EVALUATING OF SOME FUNCTIONAL PROPERTIES OF THE MYOFIBRILLAR PROTEIN CONCENTRATE FROM THE BEEF HEART

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Abstract: We have analyzed from a chemical and functional point of view the myofibrillar protein concentrate obtained by repeatedly washing of the minced beef heart with a solution of phosphate buffer with/without added NaCl or antioxidants (PG – propyl gallate and BHA – butylhydroxyanisol) in cooled potable water. We determined the effect of washing solutions on the yield recovery of myofibrillar proteins, on their solubility in SDS (pH = 8.0) and in sodium chloride solutions 0.6 M (pH = 6) and on maintaining the stability of the myofibrillar protein concentrate of beef heart (MPCBH) during the refrigerated storage of the product. Moreover, the rheological properties of MPCBH were studied to prove the effect that the washing environment and temperature have on the shear flow behaviour.

Keywords: *beef heart, myofibrillar protein concentrate, antioxidants, rheological behaviour, apparent viscosity.*

INTRODUCTION

Besides carcasses, animal slaughtering also results in various alternate products, either fit for human consumption or not. In the meat industry, such by-products are often responsible for the increase in productivity of the specialized enterprises, sometimes raising the value of slaughter house products by up to 10%, varying upon the species of the animal. Edible by-products are internal organs (liver, lungs, tongue, heart, brain, timus, and spinal marrow), the actual by-products and fats. Due to their high nutritional value and wide range of colours and textures, organs are used directly in human diet and less utilized in various processed meat products where they only lend their specific flavour or characteristics. The heart represents 0.3–0.5% of the initial weight of the cattle. The heart tissue reflects the nature and function of the heart muscle and is generally viewed with caution by consumers and producers, being utilized in some summer salami recipes in order to obtain a deep red colour. The myofibrillar proteins of the heart tissue have a more limited functionality than the myofibrillar proteins from skeletal muscles. Myofibrillar proteins play a crucial role during meat processing; being responsible for the formation of heat induced cohesive structures and the firm textures of meat products [1]. Myofibrillar protein's functional behaviour is characterized by its ability to produce viscous gels through protein-on-protein interactions, to retain water and to form durable layers at the surface of fat globules in emulsions. By these functional properties, the tenderness, succulence and taste of processed meat products are ensured. To improve the functional properties of meats, producers use vegetal ingredients, especially soy protein derivatives. Consumers often claim that these additives are chemically enhanced or obtained from genetically modified plants. Consequently, the development of technologies to obtain functional ingredients and extracts from slaughterhouse sub-products is extremely timely [2 – 6]. Desmond [7] recommends the myofibrillar protein concentrate from beef heart tissue as a functional ingredient for making products processed from emulsion type meats (Frankfurt).
This study aims were to evaluate the effects that different washing solutions have on the MPCBH's chemical composition, colour, and behaviour to shear flow, gellification properties and oxidant stability in refrigerating conditions.

MATERIALS AND METHODS

Preparation of the myofibrillar protein concentrates from the beef heart tissue

The raw material consisting of 8 beef hearts was obtained from a local butchery within 24-36 hours after the animals were slaughtered. The hearts were immediately processed in order to eliminate the outer layer of fat, the connective tissue, the large blood vessels and any blood clogs. Afterwards, the heart muscle was cut into cubes with a 2–3 cm sides. Half of the resulting quantity was introduced in plastic bags (polyethylene), frozen at -15 °C and stored for 3 weeks while the other half was immediately processed in order to obtain the myofibrillar protein concentrate. The heart meat was chopped with the laboratory's electrical mincing machine through a sieve with 3 mm holes. The chopped meat was homogenized for 1 minute with iced tap water (1 : 5, w/v) in a Braun mixer at high speed. The resulting suspension was kept at +4 °C for an hour in order to

fully separate the sarcoplasmatic proteins, the water soluble substances and the fats from the meat. The separation of the washing liquids was done by centrifugation at 3200 rpm for 15 minutes at +4 °C. Afterwards, the supernatant was removed and the precipitate was collected and homogenized for 1 minute with iced tap water in proportion of 1 to 5. This process was repeated three times. Before the last centrifugal separation, the homogenate was passed through two layers of nylon cloth having a 1mm space between threads in order to retain the connective tissue from the slurry. The resulting connective tissue was washed three times with cooled water to recover any remaining myofibrils. After the last washing with cooled water, the precipitate was collected, mixed, weighed and separated into 4 parts. Each part was washed under different conditions: MPCBH-TP was washed in a solution of 25 mM phosphate buffer (NaH_2PO_4 / $NaHPO_4$), pH 6.0; MPCBH-PG was washed in a solution of phosphate buffer with 0.01% PG alcoholic solution as an antioxidant; MPCBH-BHA was washed in a solution of phosphate buffer with 0.1% BHA alcoholic solution as an antioxidant, while MPCBH-NaCl was washed in a solution of phosphate buffer with 0.25% NaCl. Each sample with its corresponding washing solution (1:5) was homogenized for 30 seconds, and the slurries were centrifuged for 20 minutes at 3200 rpm and +4 °C for an advanced dehydration. The pellet was collected, weighed and kept for further chemical analysis and study of their functional properties. Aliquot parts from the samples were kept in closed containers at +4 °C for 7 days in order to study the stability at oxidation of the myofibrillar protein concentrate from the beef heart.

Chemical analysis

The moisture, fat, proteins and the ash content of the heart meat and of the protein concentrates were determined according to the AOAC standard procedures [8].
The collagen content was determined according to the International Standard ISO 3496/1944: Meat and meat-products determination of hydroxyproline content.
pH measurements were made according to the AOAC procedures [9]: 10 g of the sample were homogenized for 2 minutes with 90 mL of distilled water in a laboratory blender; the mix was then filtered and its pH was determined with a digital Hanna pH-meter.

Myofibrillar protein solubility in sodium dodecyl sulphate (SDS)

In order to determine the proteins' solubility in SDS (2% Sodium dodecyl sulphate, 8 M urea, 20 mM β-mercaptoethanol; pH 8.0), 0.8 g samples from each type of myofibrillar protein concentrate were homogenized with 15 mL of SDS solution (pH = 8.0) using the Ultraturax agitator (10,000 rpm) for 3 minutes. The agitator was then washed with 10 mL of distilled water and the homogenized samples were transferred into closed glass containers which were kept for 24 hours at room temperature and occasionally stirred. After 24 hours, the samples were centrifuged for 20 minutes at 4000 rpm and, from the resulting supernatant the soluble proteins were determinate through the Lowry colorimetric method recommended by Ionescu et al [10] and through the micro-Kjeldahl method.

Preparation of the myofibrillar protein suspension

For a more advanced solubility of the myofibrillar proteins from the beef heart we used the 25 mM phosphate buffer with 0.6 M NaCl (pH = 6.0) as recommended by Xiong and Brekke [11]. 20 g of pellet were homogenized with 80 g of phosphate buffer for 3 minutes and at below 10 °C in a high rotation speed mixer. The protein suspensions were kept at 4 °C for 18 hours in order to ensure the maximum solubility of the myofibril proteins [12]. An aliquot part of the protein suspension was subjected to centrifugation for 20 minutes at 4200 rpm, 4 °C. The supernatant was collected, measured and used to determine soluble proteins in the phosphate buffer pH 6.0 with NaCl 0.6 M through the micro-Kjeldahl method.

Preparation of the protein gels

After having been left for 2 hours to reach room temperature, the protein suspensions were distributed into glass containers, closed and heat-treated in water in a dynamic regime, using a temperature raising rate of 1 °C/minute until reaching 70 °C at the thermal centre of the product. The samples thus treated were immediately cooled in ice until they reached 20 °C and they were stored overnight at 4 °C.

Weight losses during the heat-treatment and the water holding ability (WHA)

Weight losses during the heat-treatment were determined after a careful separation of the protein gel from the liquid formed during boiling. After wiping the released liquid using filter paper, the resulting gel was weighed. The weight yield after heat treatment (Y) is given by:

$$Y = \frac{w_s - w_g}{w_s} \cdot 100$$

where: w_S – weight of the protein suspension, g, w_g – weight of the gel, g.
In order to determine the capacity of protein gel to retain water, aliquot parts of the gel were placed on double layer filter papers in centrifugal tubes, weighed and centrifuged at 3000 rpm, for 10 minutes. Finally, the gel was carefully separated and weighed. The water holding ability (WHA) of the centrifugation gel is given by:

$$WHA = \frac{w_{g_0} - w_{g_1}}{w_{g_0}} \cdot 100$$

where: w_{g_0} - weight of the gel before centrifugation, g, w_{g1} - weight of the gel after centrifugation, g.

Shear rheology of the MPCBH

The viscous and elastic properties of the MPCBH have been evaluated using RHEOTEST-2 rotating viscometer based on concentric cylinders system, made by VEBMEDINGEN-Germany. The rheological behaviour of the MPCBH was examined with the cylinder rotation method using the coaxial cylinder S_3 device, which is accurate for a medium viscosity test. 50 g of the sample to be analyzed was introduced in the

external cylinder, and the working frequency was set at 50 Hz. The shear rate ($\dot{\gamma}$) varied between 0.1667 and 145.8 s^{-1}. By testing different shear rates, the corresponding values of α displayed on the device's grid were used to evaluate the shear tension, τ_r, with the relation:

$$\tau_r = z \cdot \alpha \text{, (Pa),}$$

where: z is the device's constant corresponding to the 1st or 2nd field of rates of the S_3 cylinder, while the apparent viscosity η, was given by:

$$\eta = \frac{\tau_r}{\dot{\gamma}} \cdot 100 \text{, (Pa·s).}$$

Fat oxidation measurements

The quantity of substances which react with the 2-thiobarbituric acid was considered a measure of the oxidation degree of fats [10].

Statistical analysis

Three experimental batches were realized for each kind of treatment. Statistical analysis, which consist in evaluating the mean values, standard error and standard deviation with the framing into the confidence interval of 95%, was performed using Sigma Plot 2001/Statistics Date software. Experimental data were fitted using Table Curve 2D software and the regression equations were established based on statistical criteria (r^2, Fit Standard Error or F Statistic).

RESULTS AND DISCUSSIONS

The chemical composition of the protein concentrates

Table 1 presents data referring to the approximate chemical composition of MPCBH. The presented values indicate an adequate recovery of the myofibrillar proteins with the laboratory equipment from the heart proteins (15.45%), the recovery yield being above 80%. At the same time was realized a superior removal of the fats from the heart meat. During the washing of the chopped heart meat, more than 94% of the fat of an adult sized heart (9.26%) was removed. McKeith et al [6] and James et al [13] have reported similar fat contents but without mentioning the initial fat content of the raw materials they used.

The washing cycles (5 washings) have also ensured the adequate removal of mineral salts, of sarcoplasmatic proteins and of extractable substances. The solutions used for the final washing have had little influence on the global composition of the moist myofibrillar protein concentrate of beef heart tissue. The PG, BHA and NaCl at the levels we are using have not influenced the water-holding ability at centrifugation as results from the comparison with the black sample (MPCBH-TP). Due to having added NaCl the ash content increased by 9.8% as compared to the black sample. By reducing the fat and ash levels, we have ensured an increase of the myofibrillar protein concentration in the moist product. The filtering through the double nylon layer enabled

the reduction of the collagen content down to levels between 0.53 and 0.59 mg%, slightly higher than the levels reported by James et al [13], the connective proteins being known to significantly diminish the meat's functionality and nutritive value. The protein concentrates displayed various beige nuances, the colour being slightly darker for the samples washed with a phosphate buffer with PG or BHA added.

Table 1. *Total chemical composition of the myofibrillar protein concentrate of beef heart*

Samples	Moisture, g%	Total proteins, g%	Fats, g%	Ash, g%	Collagen, mg%	Recovery yield, %
CPMIV-TP*	86.15 ± 0.45	12.83 ± 0.72	0.56 ± 0.08	0.51 ± 0.02	0.59 ± 0.32	83.0
CPMIV-NaCl	86.09 ± 0.38	12.76 ± 0.50	0.52 ± 0.12	0.56 ± 0.05	0.53 ± 0.45	82.6
CPMIV-PG	86.21 ± 0.47	12.74 ± 0.67	0.54 ± 0.05	0.53 ± 0.03	0.55 ± 0.29	82.5
CPMIV-BHA	86.24 ± 0.43	12.45 ± 0.19	0.60 ± 0.03	0.52 ± 0.04	0.57 ± 0.51	80.6

* - Control

The data represents the approximate values obtained from three different samples and their standard variations. 95% was considered the confidence interval. The values are duplicated for each sample.

The solubility of myofibrillar proteins in SDS and phosphate buffer with NaCl 0.6M

The Protein Solubility Index (PSI) for the myofibrillar protein concentrate of beef heart depends on the type of solvent used, on the pH and on the ionic strength of the solution. The refrigerated myofibrillar proteins of beef heart tissue showed a good solubility in SDS, the registered PSI values being over 85.5% in all cases.

The solubility of the myofibrillar protein concentrate of beef heart tissue in SDS (pH 8.0) was used by us in order to discover the influence that substances added to the final washing solution have on the myofibril proteins. The protein concentrate with the lower solubility was the one washed with a solution which contains BHA. This antioxidant seems to interact with the myofibrillar proteins by blocking some hydrophilic groups from the proteins and consequently reducing their solubility. The presence of a precipitate after centrifugation proves that myofibrillar protein-BHA complexes with great molecular mass have formed. The PG has determined a slight decrease of the myofibril proteins' solubility while the NaCl led to an increase of their solubility due to the hydrophilic nature of the NaCl and to the greater ionic strength of the washing solution.

Slowly freezing the heart and storing it at -15 °C for 3 weeks had determined modifications at the level of myofibrillar proteins which affected the solubility in SDS of the protein concentrates. The MPCBH's solubility in the SDS for the refrigerated samples has decreased by 3.92% from that of the black sample, by 3.94% from the NaCl sample, by 5.59% from the PG sample and by 6.38% from the BHA sample. As in the

case of processing the refrigerated heart, the propyl gallate and the butylhydroxyanisol have diminished the solubility of the myofibrillar proteins by comparison with the control sample but the denaturation of the proteins during freezing and storage state freeze were major factor which have influenced the solubility of the myofibrillar proteins. Xiong [11] mentioned that myofibrillar proteins are generally sensitive to the freezing process and to conditions of storage and their solubility decreases during long storage periods in such conditions.

The solubility of the myofibril protein concentrates of beef heart tissue in a saline solution of 0.6M and pH 6.0 was significant lower (table 2) compared to when a SDS was used but these conditions match the practical goals of utilizing the MPCBH as a functional ingredient in processed meat products. Solubilized myofibrillar proteins in saline solution are responsible for the heat induced gellification properties, for the stabilization of fats and water in finely chopped meat products and for cohesion between the meat pieces in restructured products based on salted meat [13].

Table 2. *The solubility of myofibrillar proteins in SDS and phosphate buffer with NaCl 0,6 M*

	Sample			
	CPMIV-TP (Control)	**CPMIV-NaCl**	**CPMIV-PG**	**CPMIV - BHA**
Refrigerated beef heart				
Soluble proteins in SDS, g%	11.25 ± 0.12	11.29 ± 0.21	10.99 ± 0.16	10.65 ± 0.25
PSI in SDS,%	87.69	88.48	86,26	85.54
Soluble protein in NaCl, g%	6.45 ± 0.45	6.59 ± 0.37	6.24 ± 0.76	6.00 ± 0.32
PSI in NaCl,%	50.25	51.65	48.97	48.21
Frozen beef heart, after 3 weeks storage at -15 °C				
Soluble proteins in SDS, g%	10.89 ± 0.11	10.99 ± 0.3	10.56 ± 1.1	10.18 ± 0.4
PSI in SDS,%	83.77	84.54	81.67	79.16
Soluble protein in NaCl, g%	6.34 ± 0.35	6.42 ± 0.28	5.95 ± 0.47	5.52 ± 0.23
PSI in NaCl,%	48.75	49.38	46.02	42.92

The solubility of the MPCBH in saline solution is a very important physical and chemical property which affects the functionality of the composing proteins (their capacity to bind and retain water, to swell, to become emulsions or gels); it is conditioned by the washing solution as well as by the freezing treatment of the heart. The utilized antioxidants (PG and BHA) have diminished the solubility of the myofibrillar proteins of beef heart tissue with 1.28%, and respectively with 2.04% by comparison with that of the sample washed with TP while the NaCl has determined an increase of the solubility by 1.4%. As to the frozen heart, the decrease of the solubility of proteins in the saline solution was more visible, because besides the antioxidant, the freezing has negatively influenced the structural proteins of the heart. The myofibrillar protein concentrate of beef heart tissue with the highest solubility in a saline solution was obtained when the raw materials was refrigerated heart tissue, processed not longer than 36 hours since the slaughtering of the animal.

The capacity to form gels

In the case of diluted protein systems as well as in the case of the ones supplemented with 0.2% xanthan (g/100 g proteins), the gels induced through heat treatment were generally weak, with synaergesis tendencies; this is why we decided to study the gel-forming capacity of undiluted myofibrillar protein concentrate of beef heart tissue. Generally, the utilized antioxidants have not affected the gellification properties of myofibrillar proteins but the resulting gels had different colours, with a grey tint for the samples washed with propyl gallate and light beige for the rest. The darkening of the colour is due to the presence of the PG in the sample as a result of its reaction with the iron ions from the residual pigments.
Lee and Lanier [15] mention that the three-dimensional protein matrix formed during the gellification of the surimi implies the participation of ionic, hydrogen, disulfide links and hydrophobic interactions. The forming of covalent and non-covalent links doesn't seem to be influenced by the presence of antioxidants, the gels' resistance to compression and their capacity to retain water during centrifugation being similar for all protein concentrates from the heart. From the myofibrillar proteins, the myosin is the main one soluble in saline solutions with an ionic strength greater than 0.3, which, through heat induced denaturation, leads to the gel three-dimensional matrix [16, 17]. Wang and Smith [18] have noted that the heat induced denaturation of the myosin from the poultry breast occurs between 39 – 67 °C.

Cooking yield and protein loss at heating

Cooking yield presented significant differences between the MPCBH samples due to the washing environment (figure 1). The greatest losses due to the heat treatment in dynamic regime were recorded for the myofibrillar protein concentrate that was washed with phosphate buffer with NaCl added, possibly because of the more advanced solubility of some myofibrillar proteins which were not part of the gel's matrix. The juices formed during the forming of gels contained different levels of soluble proteins: 1.94 g/100 g of proteins at MPCBH-NaCl; 1.53 g/100 g of proteins at MPCBH-TP and 1.84 g/100 g of proteins at MPCBH-PG (figure 2). Actin, troponin I and light meromyosin have weaker gellification properties and are usually found in the supernatant dropped out from the gel's structure at cooking or at centrifugation [19, 20].

Water holding ability of gels

No significant differences were noticed between the water-holding ability during centrifugation of gels based on MPCBH-NaCl (13.24%), MPCBH-BHA (13.31%) and MPCBH-PG (13.24%). The black sample MPCBH-TP registered the greatest water loss at centrifugation (14.15%).

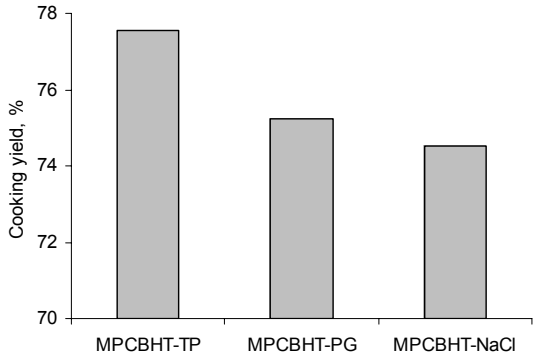

Figure 1. *Influence of washing environment on cooking yield*

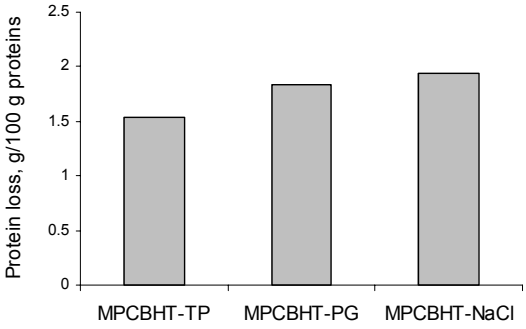

Figure 2. *Influence of washing environment on protein loss at heat treatment*

MPCBH's stability when stored in refrigeration

Three hours after preparation, the myofibrillar protein concentrates of beef heart tissue presented a high content of various substances capable of reacting with the 2-thiobarbituric acid (TBARS), depending on the washing environment used. The smallest values were found in MPCBH-PG and MPCBH-BHA which suggests that fat and protein oxidation during the preparation of the samples was inhibited by antioxidant treatments [4]. During storage at 4 ^{0}C we noticed a varied and constant increase of the number TBA depending on the washing solution utilized. For samples washed only with phosphate buffer the TBA number increased by 6.5 times, by 5.2 times for the ones washed with MPCBH-NaCl, by 3.94 times for MPCBH-BHA and by 3.60 times for MPCBH-PG, proving the inhibitive effect of the antioxidants. The NaCl at the level utilized by us did not function as a prooxidant for the remaining lipids from the myofibrillar protein concentrate of beef heart tissue. Osinchack et al [21] indicated concentrations higher than 0.6 M should make the NaCl function as prooxidant. The PG ensured the best protection against lipids oxidation. It is possible that the remaining iron from our systems to have a role in lipids oxidation.
TBA values higher than 1.0 mg MDA/kg (MDA- malondialdehyde) correlate with the development of the sensorial characteristics which define the rancid taste and smell.

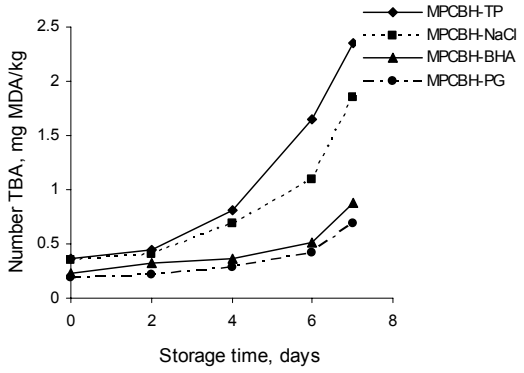

Figure 3. *Variation number TBA during storage refrigeration of MPCBH's*

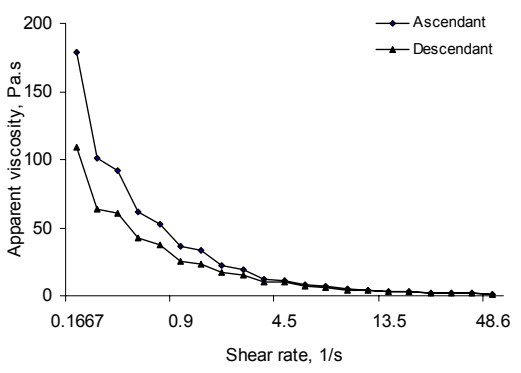

Figure 4. *Rheograms: Apparent viscosity-shear rate for MPCBH-TP*

The rheology of the myofibrillar protein concentrates of beef heart tissue

The rheology of the shear flow of the MPCBH is of practical interest during transportation by pumps, mixing and extrusion operations to which the raw paste can be submitted [22]. Through rheological measurements we have determined the shear tension and the apparent viscosity of the beef surimi paste covering all range shear rate between 0.1667 – 145.8 s^{-1}. The shear flow rheograms were obtained by graphically transposing the experimental data obtained concerning the apparent viscosity's dependence on the shear rate. All regression equations of rheogram were compliant with simple mathematical patterns: the Herschel-Bulkley patterns and the Rank Eqn 78 (Casson) mathematical one, the regression coefficients being, generally, higher than 0.99. The resulting nonlinear regression equations led to determining the rheological parameters of the myofibrillar protein concentrate: the consistency coefficient (b); the index of flow behaviour (c) and the threshold tension (a); the two consecutive equations which were utilized shared the b and a parameters. According to the charts from figures 4 – 6, the raw MPCBH, without any added cryoprotective substances, has a non-newtonian shear flow behaviour, pseudo plastic at shear melting ($c < 1$). All samples behaved as thixotropic fluids which in time have suffered a decrease of viscosity when they were submitted to a constant shearing force, because of the progressive degradation during shearing of the components' structure. The restructuring process for the MPCBH was not completed which explains why the ascending and the descending rheograms are not similar. The descending rheograms were smoother are more uniform but they presented values below those of the ascending rheograms. Our results confirm those of Bouraoui [22] concerning the viscous properties of the raw paste of surimi salmon.
The apparent viscosity/shear rate rheograms were little influenced by the washing solution utilized (figure 7). The measurements were taken at 4 ˚C.

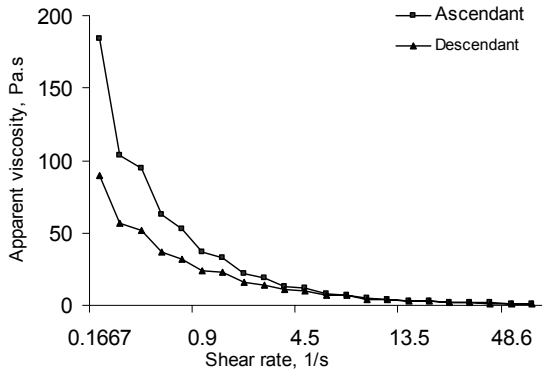

Figure 5. *Rheograms: Apparent viscosity-shear rate for MPCBH-NaCl*

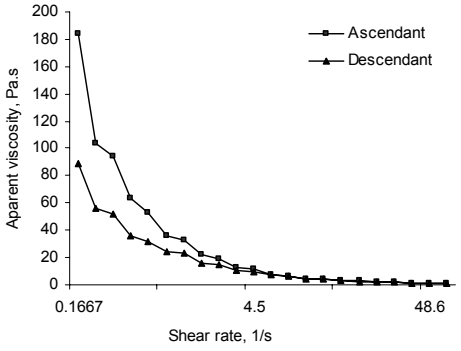

Figure 6. *Rheograms: Apparent viscosity-shear rate for MPCBH-PG*

The temperature's influence

The protein concentrate washed in the final stage with only phosphate buffer (MPCBH-TP) was studied for the effects of the measuring temperature (4, 15 and 22 °C) on the shear flow behaviour of the myofibrillar protein concentrate of beef heart tissue in the form of raw paste. The rheograms from (figure 8) indicate the decrease of the apparent viscosity with the increase of the shear rate and of the temperature of the paste from 4 °C to 22 °C. At a temperature of 22 °C, the raw paste of MPCBH had the best fluidity but for reasons of food safety the temperatures presently used for processing meat is below 10 °C. The MPCBH-TP at a higher temperature had a smaller resistance to shear flow due to the decrease of the intensity of the inner friction at the movement between adjacent particles, fact which explains the decrease in apparent viscosity at 22 °C. Our results match those obtained by Wu et al [23] who have found that the viscosity of the actomyosin solution from fish decreases with the increase in temperature up to 31 °C; our results however differ from those obtained by Bouraoui et al [22] who have used in their experimentation surimi with added salt and starch. Starch is known as a poliglucide with a dilatation pseudoplastic shear flow behaviour.

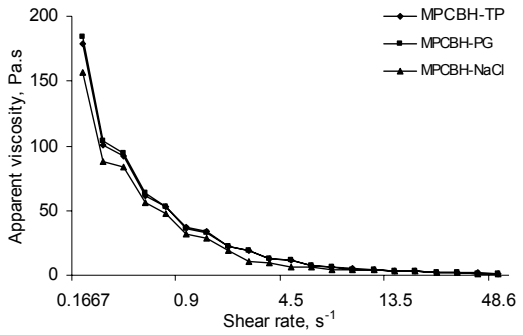

Figure 7. *Influence of washing environment on ascendant rheograms: Apparent viscosity/shear rate*

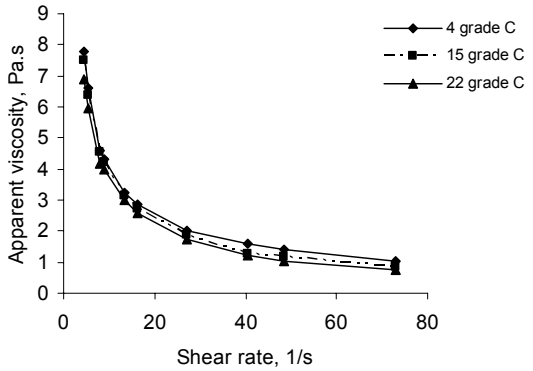

Figure 8. *Rheograms: Apparent viscosity-shear rate function temperature (CPMBH-TP)*

Table 3 describes the rheological parameters for the myofibrillar protein concentrates of beef heart tissue depending on the washing environment and on the temperature at which the shear flow behaviour was studied. The quantification of the threshold tension is necessary in practice to establish if the pump is strong enough to make fluid flow. The consistency coefficient decreased with temperature's rise from 4 to 22°C.

CONCLUSIONS

Adding antioxidants (BHA and PG) or NaCl to the final washing solution (phosphate buffer, pH = 6.0) did not influence the yield of recovering heart proteins or the chemical composition of the myofibrillar protein concentrate of beef heart tissue.
BHA and PG have led to the diminution of the solubility of myofibrillar proteins from the heart muscle in a saline solution of NaCl 0.6 M and of the response to heat

treatment; however, it did not affect the gellification properties and the water loss at centrifugation of the gel. The propyl gallate determined the change of colour of the heat induced gel.

Table 3. *Rheological parameters of ascendant rheograms*

Samples	Temp., °C	Threshold tension (a), Pa	b	c	r^2	Shear rate, s^{-1}
Mathematic model Herschel –Bukley: $y=a+bx^c$						
CPMIV-TP	4	0.639	31.93	-0.975	0.9999	0.1667 ÷ 48.6
CPMIV-TP	15	0.529	26.69	-0.951	0.9998	
CPMIV-TP	22	0.954	22.99	-0.954	0.9999	
CPMIV-PG	4	0.627	31.94	-0.975	0.9999	
CPMIV-NaCl	4	0.412	28.56	-0.948	0.9997	
Mathematical model Casson: $y^{0,5}=a + b/x^{0,5}$						
CPMIV-TP	4	0.296	5.42	-	0.9999	0.1667 ÷ 48.6
CPMIV-TP	15	0.429	4.97	-	0.9998	
CPMIV-TP	22	0.359	4.56	-	0.9999	
CPMIV-PG	4	0.419	4.91	-	0.9996	
CPMIV-NaCl	4	0.297	5.42	-	0.9999	

The PG and BHA have protected the protein concentrates derived from the beef heart against the oxidation of the remaining lipids during storage at 4 °C. The refrigeration interval of the MPCBH without the oxidation of lipids is of 4 days at the most.
Rheological analysis has underlined the pseudoplastic behaviour of the moist protein concentrates; they are non-newtonian fluids with a flow threshold and structural viscosity.
The myofibril protein concentrate of beef heart tissue can be a valuable ingredient for the production of meat pates and emulsion-type sausages, as it can improve their texture and the nutritive value.

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