates compared to protein isolates.

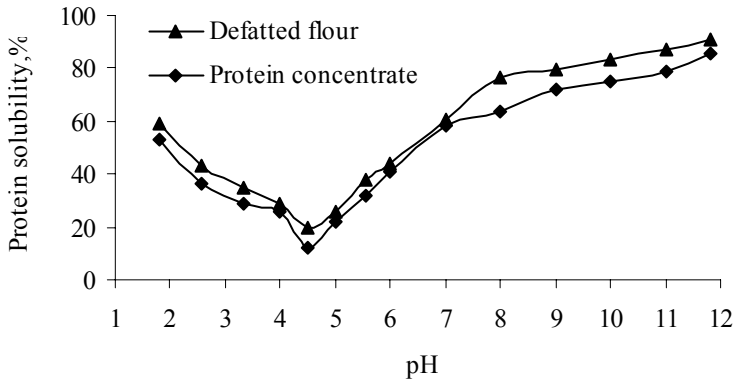

Figure 1. The solubility profiles for chickpea whole flour and lyophilized protein concentrate

Carbohydrates and other components present in different flours or various concentrates and isolated from vegetable protein negatively influence the water absorption properties (Kilara et al., 1972; Kinsella, 1979, Tjahjadi et al., 1988).

The obtained chickpea protein concentrate presented a more reduced water absorption capacity compared to the isolates analyzed by Sánchez-Vioque et al. (1999) (water absorption capacity of 343.7 and 199.5%, depending on the isolation technique used), but similar to the value reported by Sathe, et al. (1982) for the chickpea protein concentrate (1.84 ml H_2O / g).

These differences are explained by the higher protein content of protein isolates and also can be accounted for distortions during drying by lyophilization. In addition, Summer et al. (1981) reported similar water absorption capacity (205%) for the lyophilized chickpea protein concentrate.

Concentrates and protein isolates from chickpea, compared with flour, have a higher capacity to swell, distort and separate, that allows additional exposure of binding sites of water and increase water absorption.

3.3.2. Oil absorption capacity

At industrial level, oil absorption capacity is very important in the case of mayonnaise manufacture (Escamilla-Silva et al., 2003), due to its influence upon the emulsifying capacity.

Whole chickpea flour examined by us, had an oil absorption capacity of 0.72 ml oil / g flour (313 ml ± 12.2 ml ulei/100 g protein) versus 1.0 ml oil / g flour (426 ml ± 16.1 ml ulei/100 g protein) for whole chickpea flour, values lower than those reported by Kaur (2007) (1.05-1.25 g oil /g). These differences arise from the oil type used (corn oil instead of sunflower oil) and the centrifugation conditions.

Fat removal caused the increase of oil absorption capacity, when flours are used as extension agents in salamis, and meat substitutes as well as in the bakery production.

Oil absorption capacity varied with the type of protein derivate (Figure 2.), protein solubility and the degree of protein distortion, being smaller in the case of the protein concentrate (205.1 ml ± 8.23 ml oil/100 g protein). The obtained results are comparable with those reported by Kinsella (1979) indicating significant variation due to the year of cultivation of chickpea (1.59-2.58 ml/g) and with the values

reported by Paredes-Lopez et al. (1991), for chickpea isolate (1.59-2.58 ml/g) and Sefa-Dedeh and Yiadom-Farkye (1988), for the cowpea isolate (2.0-2.22 ml oil/g).

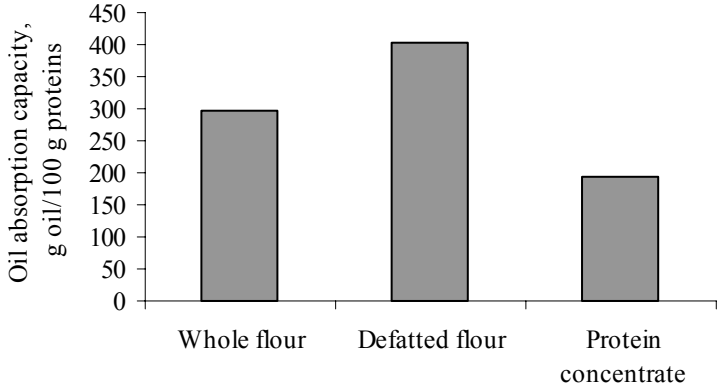

Figure 2. Oil absorption capacity of chickpea flours and protein concentrate

3.3.3. Emulsifying capacity -The effect of pH on the emulsifying properties

Emulsions play an important role in the manufacture of food products such as ice cream, mayonnaise, dressings, emulsified sausages and pastry products. Emulsion, as a heterogeneous structure, consists mainly of two immiscible phases; the fat phase is, most of the cases, dispersed in the continuous phase.

This structure has a low stability, which can be improved by adding surface active agents - named emulsifiers, as is the case of chickpea protein derivates. The emulsifying capacity and the emulsion stability are indicators used to evaluate the emulsion stabilising properties of the vegetable protein derivates (Han and Khan, 1990; Sánchez-Vioque, et al., 1999).

The ability of proteins to form stable emulsions depends on the size, charge, hydrophobic surface and flexibility of protein molecules (Turgeon et al., 1992). These properties of proteins are affected by environmental factors such as pH and ionic strength.

Emulsifying capacity of chickpea flour was measured at different pH values of the protein suspension. Relationship between emulsifying capacity and pH, for each type of protein derivate, is shown in Figure 3.

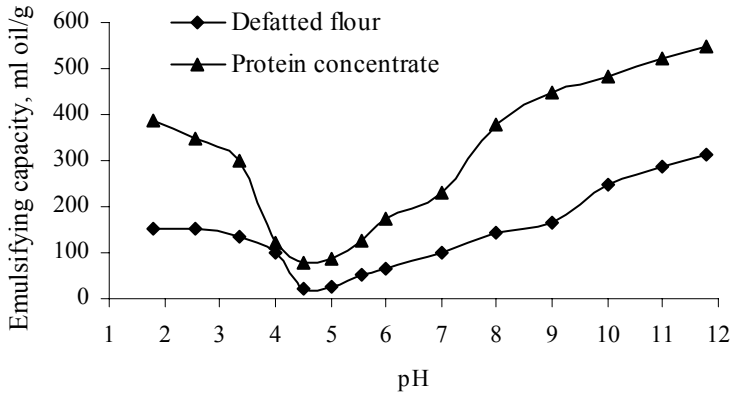

Figure 3. The effect of pH value on emulsifying capacity of chickpea whole flour and protein concentrate

The emulsifying capacity of chickpea protein concentrate was much higher than that of defatted flour. Flours and protein concentrates capacity to emulsify oil into the form of fine particles in a protein suspension, is assigned to soluble proteins. Soluble proteins have surface properties due to their amphiphilic nature and tendency to form protein films at oil-water interface. In the case of 1% protein suspension, the protein adsorption at oil-water interface is achieved by controlled diffusion, where the protein is oriented with lipophilic residues to the oil phase and the hydrophilic aqueous phase.

The emulsifying capacity of proteins depends on the hydrophilic-hydrophobic balance (Chi-Fui et al, 1997), which is affected by the pH value. The maximum levels of emulsifying capacity are recorded at extreme pH values (EC of 152.67 ml oil/g at pH 2.56, and EC of 550 ml oil/g at pH 11.8). Lower emulsifying properties were found for the pHi (4.0 to 5.0) of chickpea proteins. The lowest values were recorded at pH 4.5 (23.3 ml oil/g whole flour and 78 ml oil/g for protein concentrate). At this pH value, the net electrical charge of proteins was zero and the lowest solubility corresponds to pHi of chickpea proteins and of vegetable proteins in general. Zhang et al., (2007) reported that at the pHi, the amount of proteins adsorbed at the oil - water interface is lower and the oil particle size is larger. Creenwedge et al., (1974), and Hung and Zayas (1991) found similar emulsifying capacity vs. pH and protein solubility vs. pH variations.

Our results regarding the dependence of the emulsifying capacity on the pH of protein suspension are consistent with the results of other researchers for different vegetable proteins (Mwarsanu et al., 1999; Lawal and Adebowal, 2006).

3.3.4. Foaming capacity and foam stability

Foaming capacity and foam stability are used as indicators of foaming properties of flours, concentrates, and protein isolates (Mwasaru et al., 1999). Proteins foam when agitated, due to their surface properties.

Whole chickpea flour led to relatively small volume increment and low density foams were formed with relatively high stability. Foaming capacity of whole flour depends on the concentration of aqueous suspension. We noted an increase of the foam volume of 27% in the case of 1% protein suspension and of 50% in the case of 5% protein suspension, while a decrease of the foam volume was noticed in the case of 7 and 10% suspensions (Figure 4a.). A similar trend was observed for proteins derived from beans (Sathe and Salunkhe, 1981; Adebowale and Lawal, 2003).

Defatting led to an improvement of surface properties of chickpea protein and to the foam volume increase for concentrations ranging from 5% to 60% whole chickpea flour. By increasing the whole flour concentration, denser and more stable foams are obtained (Figure 4b.). Foam stability of the chickpea flour was assessed based on the foam volume decrease in time. Foam stability is important because the choice of suitable foaming agents depends on their ability to maintain the foam for as long time as possible (Lin et al., 1974).

The whole chickpea flour presented a good stability of the foam (> 90%) after 90 min of storage at room temperature for samples with a concentration of 5%. According to Adebowale and Lawal (2003), increased concentrations of chickpea flour protein brings about protein – protein interaction improvement, as a consequence, easing the forming of a multilayered cohesive protein film, at the air/water interface.

Protein film formation provides resistance to coalescence of air bubbles. Also, by increasing the concentration of chickpea flour ensures the formation of a thicker film, preventing the movement of proteins away from the film.

Stability of the foam is ensured by the ability of the foam film formed around the air bubbles to remain intact without leakage, therefore, stable foams can be formed only by agents with a high surface activity

(Cherry and McWatters, 1981). The good stability of the foam resulted from chickpea whole flour suggests that the globular chickpea proteins have good surface properties.

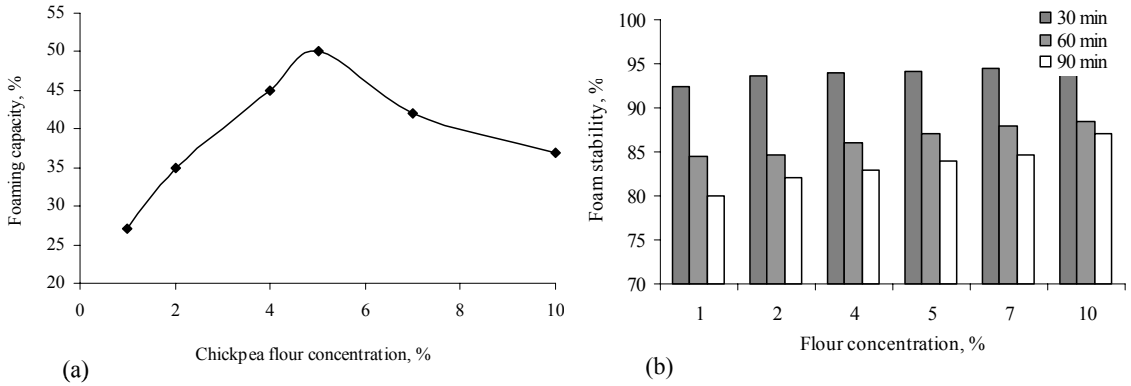

Figure 4. The influence of defatted flour concentration on foaming capacity (a) and foam stability (b)

The foaming capacity of 1% (w/v) whole chickpea flour aqueous suspension was lower than that determined for the protein concentrate, respectively 40%, value that falls within 30.4 to 44.3%, indicated by Kaur (2007) for the chickpea protein concentrate. For various vegetable protein concentrates, different values were reported e.g.: soy protein isolate is characterized by a Foaming capacity of 235% (Lin et al, 1974), bean protein concentrates 36 and 58% (Sathe et al.1982; Adebowale and Lawal, 2003), lupine seed protein 32% (Sathe et al., 1982b) and peas 80% (Akintayo et al., 1999).

The foaming capacity of lyophilized chickpea protein concentrate depended on the concentration of protein concentrate suspension (Figure 5a). Graham and Phillips (1976) linked the good foaming capacity on the protein molecules flexibility which can reduce the surface tension; the globular proteins are relatively difficult to distort on the surface and have a reduced foaming capacity. Most vegetable proteins are globular proteins with low foaming properties (Sathe et al., 1982).

The foam stability of chickpea concentrate (1%) depended on the time of shaking, being higher in the case of the samples shaken for 5 min. (Figure 5b). Chickpea protein concentrate showed a relatively high stability at 22°C after 2.5 hours of storage, similar to that reported for chickpea isolate (> 85%), which suggests that chickpea proteins, soluble in the continuous phase, displayed a higher surface activity.

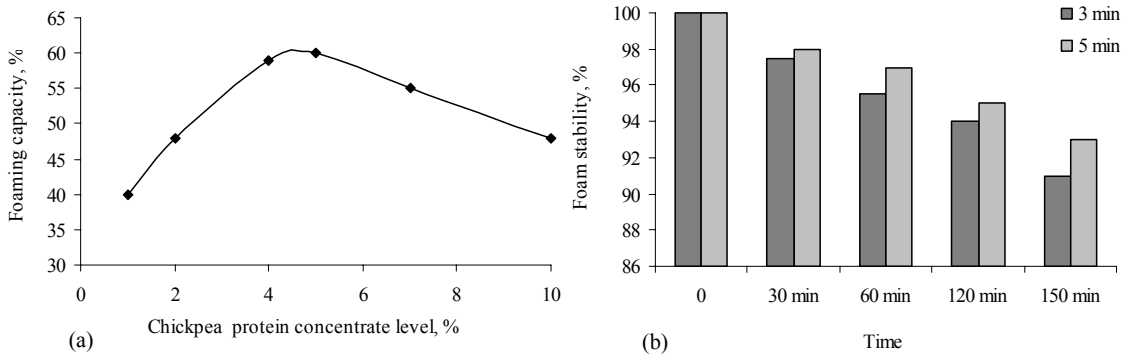

Figure 5. Influence of concentration of chickpea protein concentrate dispersion on the foaming capacity (a). Influence of the shaking time on the foam stability (b)

4. Conclusions

Our results concerning the chickpea flours and lyophilized protein concentrate characterization show that these protein derivates can be successfully used as food ingredients based on their technological properties. Chickpea flours and protein concentrate displayed good water and oil absorption capacities, protein solubility and emulsifying capacity. These functional properties are highly dependent on the pH values. The lowest protein solubility and emulsifying capacity was observed at pH 4.5 which is the isoelectric pH of chickpea albumins and globulins. Chickpea proteins do not have good foaming properties, but lead to high stable foams.

References

AOAC, 1990. Official methods of analysis (15th Ed.). Washington, DC:Association of Official Analytical Chemists.

Achouri, A., Zhang, W. and Shying, X. U., 1998. Enzymatic hydrolysis of soy protein isolate and effect of succinylation on functional properties of resulting protein hydrolysates. *Food Research International*, **31**, 617-623.

Adebowale, K.O. and Lawal, O.S., 2003. Foaming, gelation and electrophoretic characteristics of mucuna bean (*Mucuna pruriens*) protein concentrates. *Food Chemistry,* **83**, 237 - 246.

Akintayo, E.T., Oshodi, A.A. and Esuoso, K.O., 1999. Effects of NaCl, ionic strength and pH on the foaming and gelation of pigeon pea (*Cajanus cajan*) protein concentrates. *Food Chemistry,* **66**, 51 - 56.

Aluko, R.E. and Yada, R.Y., 1993. Relationship of hydrophobicity and solubility with some functional properties of cowpea (*Vigna unguiculata*) protein isolate. *Journal of the Science of Food and Agriculture*, **62**, 331-335.

Beuchat, L.R., 1977. Functional and electrophoretic characteristics of succinylated peanut flour protein. *Journal of Agricultural and Food Chemistry*, **25**, 258–261.

Bora, P.S., 2002. Functional properties of native and succinylated lentil (*Lens culinaris*) globulins. *Food Chemistry*, **77**, 176 - 176.

Burgess, K.J. and Kelly, J., 1979. Technical note: selected functional properties of a whey protein isolate. *Journal of Food Technology*, **14**, 325.

Cherry, J.P. and McWatters, K.H., 1981. Whippability and aeration in "protein functionality in foods". In: Cherry, J.P., Editor, ACS Symp. Ser., 147, American Chemical Society, Washington, DC, 149.

Chi - Fai, C., Cheung, P.C. and Wong, Z., 1997. Functional properties of protein isolates from three Chinese indigenous legume seeds. *Journal of the Science of Food and Agriculture*, **45**, 2500 - 2503.

Creenwedge D., Dill, C.W., Tybor, P.T. and Landmann, W.A., 1974. A comparison of the emulsifying capacity of some protein concentrates. *Journal of Food Science*, **39**, 175 - 179.

Derbyshire, S., Wright, D. J. and Boulter, D., 1976. Legumin and vicilin, storage proteins of legume seeds. *Phytochemistry,* **15**, 3-24.

Escamilla-Silva, E. M., Guzman-Maldonado, S.H., Cano-Medinal, A. and Gonzalez-Alatorre, G., 2003. Simplified process for the production of sesame protein concentrate. Differential scanning calorimetry and nutritional, physicochemical and functional properties. *Journal of the Science of Food and Agriculture*, **83**, 972 - 979.

Friedman, M., 1996. Nutritional value of proteins from different food sources. A review. *Journal of Agricultural and Food Chemistry*, **44**, 6 - 29.

Goncalves, N., Vioque, J., Clemente, A., Sanchez-Vioque, R. Bautista, J. and Millan, F., 1997. Obtencion y caracterizacion de aislados proteicos de colza. *Grasas y aceites*, **48**, 282-289.

Graham, D.E. and Phillips, M.C., 1976. The conformation of proteins at the air-water interface and their role in stabilizing foams. In: R.J. Akers, Editor, Foams, Academic Press, N.Y., 237 - 255.

Grelda, A.Y.F., Moreno-Valencia, J.G., Falcon-Villa Ma del Refugio and Barron-Hoyos, J. M., 1997. Isolation and partial characterization of starches from dry beans (*Phaseolus vulgaris*) and chickpeas (*Cicer arietinum*) grown in Sonora, Mexico. *Starch*, **49**, 341-345.

Han, J. and Khan, K., 1990. Physicochemical studies of pin-milled and air-classified dry edible bean fractions, *Cereal Chemistry*, **67(4)**, 384 - 390.

Hermansson, A.M., 1979. Methods of studying functional characteristics of vegetable proteins. *Journal of American Oil Chemists Society*, **56**, 272 - 279.

Horax, R., Hettiarachchy, N.S., Chen, P. and Jalaluddin, M, 2004. Functional properties of isolate protein from cowpea (*Vigna unguiculata* Walp). *Journal of Food Science*, **69**, 114-118.

Hung; S.C. and Zayas J.F., 1991. Emulsifying capacity and emulsion stability of milk proteins and corn germ proteins flour. *Journal of Food Science*, **56**, 1216 - 1218.

Johnson, E.A. and Brekke, J., 1983. Functional properties of acylated pea protein isolates. *Journal of Food Science*, **48**, 722 - 725.

Kaur, M. and Singh, N., 2007. Characterization of protein isolates from different Indian chickpea (*Cicer arietinum L.*) cultivars. *Food Chemistry*, **102**, 366 - 374.

Kikugawa, K., Ido, Y. and Mikami, A, 1981. Studies on peroxidized lipids. VI. Fluorescents products derived from the reaction of primary amines, malonaldehyde and monofunctional aldehydes. *Journal of American Oil Chemists Society*, **61**, 1574 - 581.

Kilara, A., Humbert, E.S. and Sosulski, F.W., 1972. Nitrogen extractability and moisture absorption characteristics of sunflower seed products. *Journal of Food Science*, **37**, 771 - 773.

Kinsella, J. E. (1979). Functional properties of soy proteins. *Journal of the American Oil Chemists' Society*, **56**, 940 - 958.

Lawal, O.S. and Adebowale, K.O., 2006. The acylated protein derivates of *Canavalia ensiformis* (Jack Beans): A study of functional Characteristics, *LWT*, **39**, 918 - 929.

Lillford, P.J, 1983. Extraction processes and their effect on protein functionality. *Plantarum Qualitas Plant Food for Human Nutrition*, **32**, 401 - 409.

Lin, M. J. Y., Humbert, E. S. and Sosulki, F. W., 1974. Certain functional properties of sunflower meal products. *Journal of Food Science,* **39**, 368.

Meares, C. A., Bogracheva, T. Y., Hill, S. E. and Hedley, C. L., 2004). Development and testing of methods to screen chickpea flour for starch characteristics. *Starch/Stärke,* **56**, 215-224.

Mwasaru, M.A., Muhammad, K., Bakar, J. and Cheman, Y.B., 1999. Effect of isolation technique and conditions on the extractability, physicochemical and functional properties of pigeon pea (*Cajanus cajan*) and cowpea (*Vigna unguiculata*) protein isolates II. Functional properties. *Food Chemistry*, **67**, 445 - 452.

Pawar, V.D. and Ingle, U.M., 1988. Functional properties of raw and cooked moth bean (*Phaseolus acontifolius* Jacq) flours. *Journal of Food Science and Technology*, **25(4)**, 186-189.

Paredes-Lopez, O., Ordorica-Falmir, C. and Olivares-Vasquez, M. R., 1991. Chickpea protein isolates: physiochemical, functional and nutritional characterization. *Journal of Food Science*, **56**, 726 - 729.

Rackis, J.J., Sessa, D.J. and Honing, D.H., 1979. Flavor problems of vegetable food proteins. *Journal of American Oil Chemists Society*, **56**, 262–271.

Sánchez-Vioque, R., Clemente, A., Vioque, J., Bautista, J. and Millán, F., 1998. Polar lipids of defatted chickpea flour and protein isolates. *Food Chemistry*, **63**, 357 - 361.

Sánchez-Vioque, R., Clemente, A., Vioque, J., Bautista, J. and Millán, F., 1999. Protein isolates from chickpea (*Cicer arietinum* L.): chemical composition, functional properties and protein characterization. *Food Chemistry,* **64**, 237-243.

Santiago Cardoso, R.A., Moreira-Araújo, R.S.R., Pinto de Silva, M.E.M. and Arêas, J.A.G., 2001. The potential of extruded chickpea, corn and bovine lung for malnutrition programs. *Innovative Food Science and Emerging Technologies*, **2(3)**, 203 - 209.

Sathe, S. K. and Salunkhe, D. K., 1981. Functional properties of the great Northern bean (*Phaseolus vulgaris* L.) Proteins: Emulsion, Foaming, Viscosity, and Gelation Properties. *Journal of Food Science,* ***46***, 71-75.

Sathe, S. K., Deshpande, S.S. and Salunkhe, D.K., 1982a. Functional properties of winged bean (*Psophocarpus tetragonolobus* L. DC) proteins. *Journal of Food Science*, **47**, 503-509.

Sathe, S.K., Deshpande, S.S. and Salunkhe, D.K., 1982b. Functional properties of lupin seeds (*Lupinus mutabilis*) proteins and protein concentrates. *Journal of Food Science*, **47**, 491-497, 499-500.

Sefa-Dedeh, S. and Yiadom-Farkye, N.A., 1988. Some functional characteristics of cowpea (*Vigna unguiculata*), bambara beans (*Voandzeia subterranean*) and their products. *Canadian Institute of Food Science and Technology Journal*, **21**, 266 - 270.

Singh, D.G., Abas, A.W., Kaur, D., and Sogi, Singh, D.S., 2008. Characterisation and functional properties of proteins of some Indian chickpea (Cicer arietinum) cultivars. *Journal of the Science of Food and Agriculture*, **88(5)**, 778 - 786 (9).

Summer, A.K., Nielsen, M.A. and Youngs, C.G., 1981. Production and evaluation of pea protein isolate. *Journal of Food Science*, **46,** 364 - 367.

Tharanathan, R.N. and Mahadevamma, S., 2003. Grain legumes-A boon to human nutrition. *Trends in Food Science and Technology*, **14**, 507-518.

Tjahjadi, C., Lin, S. and Breene, W.M., 1988. Isolation and characterization of adzuki bean (*Vigna angularis* cv. Takara) proteins. *Journal of Food Science*, **53**, 1438 - 1443.

Turgeon, S.L., Gauthier, S.F., Mollé, D. and Léonil, J., 1992 Interfacial properties of tryptic peptides of ß-lactoglobulin. *Journal of Agricultural and Food Chemistry*, **40**, 669 - 675.

Vani, B. and Zayas, J.F., 1995. Wheat germ protein flour solubility and water retention. *Journal of Food Science*, **4(60)**, 845 - 851.