POLISH JOURNAL OF FOOD AND NUTRITION SCIENCES
Pol. J. Food Nutr. Sci. 2003, Vol. 12/53, No 4, pp. 51–54

THE EFFECT OF CARRAGEENANS ON THE TEXTURE OF LOW-FAT BREAKFAST SAUSAGES*

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Key words: functional food additives, carrageenan, texture parameters, low-fat products

Model pork-beef sausages constituted the experimental material. The following parameters of their texture were determined by means of a texture analyzer TA-XT2i: hardness I [N], hardness II [N], adhesion, cohesion, elasticity, gumminess, chewiness. Fat replacement with water and carrageenan resulted in an increase in hardness, elasticity and gumminess, compared with the control samples. Carrageenan G-WG (fraction kappa 1) as well Carrageenan kappa II (A-MR and H-KMR) had the best effect on the texture of low-fat breakfast sausages. Reduction of fat content to 25% and 15% with water and carrageenan significantly increased the quality of low-fat breakfast sausages.

INTRODUCTION

Hydrocolloids constitute an important group of functional additives characterized by texture-forming and stabilizing properties, used in the production of low-calorie food. Carrageenans hold a special position among the hydro-colloids applied in meat processing. Their thickening and gelling properties allow to modify, to a high degree, the rheological properties of meat products [Trius & Sebranek, 1996]. The main factor limiting the production of low-fat products is their consistency, which should be identical, or at least similar, to the consistency of traditional products. This is connected with the fact that, according to consumers, low-fat products are less juicy, too dry, and characterized by tough, firm and gum-like texture [Berry, 1992; Troutt *et al.*, 1992; Lin & Keeton, 1998; Shand, 2000] Many authors report that kappa and iota carrageenan improves the texture of low-fat meat products, as these fractions can form complexes with water and proteins [Mittal & Barbut, 1994; Cofrades *et al.*, 2000]. Among many hydrocolloids investigated and described in professional literature, carrageenans turned out to be especially effective in the production of low-fat meat products, which is confirmed by the results of numerous studies [Mittal & Barbut, 1993, 1996; Trius & Sebranek, 1996]. The aim of the studies was to determine the effect of various types of carrageenans on the texture parameters of low-fat breakfast sausages.

MATERIAL AND METHODS

Model pork-beef breakfast sausages containing 25% and 15% of fat constituted the experimental material. Their fat content was reduced by replacing part of the fat with carrageenan and water. Various types of carrageenan were added to low-fat stuffing, *i.e.* G-WG – fraction kappa I, G-MR – fraction kappa II, obtained as a result of the process "Gell press", A-PI – fraction iota, A-MR – fraction kappa II, obtained as a result of an alcohol process, H-KMR – fraction kappa II, obtained as a result of a heterogenous process, A-KI – fraction kappa-iota-lambda. Four variants of breakfast sausages, *i.e.* I a, I b, II a, II b, were produced for each carrageenan type. They differed in the fat content (variants I – 25%, variants II – 15%) and in the amount of carrageenan added (variants a and b). In variants II a and II b, the carrageenan content was 0.5% and 0.7% respectively, whereas in variants I a and I b – 0.40% and 0.56% respectively, in relation to meat, fat and water. The carrageenan concentration in low-fat sausages did not exceed the level permissible in Poland. The ratios between carrageenan and water in variants I a – I ia and I b – I ib were equal. Two control variants of breakfast sausages contained no carrageenan. The stuffing for the production of fine-ground model sausages was prepared from class I pork (shoulder), class I beef (ham), and fine pork fat (Table 1).

TABLE 1. Composition of model fine-ground breakfast sausages.

Variant	$K_{25\%}$	I a	I b	$K_{15\%}$	II a	II b
Class I pork	25	25	25	25	25	25
Class I beef	9	9	9	9	9	9
Fine pork fat	25	25	25	15	15	15
Water/ice	41	41	41	51	51	51
Total	100	100	100	100	100	100
	Seasonings, spices and additives					
Corning mixture	1.8	1.8	1.8	1.8	1.8	1.8
Pepper	0.08	0.08	0.08	0.08	0.08	0.08
Nutmeg	0.04	0.04	0.04	0.04	0.04	0.04
Sugar	0.2	0.2	0.2	0.2	0.2	0.2

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The meat and fat were ground in a meat grinder with 3 mm meshes. Then the raw material was cut by means of a mechanical cutter, and water, ice, corning salt, spices and carrageenan were added (depending on the variant). The cutting process lasted for 10 min and the temperature of the stuffing did not exceed 12°C. Meat prepared this way was stuffed into casings (20 mm in diameter), smoked at a temperature of 62°C and parboiled until a temperature of 68°C was achieved inside the tube. A texture profile analysis (TPA) was made on the model sausages by the method of double compression, using a texture analyzer TA-XT2i (load cell = 25 kg; Stable Micro Systems), coupled with a PC, software TEXTURE EXPERT EXCEED [Bourne, 1978; Szczęśniak, 1990]. Cylindrical sausage samples (13×10 mm) were subjected to double compression, to 50% of their height, using a piston 75 mm in diameter, at the head velocity of 5 mm/s. The following texture parameters were determined: hardness I [N], hardness II [N], adhesion [N·s], cohesion, elasticity, gumminess, and chewiness. The results were analyzed statistically. The mean values were compared by the Duncan test. The calculations were done applying a computer program STATISTICA 6.0 PL. [StatSoft Inc., 2001].

RESULTS AND DISCUSSION

The texture profile of breakfast sausages containing 25% of fat was analyzed in the first place. Hardness I of the control sample ($K_{25\%}$) with a 25% fat content was 1.88 N (Table 2). All sausages containing carrageenan, regardless of its type and level, were characterized by significantly higher values of hardness I than the control sample ($K_{25\%}$). An exception was only a sausage with 0.56% of carrageenan A-MR (2.43 N) (variant I b), which did not differ much from the control sample as regards hardness I. The highest level of hardness I (5.30 N) was observed in a sausage with a 0.56% addition of carrageenan G-WG (variant I b). It was also high (4.91 N) in the case of a sausage containing 0.56% of carrageenan H-KMR (variant I b) (Table 2).

The values of hardness II were slightly lower than the values of hardness I in all variants of sausages with 25% of fat. Again, its highest level (3.56 N) was noted in a sausage with carrageenan G-WG (variant I b). Sausages containing carrageenan A-MR were characterized by the lowest levels of hardness II (2.24 N in variant I a and 2.32 N in variant I b) (Table 2).

The adhesion of the control sample with a 25% fat content was 0.14 N·s (Table 3). In breakfast sausages containing carrageenan, the values of adhesion varied from 0.06 to 0.14 N·s. A significant decrease in adhesion (to 0.06 N·s), compared with the control sample ($K_{25\%}$), was observed in a sausage with a 0.56% addition of carrageenan H-KMR (variant I b), whereas its considerable increase (to 0.21 N·s) – in a sausage with 0.40% of carrageenan A-PI (variant I a) (Table 2). No significant differences concerning adhesion were noted between the control sample ($K_{25\%}$) and the other sausage variants (Table 2).

The level of elasticity was by *ca.* two times higher in all breakfast sausages containing carrageenan than in the control sample ($K_{25\%}$) (Table 2). Its highest values were noted in sausages with a 0.40% addition of carrageenan A-PI (0.95 unit) and H-KMR (0.99 unit – variant I a; 0.95 unit – variant I b). There were no statistically significant differences in the elasticity of the other variants of sausages containing carrageenan (Table 2).

The cohesion of the experimental sausages ranged from 0.29 unit to 0.40 unit (Table 2). No statistically significant differences were observed in this parameter between the control sample and sausages containing carrageenan. Exceptions were here only sausages with a 0.40% addition of carrageenan A-PI (variant I a) – an increase in cohesion to 0.40 unit, and with carrageenan A-MR (variant I b) – a decrease to 0.29 unit (Table 2).

The gumminess of the control sample with a 25% fat content was 0.74 unit (Table 2). Sausages containing carrageenan were characterized by higher values of this parameters. Its highest level was noted in sausages with a 0.56% addition of carrageenan G-MR (2.14) and G-WG (variant I b) (Table 2). The gumminess of experimental sausages containing 0.40% of carrageenan G-MR (1.03 units) and A-MR (1.07 units) (variant I a), and 0.54% of carrageenan A-MR (variant I b) did not differ

TABLE 2. Values of TPA of breakfast sausages containing 25% of fat, depending on the type and level of carrageenan.

Variant	Sample/ carrageenan	Parameters of TPA													
		Hardness I [N]		Hardness II [N]		Adhesion [N·s]		Elasticity		Cohesion		Gumminess		Chewiness	
		X	V [%]	X	V [%]	X	V [%]	X	V [%]	X	V [%]	X	V [%]	X	V [%]
	K_{25}	1.88^{a}	2.12	1.68^{a}	14.67	0.14^{a}	10.36	0.44^{a}	2.86	0.36^{adf}	6.51	0.74^{a}	17.40	0.34^{a}	16.19
I a	G-WG	4.62^{be}	18.26	3.06^{bd}	14.09	0.14^{a}	9.69	0.77^{bd}	12.71	0.36^{adf}	15.73	1.67^{bc}	28.61	1.66^{be}	25.93
	G-MR	3.13^{cd}	18.26	2.26^{c}	15.65	0.14^{a}	18.54	0.69^{b}	20.99	0.33^{ag}	7.22	1.03^{a}	20.49	0.73^{ad}	33.38
	A-PI	4.42^{be}	23.66	2.87^{bef}	15.10	0.21^{b}	22.19	0.95^{ce}	19.53	0.40^{be}	3.93	1.80^{b}	24.26	2.01^{be}	26.90
	A-MR	3.67^{bc}	17.43	2.24^{c}	14.67	0.15^{a}	6.83	0.88^{de}	7.48	0.33^{adg}	8.99	1.19^{ac}	23.41	1.07^{cd}	30.57
	H-KMR	4.88^{eg}	17.76	2.61^{bc}	13.42	0.14^{a}	2.70	0.99^{ce}	15.26	0.35^{adf}	2.70	1.67^{bc}	16.21	1.75^{be}	25.40
I b	G-WG	5.30^{ef}	21.68	3.56^{d}	20.13	0.15^{a}	12.46	0.84^{bc}	21.11	0.36^{adf}	10.42	1.93^{b}	37.72	2.14^{b}	25.95
	G-MR	4.62^{be}	26.67	3.33^{de}	26.78	0.14^{a}	10.02	0.70^{b}	19.07	0.34^{dg}	1.63	2.14^{b}	32.54	1.57^{e}	30.88
	A-PI	4.43^{be}	26.43	2.98^{be}	23.06	0.16^{a}	11.62	0.86^{cd}	18.86	0.39^{ef}	5.40	1.67^{b}	26.18	1.68^{be}	34.71
	A-MR	2.43^{ad}	10.24	2.32^{cf}	25.06	0.15^{a}	4.59	0.86^{de}	18.04	0.29^{c}	5.17	1.07^{a}	29.80	1.62^{be}	12.61
	H-KMR	4.19^{bfg}	19.13	2.95^{be}	16.87	0.06^{c}	27.80	0.95^{ce}	15.99	0.34^{ad}	13.01	1.74^{b}	24.08	1.94^{be}	17.82

a–f – mean values denoted in columns by different letters differ statistically significantly ($\alpha = 0.05$); G-WG – fraction kappa I, G-MR – fraction kappa II obtained by "Gell press" process, A-PI – fraction jota, A-MR – fraction kappa II obtained by alcohol process, H-KMR – fraction kappa II obtained by heterogeneous process, A-KI – fraction kappa-jota-lambda.

significantly from the gumminess of the control sample (Table 2).

The chewiness of the sausages examined varied from 0.34 unit in the control sample to 2.14 units in a sausage with a 0.56% addition of carrageenan G-WG (variant I b) (Table 2). A high level of chewiness (2.01 units) was noted in a sausage containing 0.40% of carrageenan A-PI (variant I a). No considerable chewiness changes, in relation to the control sample, were observed in a sausage with a 0.40% addition of carrageenan G-MR (variant I a) (Table 2).

The texture profile of sausages with a 15% fat content was also analyzed. A part of the fat was replaced with water and carrageenan (Table 3).

Hardness I of the control sample containing 15% of fat was 1.33 N. All sausages containing carrageenan, regardless of its type, were characterized by higher values of hardness I than the control sample ($K_{15\%}$). The highest level of hardness I (8.11 N) was observed in a sausage with a 0.7% addition of carrageenan G-WG, and the lowest – in a sausage with a 0.5% addition of carrageenan A-PI (variant II a) (Table 3). The values of hardness II in sausages containing 0.5% of carrageenan A-PI (1.90 N) and G-MR (2.29 N), and 0.7% of carrageenan A-PI did not differ significantly from its values determined for the control sample.

Hardness II of sausages containing carrageenan varied from 1.72 N in a sausage with a 0.5% addition of carrageenan G-MR to 5.16 N in a sausage with a 0.7% addition of carrageenan G-WG (Table 3). There were no significant differences in hardness II between the control sample and sausages containing 0.5% of carrageenan A-PI (1.44 N), A-MR (1.68 N) and G-MR (1.72 N), and 0.7% of carrageenan A-PI (variant II b) (Table 3).

All sausages containing carrageenan, irrespective of its type and level, were characterized by significantly higher (by *ca.* 10 N·s) values of adhesion than the control sample ($K_{25\%}$) (Table 3). It should be emphasized that the experimental sausages did not differ considerably from one another as regards this parameter.

No significant elasticity changes, in relation to the control sample ($K_{25\%}$), were observed in sausages with a 0.5% addition of carrageenans G-MR (0.70 N·s) and A-PI (0.73 N·s), and with a 0.7% addition of carrageenan G-MR (0.66 unit) (Table 3).

Another parameter analyzed in the studies was cohesion (Table 3). Its value in the control sample ($K_{25\%}$) was 0.37 unit. There were no significant differences concerning elasticity between the control sample and sausages containing carrageenan G-WG, A-PI and H-KMR (irrespective of its level). A considerable decrease in elasticity was noted in sausages with 0.5% and 0.7% of carrageenan G-MR and A-MR, compared with the control sample (Table 3).

The gumminess of sausages with a 15% fat content ranged from 0.49 unit in the control sample to 3.59 units in a sausage containing 0.7% of carrageenan G-WG (variant II b) (Table 3). It should be stressed that the highest level of gumminess was observed in sausages with carrageenans forming the hardest gels. The gumminess of a sausage with a 0.5% addition of carrageenan G-WG was 2.47 units, and with a 0.7% addition of carrageenan H-KMR – 1.32 units. Its values noted for sausages containing 0.5% of carrageenan A-PI and A-MR were very similar (0.78 unit and 0.76 unit, respectively). Generally, all sausages containing carrageenan were characterized by higher values of gumminess than the control sample (Table 3).

The chewiness of the control sample with a 15% fat content was 0.27 unit (Table 3). A 0.5% addition of carrageenan G-MR and A-MR (variant II a) had no significant effect on the values of this parameter. Its highest level was observed in sausages with carrageenan G-WG (2.38 units – variant II a and 3.13 units – variant II b), and the lowest – in sausages with carrageenan A-PI (Table 3).

CONCLUSIONS

1. Carrageenan G-WG caused a significant improvement in the texture parameters of fine-ground low-fat breakfast sausages, mainly hardness I, gumminess and chewiness.

2. It was found that carrageenans forming hard gels (G-WG, G-MR, H-KMR) affect considerably sausage hardness.

TABLE 3. Values of TPA of breakfast sausages containing 15% of fat, depending on the type and level of carrageenan.

Variant	Sample/ carrageenan	Parameters of TPA													
		Hardness I [N]		Hardness II [N]		Adhesion [N·s]		Elasticity		Cohesion		Gumminess		Chewiness	
		X	V [%]	X	V [%]	X	V [%]	X	V [%]	X	V [%]	X	V [%]	X	V [%]
	K_{25}	1.33^{ac}	11.73	1.03^{a}	10.40	0.03^{b}	15.23	0.56^{a}	0.59	0.37^{a}	2.20	0.49^{a}	10.01	0.27^{a}	9.61
I a	G-WG	5.81^{b}	30.98	3.66^{b}	20.95	0.15^{acd}	5.31	0.87^{b}	17.83	0.35^{ab}	7.63	2.47^{b}	12.34	2.38^{b}	17.93
	G-MR	2.29^{cd}	27.15	1.72^{cg}	24.52	0.14^{acd}	3.37	0.70^{a}	23.88	0.30^{c}	6.76	0.68^{ac}	20.91	0.53^{ac}	34.93
	A-PI	1.90^{ce}	17.84	1.44^{ac}	19.25	0.12^{a}	8.38	0.73^{b}	8.84	0.36^{a}	11.24	0.78^{cd}	16.77	0.58^{c}	13.24
	A-MR	2.60^{de}	21.81	1.68^{cf}	14.50	0.14^{acd}	7.97	0.84^{b}	8.70	0.29^{cd}	6.09	0.76^{ce}	22.90	0.65^{c}	25.76
	H-KMR	3.35^{df}	5.84	2.31^{dg}	13.94	0.13^{ad}	7.06	0.96^{e}	16.32	0.34^{ae}	6.34	1.08^{f}h	3.72	1.08^{df}	10.13
I b	G-WG	8.11^{g}	16.95	5.16^{e}	19.23	0.16^{c}	11.43	0.82^{b}	10.71	0.37^{a}	19.37	3.59^{g}	9.82	3.13^{e}	14.65
	G-MR	3.09^{df}	24.03	2.04^{dg}	20.47	0.14^{acd}	3.30	0.66^{a}	23.53	0.29^{cd}	4.25	0.95^{def}	20.39	0.70^{c}	32.13
	A-PI	2.62^{de}	14.77	1.78^{cd}	13.34	0.13^{acd}	3.46	0.97^{e}	14.38	0.37^{a}	8.17	0.94^{def}	19.13	0.99^{d}	13.92
	A-MR	3.97^{f}	23.39	2.21^{dfg}	13.64	0.14^{acd}	14.80	0.88^{b}	17.39	0.30^{c}	2.49	1.17^{f}h	23.30	1.24^{df}	21.41
	H-KMR	3.78^{f}	23.05	2.33^{d}	20.62	0.13^{ad}	28.57	0.96^{e}	18.22	0.31^{bcde}	6.80	1.32h	8.89	1.34^{f}	10.69

a–f – mean values denoted in columns by different letters differ statistically significantly ($\alpha = 0.05$); G-WG – fraction kappa I, G-MR – fraction kappa II obtained by „Gell press" process, A-PI – fraction jota, A-MR – fraction kappa II obtained by alcohol process, H-KMR – fraction kappa II obtained by heterogeneous process, A-KI – fraction kappa-jota-lambda.

3. Carrageenan A-PI, forming gels characterized by low hardness, causes a significant increase in sausage hardness.

4. Carrageenans may be used as fat replacers in fine--ground sausages, improving their textural and water-holding properties.

* Paper presented on the IX Scientific Conference "Better Food", 27 June 2002, Olsztyn, Poland, organised by the University of Warmia and Mazury in Olsztyn.

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Received May 2002. Revision received July 2002 and accepted February 2003

WPŁYW KARAGENÓW NA TEKSTURĘ PARÓWEK O OBNIŻONEJ ZAWARTOŚCI TŁUSZCZU

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Celem pracy było określenie wpływu różnych typów karagenów na teksturę parówek o obniżonej zawartości tłuszczu. Materiałem doświadczalnym były modelowe parówki wieprzowo-wołowe. Za pomocą analizatora tekstury TA-XT2i określono następujące parametry tekstury kiełbas: twardość I [N], twardość II [N], adhezyjność, kohezyjność, sprężystość, gumowatość, podatność na żucie. Zastąpienie tłuszczu w składzie recepturowym parówek wodą i karagenem, spowodowało wzrost twardości, sprężystości, oraz gumowatości w porównaniu z próbkami kontrolnymi. Spośród typów karagenów zastosowanych jako zamiennik tłuszczu w parówkach najlepsze właściwości funkcjonalne wykazują karageny kappa I (G-WG), oraz kappa II (A-MR i H-KMR). Obniżenie zawartości tłuszczu w parówkach do poziomu 25% lub 15% i wprowadzenie w jego miejsce roztworu karagenu kappa I powoduje istotne polepszenie cech jakościowych wyrobu gotowego (tab. 2 i 3).