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Turkey liver: Physicochemical characteristics and functional properties of protein fractions

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ABSTRACT

Turkey liver is an important edible meat by-product. However, it is generally unprocessed, underutilized and low-priced compared to mammalian livers. The present investigation was conducted to provide information on physicochemical composition and functional characteristics of turkey liver. Proximate composition (%) was: moisture (72.3 ± 1.2), protein (21.9 ± 0.6), fat (2.9 ± 1.6), carbohydrate (1.4 ± 0.7), and total ash (1.5 ± 0.1). Cholesterol, glycogen and total heme pigments (g/kg) in the turkey liver were 2.05 ± 0.06, 5.36 ± 0.01 and 2.3 ± 0.08, respectively. Contents in saturated, monounsaturated and polyunsaturated fatty acids (%) were 42.5, 14.6 and 32.6 respectively. Interestingly, turkey liver fat also contains 5% of camphor (oxygenated monoterpene). Mineral concentrations (mg/kg) in liver were: Na (817 ± 14), K (1390 ± 90), Ca (31.4 ± 0.3), Mg (23 ± 0.4), Fe (161 ± 5), Zn (40 ± 2) and Cu (34 ± 2). Liver proteins extracted at 5 or 10 g/l NaCl showed the highest foaming capacity ($P < 0.05$). Addition of xanthan (1–3 g/l) to liver proteins improved both foam formation and its stability ($P < 0.05$). Turkey liver also showed interesting emulsifying properties. The emulsion stability of liver proteins was more pronounced at high NaCl concentration (20 g/l). The highest emulsion stability was obtained at acidic or basic pH values ($P < 0.05$) and decreased at pH 6.

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Keywords: Turkey liver; Physicochemical composition; Foaming characteristics; Emulsifying properties

1. Introduction

Turkey (*Meleagris gallopavo*) meat has been perceived and marketed as a healthy alternative to red meat due to their leanness, low cholesterol content and favorable fatty acid profile (Brunel et al., 2006). Recently, turkey meat production in Tunisia has shown a significant growth. It reached 38,577 tons in 2007 (GIPAC, 2007). France produced 633,000 tons of turkey in 2005 and is the highest producer in the European Union countries and the second producer in the world after USA (2,460,000 tons) (FAOSTAT, 2005). Turkey liver, an edible meat by-product which constitutes about 1.8% of live weight in the turkey, represents the main part of red giblets. The important and increasing turkey meat production creates large amounts of valuable liver of which only a small quantity is used for domestic consumption in a fresh form. However, turkey liver is not processed and many consumers have a negative perception of such a meat by-product. In fact, turkey liver is considered as inferior protein source compared with meat. As a result, turkey liver has been underutilized and low-priced compared to lamb and beef livers.

Liver represents an important source of protein with functional characteristics that are related with different protein fractions and with physicochemical conditions such as pH and ionic strength. The amphiphilic character of proteins allowed them to adsorb at air/water or oil/water interfaces and to reduce interfacial tension which is an important attribute to optimize the input of energy involved in the foaming and emulsification process (Walstra, 1993). The production

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of smaller bubbles or droplets is an important factor for the stability of the dispersion.

Few studies have focused on giblets composition and functionality. Nuckles et al. (1990) studied the protein composition and functional properties of pork and beef by-products (lung lobes, liver, spleen and heart) in cooked batter model system. Rivera et al. (2000a) reported the composition and different protein fractions of pork by-products (lung lobes and kidney) and chicken viscera. Then, Rivera et al. (2000b) also studied water retention capacity and texture properties of pork by-products and chicken viscera in different physicochemical conditions. The physicochemical characteristics of beef and buffalo livers were reported by Shelf (1975) and Devatkal et al. (2004) respectively. Recently, emulsion characteristics of beef and sheep offal (liver, lung, kidney, spleen and heart) were studied by Kurt and Zobra (2006).

To the best of our knowledge, there are no available reports which focused on turkey liver characteristics. In fact, investigation of turkey liver nutrients would be of great importance with respect to its safety and adequacy for human nutrition. Furthermore, understanding the composition and techno-functional properties of turkey liver is essential for its processing and its incorporation in many food formulations.

2. Materials and methods

2.1. Livers

Turkey liver samples were collected from a local slaughterhouse (Chahia, Tunisia) within 4 h of slaughter. The liver samples were packed individually in polyethylene bags and stored in a refrigerator at 4 °C for 3–5 h before analysis.

2.2. Physicochemical characterization

2.2.1. Estimation of proximate composition and mineral concentrations

Dry matter was determined by oven-drying at 105 °C to constant mass (AOAC, 1997). Crude proteins were analyzed according to Kjeldhal method. A factor 6.25 was used for conversion from total nitrogen to crude protein (AOAC, 1997). Fat content was determined according to a method described by Folch et al. (1957). Carbohydrates were analyzed according to a method described by Manas et al. (1994). The ash content was determined by combustion of the sample at 550 °C for 8 h. Then, different minerals constituents (Ca, Mg, K, Na, Zn and Cu) were analyzed separately using an atomic absorption spectrophotometer (Hitachi Z6100, Japan).

2.2.2. Estimation of glycogen, cholesterol and total heme pigments

Liver glycogen content was determined by enzymatic digestion of liver glycogen (Chan and Exton, 1976). Briefly, liver glycogen was precipitated with ethanol, centrifuged and the pellet resuspended in 0.2 M sodium acetate pH 4.5. The glycogen was hydrolyzed with amylo α-(1,4)/α-(1,6)-glucosidase (Sigma, St. Louis, MO) followed by measurement of liberated glucose using the glucose oxidase assay (Sigma, St. Louis, MO). Cholesterol content of turkey liver was estimated using enzymatic assay of cholesterol oxidase assay (BioAssay Systems, USA). Total heme pigments in turkey liver were calculated following the method described by Lee et al. (1999).

2.2.3. Gas chromatography/mass spectrometry (GC/MS) analysis of fatty acid methyl esters

After lipid extraction using chloroform/methanol, methyl esters of the fatty acids contained in turkey liver oil were prepared as follows: A sample containing 50 mg of lipids was dissolved in 500 μl n-hexane. Then, 200 μl of potassium hydroxide 2 M in methanol was added and the solution was mixed for 2 min in a vortex mixer. After phase separation, the upper layer of n-hexane containing the fatty acid methyl esters was analyzed by GC/MS. A Hewlett-Packard 5890 series II gas chromatograph equipped with HP-5MS capillary column (30 m × 0.25 mm i.d., film thickness 0.25 μm; Hewlett-Packard) and coupled to a HP 5972A masse-selective detector (Hewlett-Packard, Palo Alto, CA, USA) was used. The column temperature was programmed at 50 °C for 1 min, then 7 °C/min to 250 °C, than left at 250 °C for 5 min. The temperature of the injector port was held at 250 °C (split ratio: 1/100) and the temperature of the detector was set at 280 °C. The mass spectrometer conditions were as follow: ionization voltage, 70 eV; ion source temperature, 150 °C; electron ionization mass spectra were acquired over the mass range 50–550 Da. The carrier gas was helium (99.995% purity), with a flow rate of 1.2 ml/min and the analyzed sample volume was 2 μl.

The turkey liver fat components were identified by comparing the mass spectra data with spectra available from the Wiley 275 mass spectra libraries (software, D.03.00). Percentages of the constituents were calculated by electronic integration of peak areas and were expressed as a percentage by weight of the total turkey liver fat.

2.3. Functional properties analysis

2.3.1. Preparation of liver extracts

Turkey liver sample (50 g) were suspended in 100 ml distilled water and mixed mechanically three times for 1 min using the blender system (Moulinex, France). The mixture was then stirred with a magnetic bar for 15 min while the pH was adjusted to 3, 4 or 8 using 1 M HCl or 1 M NaOH solutions. The initial pH value of turkey liver homogenate was around 6. After that, the homogenate was centrifuged for 30 min at 10,000 rpm and the clear supernatant (the extract) was collected and subjected to further analysis.

To study the influence of NaCl concentration on functional properties of liver proteins, some extractions were conducted by adding 5, 10 or 20 g/l NaCl before blending. Moreover, to study the influence of hydrocolloids on foam stability, various carrageenan or xanthan concentrations (1, 2 or 3 g/l) were added in liver extracts after centrifugation.

2.3.2. Determination of extractable protein concentration

Protein concentration was determined in different liver extracts as described in previous works (Bradford, 1976) using BSA ($E^{1\%}_{1\,cm} = 6.7$) as a reference. The proteins extracted in distilled water and in 20 g/l NaCl solution were designated as water soluble and total extractable proteins, respectively. Total extractable proteins were considered as combination of salt soluble and water-soluble proteins.

2.3.3. Foaming capacity and foam stability

The whippability of all liver extracts was determined according to the method described previously (Watanabe et al., 1981). Liver extract (20 ml) was whipped using a homogenizer (Servin, Germany) for 2 min at the highest speed and at room temperature. The whipped sample was then poured

Table 1 – Proximate composition of turkey liver ($n = 5$).

Moisture (%)	72.3 ± 1.2
Protein (%)	21.9 ± 0.6
Carbohydrate (%)	1.4 ± 0.7
Glycogen (g/kg)	5.36 ± 0.01
Fat (%)	2.9 ± 1.6
Cholesterol (g/kg)	2.05 ± 0.06
Total ash (%)	1.5 ± 0.1

into a graduated cylinder and the volume of the liquid that had drained from the foam phase was measured after 30 s. Foaming capacity (FC) is given by the following equation:

$$FC = \frac{Vt - Vd}{V_0}$$

where Vt is the total volume, Vd is the drainage volume and V_0 is the initial volume.

The foaming stability was determined by measuring the half-life of produced foam, i.e., corresponding to the time necessary for draining 50% of the initial foam volume. For some samples, foaming stability was assessed by measuring the residual foam volume (%) after 2 h.

2.3.4. *Emulsifying properties*

Fifty ml of liver extracts were mixed with 50 ml of maize oil. Subsequently, the mixture was homogenized at 9500 rpm in an Ultra-Turrax (Heidolph RZR 2021, Germany) with a fine disperser bar. The maize oil was added drop by drop using a peristaltic pump. The emulsion stability (ES) was determined by centrifugation of the samples at 11,000 × *g* for 30 min. ES was calculated by the following equation:

$$ES = \left(\frac{M_{ac}}{M_{bc}}\right)$$

where M_{ac} is the mass of emulsion after centrifugation and M_{bc} is the mass prior to the centrifugation (Huang et al., 2001).

2.3.5. *Statistical analysis*

Five liver samples ($n = 5$) were analyzed in triplicate for each experiment. Means and standard deviations were calculated. Statistical analyses were performed with STATGRAPHICS Centurium XV ver. 15.2.05 (Stat Point, Inc.) using ANOVA analysis. Differences were considered significant at $P < 0.05$.

3. Results and discussion

3.1. *General composition and physicochemical characteristics*

Mean values of turkey liver proximate composition (moisture, protein, carbohydrate, fat and ash) are presented in Table 1. Turkey liver had higher protein and moisture percentages but lower fat content than values reported for beef liver (Shelf, 1975). The carbohydrate content of turkey liver (1.4 ± 0.7%) was lower than the value (5.3%) reported for beef liver (Shelf, 1975). Average glycogen content of turkey liver was 5.36 ± 0.01 g/kg (Table 1), which was also lower than those reported for pork liver (10.7 g/kg) (Warris and Bevis, 1987) or buffalo liver (7.1 ± 0.9 g/kg) (Devatkal et al., 2004). However, livers from many species remain a rich source of carbohydrate and glycogen as compared to beef muscle (carbohydrate = 2 g/kg and glycogen = 1 g/kg). The higher level of glycogen in liver is expected since liver is the main storage organ for glycogen in the body. Nevertheless, high carbohydrate content was shown to promote growth of lactic acid bacteria on liver, resulting in a rapid spoilage (Shelf, 1975; Devatkal et al., 2004).

Table 2 – Fatty acid composition of turkey liver (% of total fatty acids).

Fatty acid[a]	(%)[c]
16:1	0.9 ± 0.05
16:0[b]	20.0 ± 0.5
18:2 n-6[b]	21.7 ± 0.6
18:1	13.7 ± 0.3
18:0[b]	22.5 ± 0.5
20:4 n-6	9.2 ± 0.1
20:5 n-3	0.7 ± 0.04
20:3	1.0 ± 0.05
SFAs	42.5
MUFAs	14.6
PUFAs	32.6

SFAs: saturated fatty acids; MUFAs: monounsaturated fatty acids; PUFAs: polyunsaturated fatty acids.
Results are mean values of duplicate injection of three samples. SDs from means did not exceed 1% of absolute values.
[a] Compounds are listed in order of their elution from a HP-5MS column.
[b] Main compound in bold font.
[c] Percentages obtained by FID peak-area normalization.

It is well established that turkey meat present a low caloric value (4510 kJ/kg) in contrast to what has been observed for beef or sheep meat (>8000 kJ/kg). This is likely due to the fact that turkey meat has a low fat content (1.3–2.9%) (Favier et al., 1995). Concerning turkey liver, our results also showed that its fat content (2.9 ± 1.6%) was lower than the value reported for buffalo (5.6 ± 0.3%) liver (Devatkal et al., 2004). Furthermore, turkey liver fat content was much lower than the value (10%) reported for beef skeletal muscle (Shelf, 1975). Cholesterol content of turkey liver (2.05 ± 0.06 g/kg) (Table 1) was also found to be lower than the values reported in mammalian livers, which ranged from 3.54 to 3.70 g/kg (Hutchinson et al., 1987). Nevertheless, cholesterol in turkey liver remains higher than the values reported for beef (1.1 g/kg) or turkey meats (0.8 g/kg) (Favier et al., 1995).

The fatty acid composition of turkey liver is shown in Table 2. Percentages of saturated (SFAs), monounsaturated (MUFAs) and polyunsaturated (PUFAs) fatty acids were 42.5%, 14.6% and 32.6%, respectively. Stearic acid (18:0, 22.5%), linoleic acid (18:2 n-6, 21.7%) and palmitic acid (16:0, 20%) were the major fatty acids in turkey liver. Stearic acid was also shown to be the major fatty acid (25%) in beef liver. Nevertheless, the contents of linoleic acid and palmitic acid in beef liver (5% and 13.3%, respectively) were found to be lower than those of turkey liver (Enser et al., 1998). MUFAs in turkey liver (14.6%) were lower than those in beef liver (19.4%). Whereas, PUFAs in turkey liver (32.6%) are slightly higher than in beef liver (29.8%) (Enser et al., 1998). PUFAs are beneficial to the human health, since their intake would lower the risk of developing artherosclerosis and cholesterol accumulation in the blood (Appel et al., 2005). This aspect will be favorable in promoting the turkey liver to consumers. It seems worthy to note that fatty acid composition of animal tissues is influenced by several factors such as feeding regime, dietary fat, sex, live weight and age. In contrast to MUFAs, PUFAs are very prone to oxidation, leading to the generation of a wide variety of oxidation products responsible for the changes in flavor

Table 3 – Concentrations of minerals (mg/kg) in turkey liver ($n = 5$).

Na	817 ± 14
K	1390 ± 90
Ca	31.4 ± 0.3
Mg	23 ± 0.4
Fe	161 ± 5
Zn	40 ± 2
Cu	34 ± 2

and to reduction in the nutritional value. Consequently, storage conditions were very important to reduce liver oxidation. Interestingly, GC/MS analysis of turkey liver oil allowed us to identify the presence of camphor (oxygenated monoterpene) at a concentration of 5% of the total oil. However, camphor has been reported to exhibit antimicrobial activity (Tirillini et al., 1996; Setzer et al., 2004) and this compound is a major constituent in a number of antibacterial essential oils (Viljoen et al., 2003; Candan et al., 2003; Setzer et al., 2004). Moreover, when camphor is applied on the skin, it is analgesic and it is also known for its topical use as a counter-irritant in fibrositis, neuralgia, and similar conditions (Martindale, 1996).

Concentrations of different minerals in turkey liver are shown in Table 3. Mean Ca (31.4 ± 0.3 mg/kg), K (1390 ± 90 mg/kg) and Mg (23 ± 0.4 mg/kg) contents in turkey liver were much lower than those of Ca (80 mg/kg), K (2980 mg/kg) and Mg (220 mg/kg) reported for beef liver (Shelf, 1975). Furthermore, Na, Zn and Cu concentrations in turkey liver were comparable to those reported for beef liver. Interestingly, livers possess a high content of Cu (34 ± 2 mg/kg) when compared to chicken (0.5 mg/kg) or beef (14 mg/kg) meats. Iron content of turkey liver (161 ± 5 mg/kg) was also higher than that of beef liver (60–120 mg/kg) (Shelf, 1975; Sales and Hayes, 1996; Devatkal et al., 2004). Iron deficiency is considered as the most prevalent nutritional disorder particularly in the developing countries. However, turkey liver seems to be a very good nutritional source of Fe which is an essential mineral. Moreover, iron in liver is a heme-iron, which is several times more absorbable than non heme-iron present in other foods. Zinc is also another essential mineral that is more available to the body when provided from a meat source (Hedrick et al., 1994; Devatkal et al., 2004). Total heme pigments in the turkey liver were found to be 2.3 ± 0.8 g/kg. The presence of high concentrations of bile and metal ions like Cu and Fe pigments might be responsible for stronger pigments in the liver. Therefore, turkey liver can be used to improve the color of different sausages.

Recommended daily intake (RDI) of protein, dietary fat and some essential minerals are 60 g, 20 g, 30 mg iron, 2 μg Cu and 15 mg Zn, respectively per day for an adult (Devatkal et al., 2004). Therefore, a serving of 100 g turkey liver per day would supply 36.5% of protein, 14.5% of fat, 55% of iron, 26.5% of zinc and more than 100% of cooper requirement for an adult with respect to RDI. Furthermore, it was shown that liver from many species presented a low caloric value around (1350 kJ/kg) (Devatkal et al., 2004). This property would also help in recommending liver as a part of a healthy diet.

3.2. *Functional properties of different turkey liver extracts*

Turkey liver is a rich source of protein and its functional properties were influenced by the protein fractions. The functional properties of various liver proteins extracts were studied. Proteins extractability from liver was related to conditions such as pH and ionic strength. Furthermore, the foaming and emulsifying characteristics of protein solutions were influenced by the pH and the ionic environment.

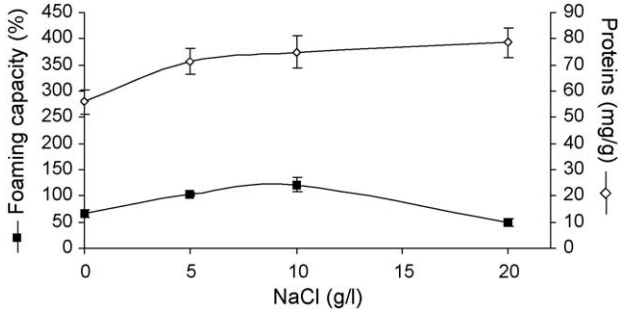

Fig. 1 – Effect of NaCl concentration on turkey liver proteins extraction and on foaming capacity at pH 6. Soluble proteins were expressed by (mg/g) of fresh liver ($n = 5$).

3.2.1. *Foaming properties*

3.2.1.1. Effect of NaCl on the protein extraction and foaming properties. Fig. 1 shows the evolution of protein concentration and foaming capacity of various turkey livers extracts produced with different NaCl concentrations. Our results showed that the concentrations of extractable proteins obtained in 5, 10 or 20 g/l were almost equal, but they were significantly higher than water-soluble proteins ($P < 0.05$) (Fig. 1). Total extractable proteins obtained are considered as combination of salt soluble and water-soluble proteins. As a result, water-soluble proteins (55.8 ± 4.5 mg/g) were higher than salt-soluble proteins (22.6 mg/g) ($P < 0.05$). These results recall those observed for buffalo liver (Devatkal et al., 2004) and various pork meat by-products (Rivera et al., 2000a) characterized by an important amount of insoluble and water-soluble proteins. In comparison to lean meat, liver and meat by-products contain high levels of sarcoplasmic and stroma proteins than myofibrillar proteins (Nuckles et al., 1990; Rivera et al., 2000a). This might explain high water-soluble protein levels.

Addition of NaCl up to 10 g/l improved foaming capacity (FC) ($P < 0.05$), which could be due to higher protein solubility and the ability of NaCl to help diffusion and spreading at the interface (Akinatayo et al., 1999). Nevertheless, these effects are concentration-dependent as liver proteins extracted at 20 g/l NaCl showed the lowest FC ($P < 0.05$) (Fig. 1) as well as a reduced foam stability (data not shown). These results suggest participation of ionic interactions in the foaming phenomena of proteins. The presence of 20 g/l NaCl in the protein solution could influence the micro-environment of extracted proteins. At high ionic strength, FC becomes depressed because ions may reduce the coulombic forces between polypeptide chains in the protein molecules (Akinatayo et al., 1999).

3.2.1.2. Effect of pH on the protein extraction and foaming properties. Our results showed that there is not a significant difference between the concentration of extracted proteins obtained at pH 3 or pH 4 and between those obtained at pH 6 or pH 8. The extracted proteins increased when increasing pH from 4 to 6 ($P < 0.05$) (Fig. 2). The FC and foam stability were much reduced at pH 3 ($P < 0.05$) (Fig. 2, Table 4). This result can be explained by the fact that at pH 3, proteins responsible for foam production were insoluble. FC reached the highest value at pH 4 in comparison to those observed at pH 6 or pH 8 ($P < 0.05$) (Fig. 2). The produced foams were more stable at pH 6

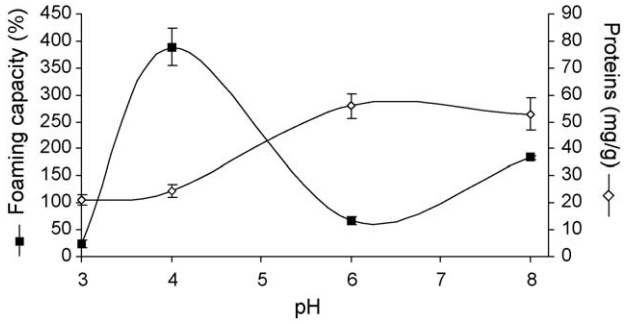

Fig. 2 – Effect of pH on turkey liver proteins extraction and on foaming capacity in the absence of added NaCl. Soluble proteins were expressed by (mg/g) of fresh liver ($n = 5$).

or pH 8 (Table 4). This result recalls that observed by Mohanty et al. (1988) which also showed that stability of acidic caseins foams increased with increasing pH.

3.2.1.3. Effect of hydrocolloids addition on foaming properties. The foaming capacity and the foam stability, is an important functional property for aerated food. Both foam formation and stability against liquid drainage and bubble breakdown depend on the amphiphilic character of protein molecules and various molecular interactions. In order to enhance the functionality of turkey liver proteins, polysaccharides such as carrageenan or xanthan were added. In fact, protein–polysaccharide interactions in the aqueous phase, have an effect on protein interfacial adsorption (Martinez et al., 2007) and consequently, on formation and stability of dispersed colloidal systems (Rodríguez-Patino et al., 2008). Fig. 3A shows the effect of varying the concentrations of xanthan or carrageenan on the liver proteins FC. Our results clearly showed that in the presence of xanthan or carrageenan, FC was higher than that of the control sample ($P < 0.05$). For both polysaccharides, FC increased up to 250% at a hydrocolloids concentration of 1 g/l ($P < 0.05$). This capacity decreased for concentrations higher than 1 g/l. Interestingly, stability of foams was improved when increasing hydrocolloid concentrations ($P < 0.05$) (Fig. 3B). For concentrations higher than 1 g/l, xanthan showed greater foaming capacity and improved the foam stability as compared to carrageenan ($P < 0.05$). These results might be explained by the fact that in the (liver proteins/hydrocolloids) mixed systems, hydrocolloids might increase the viscosity of the continuous phase as thickening agents, which leads to a decrease in bubble movement break down resulting in more stable foams (Dickinson, 2003). Moreover, attractive interactions such as electrostatic binding in (liver proteins/hydrocolloids) mixed systems might produce high structuration of the molecules at the air/water interface by forming hybrid biopolymer entities. The hybrid biopolymer entities become the basis of the excellent interfacial viscoelastic properties and foaming characteristics of the (liver proteins/hydrocolloids) mixed systems (Martinez et al., 2007). Similar results were reported by (Neirynck et al., 2004; Vega et al., 2005) who also showed that proteins and polysaccharides form hybrids (conjugates or molecular complexes) with enhanced functional properties in comparison to the proteins and polysaccharides alone.

Table 4 – Foam stability of proteins turkey liver extracted at different pH ($n = 5$).

pH	3	4	6	8
Half-life time (min)	1.7 ± 1.2	43 ± 12	>120	>120

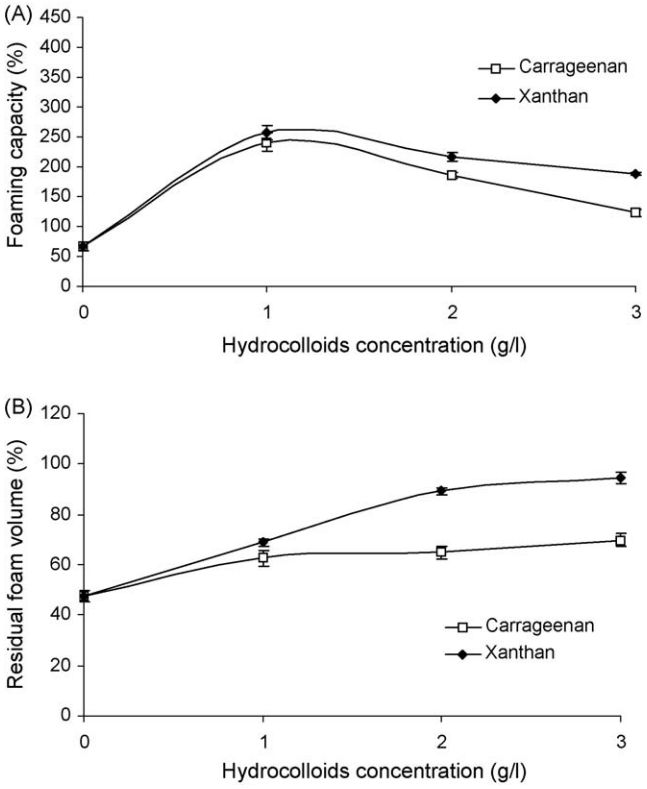

Fig. 3 – Effect of xanthan and carrageenan addition on foaming capacity (A) and on foaming stability (B). Foaming stability was assessed by measuring the residual foam volume (%) after 2 h ($n = 5$).

3.2.2. Emulsifying properties

Emulsion stability was measured to test the stability of an emulsion against centrifugal force. Emulsion stability is an important parameter for the storage time of commercial products and its measurements refer to the ability of emulsion to remain unchanged. Fig. 4A showed variation of emulsion stability with NaCl concentration. Increasing NaCl concentration from 0 to 10 g/l or 20 g/l, significantly increased emulsion stability ($P < 0.05$). Increase in ionic strength may reduce the electrostatic repulsion between the adsorbed film and arriving molecules, thereby increasing the amounts of protein molecules adsorbed at the interface. Furthermore, more compact packaging of protein molecules at the interface may be facilitated at higher ionic strengths, which could contribute to increased surface protein coverage (Srinivasan et al., 2000). Emulsifying stability was also studied for liver proteins extracted at different pH and in the absence of added NaCl (Fig. 4B). Our results showed that the lowest emulsion stability was obtained at pH 6 ($P < 0.05$) (Fig. 4B) and increased at acidic or basic pH values ($P < 0.05$). These results recall those obtained by Mohanty et al. (1988) who found that the emulsifying capacity of acidic casein solutions decreased as the pH approached the isoelectric point and then increased again on the acid side of the isoelectric point. These changes in emulsion capacity with pH or ionic strength reflect essentially changes in protein solubility and/or the thickness of the adsorbed protein film.

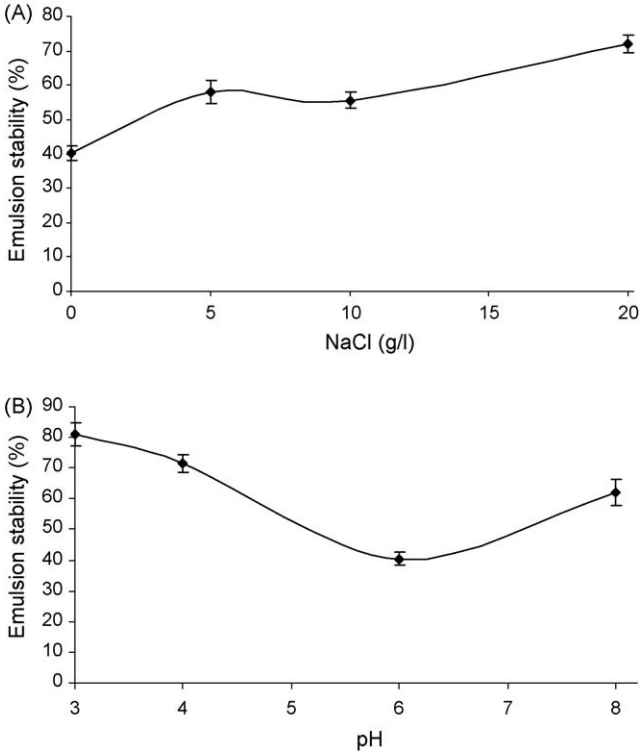

Fig. 4 – Emulsion stability at different levels of NaCl and at pH 6 (A) and at different pH in the absence of added NaCl (B) ($n = 5$).

4. Conclusion

This study was designed to develop a knowledge base of turkey liver composition and functional properties. From the obtained results, it can be said that turkey liver is a rich source of essential nutrients like proteins, iron and zinc. The fat and cholesterol contents were found to be lower than the values reported for beef liver. Meanwhile, turkey liver fat contains 32.6% of PUFAs, which are beneficial for the human health. Interestingly, turkey liver oil also contains 5% of camphor (oxygenated monoterpene). The foaming capacity of liver control sample (FC = 67 ± 8%, pH 6) was enhanced at pH 4 (FC = 390 ± 30%) or at pH 8 (FC = 183 ± 3%) ($P < 0.05$). Furthermore, in the presence of 10 g/l NaCl, liver proteins also exhibited a better foaming capacity (FC = 122 ± 7%) ($P < 0.05$). Addition of 1 g/l xanthan to liver proteins, improved both foam formation as well as its stability ($P < 0.05$). Emulsion stability of liver proteins was found to be significantly better in the presence of high NaCl concentration such as 20 g/l ($P < 0.05$). The highest emulsion stability was obtained at acidic or basic pH values ($P < 0.05$). Further investigations may be necessary to identify and/or to purify proteins responsible for these functional characteristics. This economical and underutilized turkey liver could find its increased commercial utilization for human consumption by the possibility of its processing and incorporation in many food formulations such as sausages.

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