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Influence of carrageenan addition on turkey meat sausages properties

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A R T I C L E I N F O

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A B S T R A C T

Influence of carrageenan addition on the properties of turkey meat sausages was studied. The results obtained show that carrageenan causes a decrease in emulsion stability, and an increase in water holding capacity, hardness and cohesiveness of the formulated sausage samples. Carrageenan addition at low levels (0.2% and 0.5%) increases gel elasticity. However, a higher carrageenan concentration causes a reduction in sausages elasticity. Microstructure observation shows that increasing carrageenan levels in sausage formulation leads to a progressive appearance of an additional carrageenan gel network. Sensorial analysis shows that carrageenan presence has no significant effect on sausages taste. However, it improves sausage appearance and texture.

1. Introduction

Protein–polysaccharide interactions play a significant role in the structure and stability of various processed foods. Functional properties of food proteins, such as solubility, gel forming and emulsifying capacity are affected by their interaction with polysaccharides. In the case of formulated and cooked meat products myofibrillar proteins play a key role during processing because of their ability to produce three-dimensional gels upon heating and subsequent cooling, which has a significant influence on sensorial and textural properties of the processed products (Smith, 1988; Vega-Warner et al., 1999). In the literature polysaccharide–protein interaction are well documented for non-meat proteins (eggs, milk...). However, more studies are required to understand the interaction of meat proteins with hydrocolloids in order to achieve desirable characteristics in the formulated meat products. Several functional ingredients capable of improving water binding properties and modifying texture, are of interest to meat processors. Hydrocolloids with their unique characteristics are of great interest in processed meat due to their ability to bind water and form gels (Candogan and Kolsarici, 2003a,b). One of the most interesting hydrocolloids gums, which could be used in meat industries, is carrageenan. This hydrocolloid is a linear sulphated polysaccharide, extracted from red algae. It is widely used in the food industry for a broad range of applications because of its water binding, thickening and gelling properties. In the meat industry, carrageenan is used as a gelling agent in canned meats and petfoods and it allows reduction in fat content in comminuted meat products like frankfurters (Candogan and Kolsarici, 2003a,b). In cooked sliced meat products carrageenan is used to improve moisture retention, cooking yields, slicing properties, mouth-feel and juiciness (Imeson, 2000).

The effect of carrageenan addition on the functional properties of formulated meat products has been the subject of numerous studies. Bater et al. (1992) found that carrageenan caused an increase in yield, sliceability and rigidity and a decrease in expressible juice in roasted turkey breasts. In breakfast sausages, carrageenan was also found to increase the hardness of meat batters when replacing fat by water–gum solution, whereas carrageenan importantly improved the water holding ability (Barbut and Mittal, 1992). DeFreitas et al. (1997) reported increased gel strength and water retention when adding carrageenan to salt–soluble meat protein gels. Xiong et al. (1999) reported that carrageenan increased the cooking yield, hardness and bind strength of low-fat sausages. Pietrasik (2003) studied the binding and textural properties of beef gels processed with carrageenan, egg albumin and microbial transglutaminase. Hsu and Chung (2001) observed an increase in cooking yield, hardness, and other textural profile analysis parameters by adding up to 2% carrageenan to low-fat emulsified meatballs.

In spite of these published studies, meat processors, especially turkey meat processors, need more scientific data to deliver formulated products which are able to meet special requirements of consumers. Examples of such requirements may be an improvement in moisture retention, cooking yields, slicing properties, mouth-feel and juiciness of final products.

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In this paper, attention is drawn to the influence of carrageen addition and storage time on meat emulsion stability, water holding capacity, textural properties, microstructure and sensorial properties of formulated and cooked turkey meat product.

2. Materials and methods

2.1. Materials

Turkey sausage products were formulated using mechanically separated turkey (MST) meat obtained from local processors (Chahia, Sfax Tunisie). MST meat was produced from turkey after meat cutting. Approximate chemical composition of MST was 65% water, 14% proteins, 20% fat and 1% ash. Analytical grade NaCl, $NaNO_2$, ascorbic acid and sodium tripolyphosphate (TPP) were used. Iota Carrageen samples were purchased from CEAMSA Company (CEAMSA, CEAMGEL 9623, Spain). Cold distilled water was used in all formulations (4 °C).

2.2. Sausage preparation

MST meat was ground in a commercial food processor (Universo, Rowenta, Germany), equipped with a 14 cm blade, for 2 min at the highest speed. Dry ingredients (salt, carrageen, modified starch, etc) were slowly added to the ground MST as powders while processing. Afterwards, cold water was incorporated. The addition of ingredients took less than 5 min and final temperature of batters varied between 10 and 12 °C. The batters were manually stuffed in collagen reconstituted casing (27 mm diameter) and hand-linked to form approximately 8 cm long links. The sausages were then heat-processed in a temperature-controlled water-bath (Haake L, Haake Buchler Instruments, Karlsruhe, Germany) maintained at 90 °C until a final internal temperature of 74 °C was reached. Temperature was measure using a type-T (copper–constantan) thermocouple inserted into the centre of a link, and the time/temperature data were recorded. Then, samples were cooled immediately in an ice-water-bath and stored at 4 °C for 40 days.

Different carrageenan levels were studied by adding 0.2%, 0.5%, 0.8% and 1.5% of carrageenan powder, in addition to studying a sample which did not contain carrageenan. All formulations were prepared with the same common ingredients: 60% MST, 29% water (ice- and cold-water), 8% modified starch (E1422, Sigma Chemical CO., St Louis, MO), 2% NaCl, 0.5% TPP, 0.8% $NaNO_2$ and 0.045% ascorbic acid. The process was replicated twice.

2.3. Influence of carrageenan addition on meat batter emulsion

Influences of carrageenan addition on meat emulsions stabilities before cooking were analysed. The size distribution of the oil droplets was observed using an optical microscope (Olumpus U-CMAD-2, Japan) employing a 100× objective lens. For each samples, 100 emulsion particles, selected at random, were measured. These data were processed to obtain the particle size histogram (distribution).

The stability of emulsion (ES) was determined by a centrifugation of the samples at 11,000g for 30 min at 4 °C. Emulsion stability (ES) was calculated as (Huang et al., 2001):

$$\mathrm{ES}\,(\%) = \frac{W_{ac}}{W_{bc}} \times 100 \tag{1}$$

where W_{ac} is the weight of meat emulsion after centrifugation and W_{bc} is the weight prior to centrifugation.

2.4. Influence of carrageenan addition on sausages properties

2.4.1. Sausages water holding capacity

About 10 g of each sausage sample was centrifuged at 12,000g for 30 min at 4 °C. The water holding capacity (WHC) was calculated as a percentage of bound water, using the following equation (Verbeken et al., 2005):

$$\mathrm{WHC}\,(\%) = \frac{W_{\mathrm{ac}}}{W_{\mathrm{bc}}} \times 100 \tag{2}$$

where W_{ac} is the weight of sausage sample after centrifugation and W_{bc} is the weight prior to centrifugation.

To measure the stability of formulated sausages during storage, the water holding capacity was measured after 1, 20 and 40 storage days at 4 °C.

2.4.2. Texture measurement

All instrumental texture analyses were done on cooked samples and samples stored at least for 24 h at 4 °C. For every formulation two repeated measurements were taken for each replicate and mean values are reported. Texture profile analysis (TPA) of sausage samples was performed. A cylindrical samples, 2 cm in diameter and 2 cm long, were cut from the centre of the links and compressed twice to 50% of their original height between flat plates and a cylindrical probe (1 cm^2 in diameter) using a texturometer (Texture Analyser, TA Plus, LLOYD instruments, England). In these experiments hardness, cohesiveness, elasticity and chewiness were determined.

To measure the stability of formulated sausages during storage, textural parameters were measured after 1, 20 and 40 days of storage at 4 °C.

2.4.3. Microstructure observations

Small sausage samples (1 cm long and 1 cm in diameter) were cut from the centre of the links and used to perform microscopic observation. Meat gel microstructure was examined by environmental scanning electron microscopy (ESEM) (Philips XL 30 ESEM, Japan). ESEM allows the observation of samples in their natural state, under controlled conditions of temperature and pressure. The environmental mode does not require any preliminary preparation; in addition, this mode removes completely the electronic load effects on the surface and thus preserves the native structure and content of the sample. In this study, microscopic observation was carried under vacuum (pressure = 0.1 kPa). Sausage sample was fixed to the support using double side adhesive tape. A large number of micrographs were taken in order to select the most representative ones.

2.4.4. Sensorial analysis

Sensory analysis was conducted by 15 panellists, who were experienced in sensory evaluation of foods, but received no specific training relevant to this product. Panellists were asked to indicate how much they liked or disliked each product on a 5-point hedonic scale (4 = like extremely; 0 = dislike extremely) according to taste, appearance and texture characteristics. 2 cm long pieces were distributed in white polystyrene plates and presented to the panellists with three-digit codes and in random order for evaluation. Experiments were conducted in an appropriately designed and lighted room and a mean score was estimated for each product.

2.5. Statistical analysis

Analysis and samples treatment were repeated at least three times. Means and standard deviations were calculated with Microsoft Windows Excel 2003. SPSS (version 13.0, USA) for Windows software was used to verify significant differences between treatments and means by Ducan's test at $p < 0.05$.

3. Results and discussion

3.1. Influence of carrageenan addition on meat emulsion before cooking

Microscopic observations of turkey meat batter emulsion containing different levels of carrageenan are shown in Fig. 1. These images show that the size of the oil (fat) droplets dispersed in the continuous phase is lower in control sample (0% carrageenan) than in those formulated with carrageenan. Moreover, the average size of the oil droplets formed in meat batter emulsion increase with carrageenan concentration. Fig. 1 shows that the effect of carrageenan concentration greater than 0.5% is characterised by a high degree of coalescence and the appearance of large oil droplets. Fig. 2a shows oil droplet size distribution in turkey meat batter versus carrageenan level. This figure shows clearly that the spread in oil droplets size distribution became larger with increase in carrageenan levels. For example 80% of oil droplets diameter in control samples (0% carrageenan) ranged between 0.01 and 0.03 mm. However, 45% and 35% of oil droplets diameter in meat emulsion sample containing 0.5% and 0.8% of carrageenan, respectively ranged from 0.01 to 0.03 mm. Turkey meat batters emulsion containing more than 0.8% of carrageenan exhibit a very large spread in the distribution of oil droplets size. This heterogeneity of oil droplets size caused by the presence of carrageenan can lead to destabilisation of the emulsion. Fig. 2b shows evolution of emulsion stability versus carrageenan concentration. This figure also shows that emulsion stability decreases with carrageenan concentration.

Hydrocolloids gums are not considered to be strong surface active agents or emulsifiers. Many proteins, however, are used as emulsifiers due to their hydrophilic and hydrophobic side chains. The characteristics of these proteins may be attributed to their particular properties, which influence their adsorption capacities at the oil-in-water interface. Efficiency of a protein as an emulsifier depends not only on the type and the state (native or unfolded) of protein but also on the pH of solution, presence of other emulsifiers, ionic strength and type of oil added (Hermansson, 1994). Flores et al. (2007) studied the effect of an emulsifier containing carrageenan on the functionality of meat emulsion system. Huang et al. (2001) studied the influence of hydrocolloid gum addition on particle size distribution and interfacial activity of model and meat batters emulsions. These authors reported that carrageenan and xanthan gums caused an increase in oil droplet size. They explained this phenomenon by the fact that the presence of gums cause an increase in the interfacial tension between the two non-miscible liquids, which leads to destabilization in the form of coalescence (Huang et al., 2001). For high gums concentration Huang et al. (2001) attributed the emulsion destabilisation to viscosity effects.

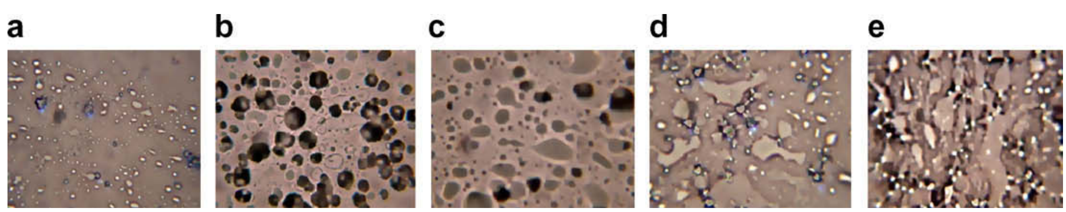

Fig. 1. Optical microscopic observation of meat batter emulsion containing different levels of carrageenan. (a) Control (0%), (b) 0.2%, (c) 0.5%, (d) 0.8% and (e): 1.5%

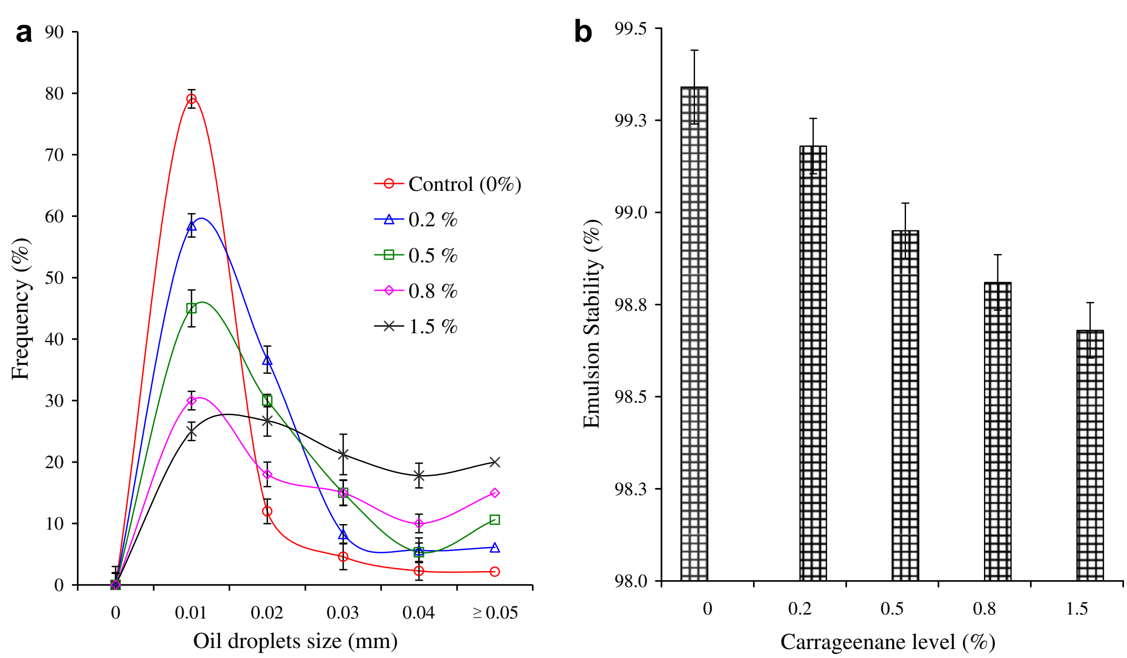

Fig. 2. Turkey meat batter emulsion state as a percentage of carrageenan incorporated. (a) Oil droplets size distribution and (b) emulsion stability.

3.2. Influence of carrageenan addition on the water holding capacity of the sausages

The combined effect of carrageenan concentration and storage time on water holding capacity of sausages formulated with mechanically separated turkey meat is shown in Fig. 3. It can be seen that increasing the carrageenan concentration from 0% to 1.5% causes an increase in WHC of about 1%. Moreover, Fig. 3 shows that during storage, WHC increases for both control (0% carrageenan) and sausages enriched with carrageenan. This increase is probably due to the water loss during storage. Indeed, with the reduction in pH, the water holding capacity of proteins decreases which leads to an exudation of water outside the product. So the quantity of water expelled during centrifugation will be weaker and the WHC will appear higher (Candogan and Kolsarici, 2003b). Moreover, a carrageenan gel appears to cause synaeresis during storage. The effects of carrageenan on the water holding capacity of different kinds of gelled meat products (especially based beef meat) have been extensively studied. Most sources report a better water retention in the presence of carrageenan (Bater et al., 1992; Pietrasik, 2003; Pietrasik and Duda, 2000; Verbeken et al., 2005). However, in some cases the addition of carrageenan seems to have no, or a very limited, effect on the water holding capacity of meat gels (Barbut and Mittal, 1992; Foegeding and Ramsey, 1987).

3.3. Influence of carrageenan addition on sausage texture and microstructure

Fig. 4 shows the evolution of textural parameters of turkey sausages as a function of carrageenan level added and storage time. Fig. 4a presents evolution of sausage hardness versus carrageenan concentration and storage time. From this figure we can conclude that, generally, storage time causes a slight decrease in sausage hardness for each carrageenan concentration. However, Fig. 4a shows that the variation of carrageenan concentration from 0% to 0.5% had no significant effect on sausage hardness. On the other hand, when carrageenan concentration reaches 0.8% and 1.5% a significant ($p < 0.05$) increase in sausage hardness was observed. Indeed, hardness of sausages varied from 12 to 16 N when carrageenan concentration varied from 0.5% to 0.8%, respectively.

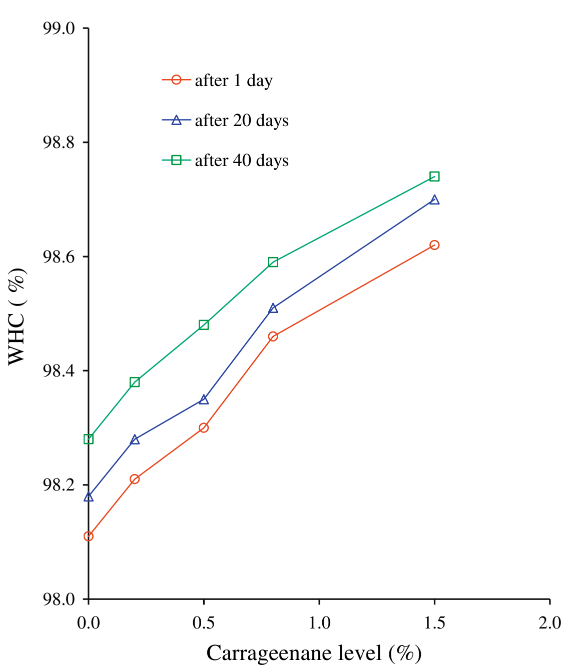

Fig. 3. Effect of carrageenan concentration and storage time on water holding capacity of sausages.

Fig. 4b shows the evolution of sausage cohesiveness against carrageenan concentration and storage time. From this figure it is clear that storage time has no effect on cohesiveness. However, a significant ($p < 0.05$) effect of carrageenan concentration was observed. Indeed, sausage cohesiveness increased continually with carrageenan concentration, except at the concentration of 1.5% where cohesiveness decreased slightly.

The evolution of sausage elasticity with carrageenan concentration and storage time is presented in Fig. 4c. In contrast to hardness and cohesiveness, both carrageenan and storage time have a significant ($p < 0.05$). Indeed, for all the tested carrageenan concentration, storage for 20 days and 40 days caused a decrease in elasticity. Evolution of elasticity with carrageenan concentration shows that the elasticity increases until the carrageenan concentration is 0.5%. Concentrations greater than this value result in a significant ($p < 0.05$) decrease in sausages elasticity.

Fig. 4d shows sausage chewiness variation with carrageenan concentration and storage time. This figure shows that chewiness increases with carrageenan concentration and decreases with storage time.

All these textural changes can be explained in terms of the influence of the presence of carrageenan on the gelling process of proteins. Carrageenan-muscle proteins interaction leads to a change in texture and microstructure of the formulated sausages. Although, the effect of carrageenan addition on the functional properties of meat products has been the subject of numerous studies, few studies focus on the influence of carrageenan on functional properties of transformed turkey meat products. Indeed, Bater et al. (1992) found that κ-carrageenan caused an increase in yield, sliceability and rigidity, and a decrease in expressible juice in roasted turkey breasts. κ-carrageenan was also found to increase the hardness of meat batters when replacing fat by water–gum solution, whereas iota-carrageenan improved the water holding ability (Barbut and Mittal, 1992; Foegeding and Ramsey, 1986, 1987). DeFreitas et al., 1997 reported increased gel strength and water retention when adding κ-carrageenan to salt-soluble meat protein gels. Both κ- and iota-carrageenan were found to increase the cooking yield, hardness and bind strength of low-fat sausages. Hsu and Chung (2001) observed an increase in cooking yield, hardness, and other textural profile analysis parameters when adding up to 2% κ-carrageenan to low-fat emulsified meatballs. Ruusunen et al (2003) and Garcia-Garcia and Totosaus (2007), reported that addition of carrageenan lead to increased hardness in low-fat sausages products.

To study the interaction between muscles proteins and carrageenan molecules during gelling, environmental scanning electronic microscopy (ESEM) was used. This microscopic technique allows observation of gel in its natural state without any pre-treatment such as fixing procedures and gold coating. Fig. 5 shows the microstructure of gelled meat product. Fig. 5a clearly shows that the meat proteins form a three-dimensional compact gel network. Fig. 5b shows that at 0.2% (low concentration), carrageenan was found to be present in discrete regions, excluding the possibility that it forms a continuous gel network and suggesting that carrageenan is present in the interstitial spaces of the protein network which cause a decrease in the compactness of protein gel network. These results are in agreement with reports by Verbeken et al. (2005) who studied the influence of κ-carrageenan on the thermal gelation of salt-soluble meat proteins. Fig. 5c and d shows that at a concentration of 0.8% a continuous carrageenan gel network appears and at 1.5% this carrageenan gel network is formed by developing connections with existing proteins gel network (Zamorano, 2006). Such an evolution of microstructure can explain the change

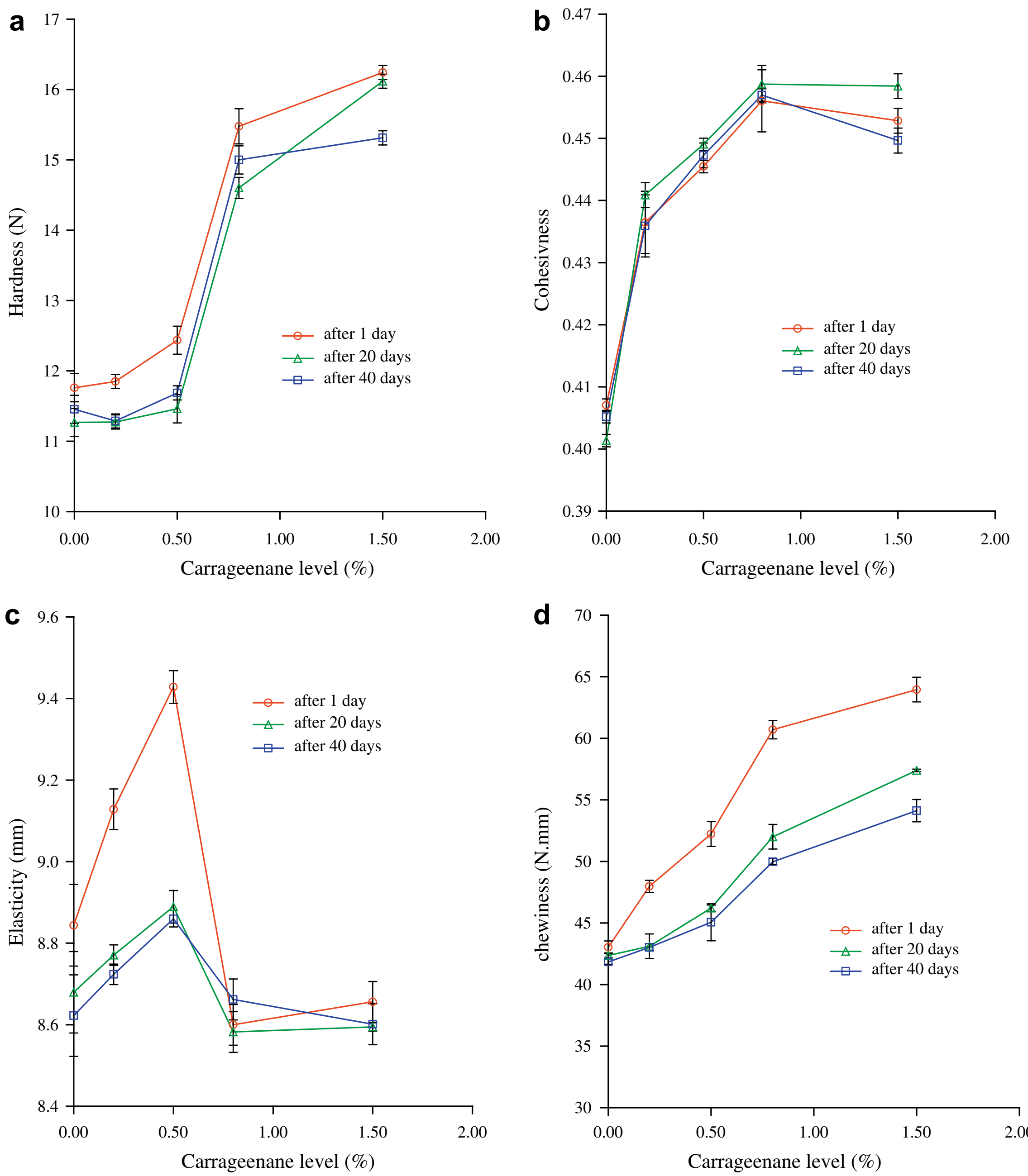

Fig. 4. Effects of carrageenan concentration and storage time on sausage textural parameters. (a) Hardness, (b) cohesiveness, (c) elasticity and (d) chewiness.

in the water holding capacity and textural parameters. At low carrageenan concentration, a reduction in the compactness of protein gel network allows more binding of water. At high carrageenan concentration (1.5%) the presence of an additional carrageenan gel network increases the water holding capacity. Microscopic observation also explains observed textural changes. A significant increase in sausage hardness was observed at high added levels of carrageenan (0.8% and 1.5%). This increase in hardness can be the result of additional carrageenan gel network formation. Variation of sausage elasticity with carrageenan concentration (Fig. 4c) shows two phases. From 0% to 0.5% the elasticity increases progressively until it reaches a maximum value at 0.5%. At greater concentrations, a significant decrease in sausages elasticity is observed. This can be explained by considering the decrease in the compactness of the protein gel network which leads to an aerated and more elastic structure. At higher concentration (0.8% and 1.5%) the presence of the second gel network leads to more compactness and less aerated structures which cause elasticity reduction.

3.4. Influence of carrageenan addition on the sensory characteristics of sausages

The results of sensory analysis of cooked products are shown in Fig. 6. This figure shows that carrageenan content had no significant effect on sausages taste ($p > 0.05$) except at 1.5% where a marginal decrease in score is observed. Average scores for texture and aspect shows that panellist acceptability of sausages formulated with carrageenan increase with carrageenan concentration. In the case of sausages formulated with 0.2% carrageenan no significant differences were observed in the texture and appearance parameters compared to control samples ($p > 0.05$). However, for sausages formulated with 0.5% carrageenan a significant increase in accept-

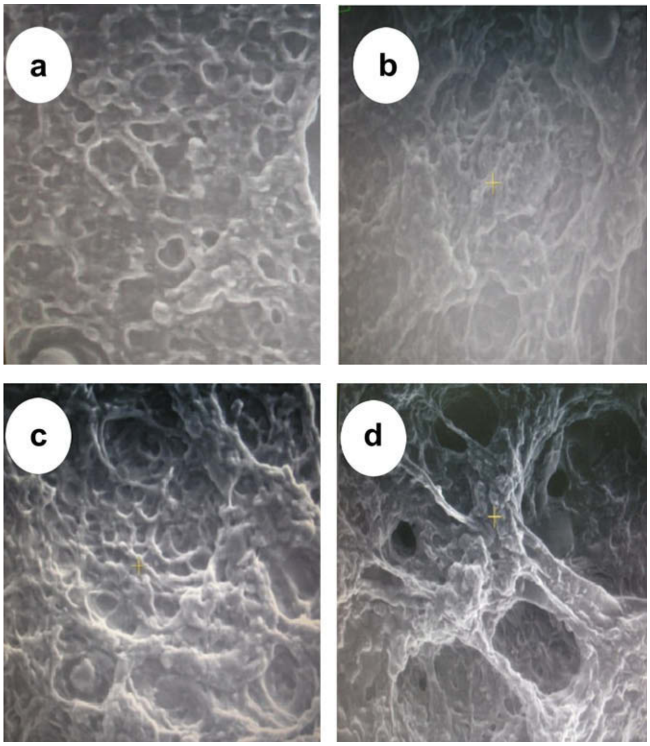

Fig. 5. Microscopic observation of sausage gels formulated with different levels of added carrageenan: (a) 0%, (b) 0.2%, (c) 0.8% and (d) 1.5%.

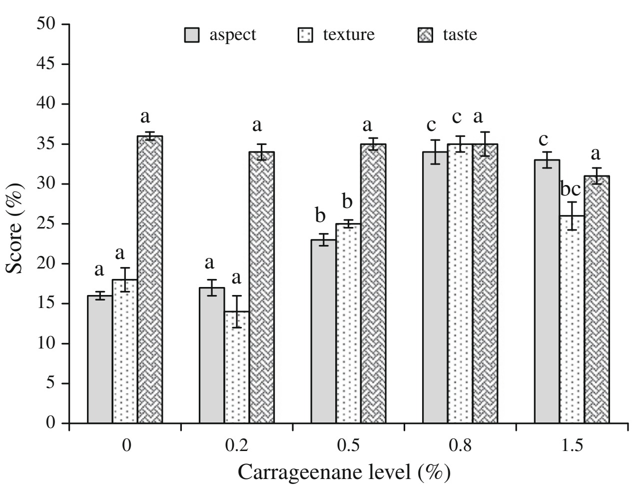

Fig. 6. Sensory scores of sausages formulated using different concentrations of carrageenan. Data with different letters for each parameter (aspect, texture and taste) represent significant difference at $p < 0.05$.

ability was observed compared to control ($p < 0.05$). The texture and aspect of sausages formulated with 0.8% and 1.5% carrageenan were very well received by panellists. However, a weak decrease in texture acceptability was observed in the case of products with 1.5% carrageenan. Thus, sensorial analysis shows that sausage formulated with 0.8% carrageenan is most acceptable to the panellist with considering all attributes.

4. Conclusion

The influence of carrageenan addition on meat emulsion stability, water binding capacity, textural parameters, microstructure and sensory properties of sausages formulated with mechanically separated turkey meat were studied. The results obtained show that carrageenan addition reduces emulsion stability and an increase in water binding capacity. Moreover, carrageenan addition causes a significant change in sausage texture and microstructure. The increase in carrageenan concentration leads to harder and more cohesive sausages. Carrageenan addition at low levels (0.2% and 0.5%) increases gel elasticity. However, at high level (0.8% and 1.5%) carrageenan addition causes a significant decrease in elasticity. Microstructure observation shows that increasing carrageenan levels in sausages formulation leads to the appearance of an additional carrageenan gel network. Sensory analysis shows that carrageenan presence has no significant effect on sausages taste. However, the sausage aspect and texture are markedly superior.

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