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High pressure processing applied to cooked sausage manufacture: physical properties and sensory analysis

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Abstract

Vacuum-packaged cooked sausages were treated at 500 MPa for 5 or 15 min at mild temperature (65 °C). Colour, texture and yield of pressure-treated sausages were evaluated, and compared to those of sausages treated with a conventional heat pasteurisation (80–85 °C for 40 min). Colour attributes did not change. Pressurised sausages were more cohesive and less firm than heat-treated sausages. Pressure treatment induced higher yield than heat treatment. Sensory analysis was also carried out. In some cases, the sensory panel did not detect differences between both types of sausages; and when there were differences, pressurised samples were preferred in more occasions because of their better appearance, taste and, especially, texture. High pressure processing can replace the second industrial heat treatment of cooked sausages.

Keywords: Cooked sausages; High pressure processing; Colour; Texture; Sensory analysis; Yield

1. Introduction

In recent years, there is a growing demand for poultry and poultry products. Furthermore, people require products that are safe, nutritious, convenient, rich in variety, attractive (in appearance, texture, odour and taste) and innovative. This stimulates the research into technologies that are alternative to conventional heat processing, to manufacture foods with such characteristics. Now, poultry industry is particularly interested in evaluating the challenge of any new technology.

One of these technologies is high pressure processing, which, besides improving the microbiological quality of foods and beverages, modifies positively some functional and organoleptic properties, and so allows to obtain different food products (Cheftel & Culioli, 1997). In comminuted and emulsified meat and poultry products, high pressure increases the binding among particles and protein solubilisation in saline solution (Macfarlane, 1974; Macfarlane, McKenzie, Turner, & Jones, 1984). Gels induced with pressure treatment at low or room temperatures usually have better appearance and texture, greater homogeneity, and less exudation than heat-set gels (Okamoto, Kawamura, & Hayashi, 1990; Tauscher, 1995; Yoshioka, Kage, & Omura 1992). In some cases, pressurisation enhances heat gelation ability of meat batters. Furthermore, it does not destabilise oil-in-water meat emulsions (Mandava, Fernandez, & Juillerat, 1994). High pressure is especially appropriate for foods and beverages with attributes and properties that are extensively changed by heat.

Some cooked meat and poultry products are handled after cooking, for example, when removing the casing of emulsion-type sausages and portioning or slicing other products. In consequence, further microbiota, mainly coming from handlers, utensils and equipment, is transferred to the product. Heat pasteurisation after vacuum packaging is the most usual process carried out to inactivate the recontaminating microbiota and so guarantee a proper preservation. But this treatment implies the use of expensive heat-resistant packages, and also induces large formation of exudate rich in connective tissue proteins, which results in yield decrease.

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In a previous study (Yuste, Pla, Capellas, Ponce, & Mor-Mur, 2000), pressurisation at mild temperature proved to be a valid technology to pasteurise cooked sausages, in substitution of heat treatment. But research into other aspects is necessary to corroborate the effectiveness of pressure treatment. Thus, pressurisation should not affect or affect positively organoleptic properties, an essential point for consumer acceptance, and yield, a very important economic issue for manufacturers of cooked meat and poultry products.

In this work, high pressure processing at mild temperature (65 °C) was applied to cooked sausages. The objective was to investigate the effect of pressure treatment on organoleptic characteristics, by means of instrumental (colour and texture) and sensory analysis, and on yield, to evaluate the challenge of pressurisation to replace the second industrial heat treatment of cooked sausages.

2. Materials and methods

2.1. Experimental procedure, sample and physicochemical analysis

Preparation and processing of cooked sausages were as described by Yuste et al. (2000). The AOAC official methods of analysis (McNeal, 1990) were applied to determine sausage composition. After industrial cooking and vacuum packaging, one group of sausages remained untreated, one was treated with a conventional heat pasteurisation (80–85 °C for 40 min), and the other two were pressurised at 500 MPa for 5 and 15 min at 65 °C. The experiment was performed twice (with two different batches of sausages).

2.2. High pressure treatment

The equipment used was a discontinuous isostatic press (ALSTOM, Nantes, France). The time needed to achieve the treatment pressure was approx. 120 s and the decompression time was approx. 30 s. The pressure chamber (22 cm height, 10 cm diameter) and the water inside were held at the appropriate temperature, monitored with a thermocouple, by circulating hot water through a coil. Sausage packages were allowed to reach the treatment temperature in this chamber before pressurisation. After processing, they were cooled in running tap water for 30 s.

2.3. Instrumental colour analysis

A portable HunterLab spectrocolorimeter, model 45/0 LAV (Hunter Associates Laboratory, Reston, VA) was used to evaluate three colour scale indices: L (lightness), a (redness) and b (yellowness) values; and the total colour difference (between untreated and treated samples), $\Delta E = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2}$. The spectrocolorimeter was standardised before starting, by using, in this order, a black glass and a white porcelain calibrated tile. For each treatment, six cylindrical replicates (4 cm length) at room temperature were longitudinally cut to analyse internal colour of sausages. Measurements were done with reference to illuminant Fcw (cool white fluorescent) and the 10° standard observer. The light reached the internal sides of sausages through a nonreflecting glass container in which samples had been slightly compressed and flatenned.

2.4. Instrumental texture analysis

A Texture Analyser (Stable Micro Systems, Haslemere, England), with a 25 kg (±1 g) load cell was used to carry out two tests: texture profile analysis (TPA) and force at cutting. For each treatment, eight cylindrical replicates (1.5 cm height for TPA and 3 cm length for force at cutting) were analysed once sausages reached room temperature. Crosshead speed was 1 mm/s. Texture profile analysis was performed as Bourne (1978) described and was carried out with an aluminium compression platen (10 cm diameter). Two 40% compression deformations were done with an interval of 5 s between them. Force at cutting was measured with a probe consisting of a standard wire (0.3 mm diameter).

2.5. Sensory analysis

Two triangle tests were carried out to discriminate between (1) heat-treated and 5 min pressurised sausages, and (2) heat-treated and 15 min pressurised sausages. A panel of 18 expert subjects (two triads per subject) fulfilled the analysis, which was designed according to Stone and Sidel (1993) procedure. Thus, a pooled database of 36 responses was obtained. The subjects were also asked for preferences and the reasons for them.

2.6. Yield determination

Per cent weight loss during heat or pressure treatment is calculated. For each treatment, six measurements were done. Each measurement is the weight loss of the six sausages of a package.

2.7. Statistical analysis

Data were subjected to analysis of variance of the General Linear Models procedure of SAS® software (the SAS® System for Windows™, release 6.12, SAS Institute, Cary, NC). Level of significance was set for $P < 0.05$.

3. Results and discussion

3.1. Composition

Proximate composition of sausages was: total solids, 35.3% (±1.13); fat, 15.5% (±0.64); total nitrogen, 2.3% (±0.14); ash, 3.3% (±0.11).

3.2. Colour

There was no significant difference among the four types of sausages (Table 1). The total colour difference was higher for 5 and 15 min pressurised samples than for heat-treated samples.

For fresh meat, poultry and derived products, pressure-induced colour modifications greatly depend on treatment conditions (pressure, time and temperature), and are due to changes in myoglobin, such as globin denaturation, heme displacement or release, and ferrous atom oxidation. Lighter tones could result from protein coagulation caused by pressurisation, which affects the structure and surface properties of the product, with increase in the ratio reflected:absorbed light. But when the product is previously cured and cooked, myoglobin turns into nitrosyl-haemochromogen pigment, which is not affected by pressure, and other proteins coagulate (Carlez, Veciana-Nogués, & Cheftel, 1995; Cheftel & Culioli, 1997; Goutefongea, Rampon, Nicolas, & Dumont, 1995). This is the reason why colour parameters almost did not change in this work. Goutefongea et al. (1995) pressurised cooked ham and reported no colour modification.

In contrast, changes in colour occur if samples are cooked under pressure. Thus, in a previous study (Yuste, Mor-Mur, Capellas, Guamis, & Pla, 1999) with sausages containing various percentages of mechanically recovered poultry meat and minced pork meat cooked (50, 60, 70 and 75 °C) for 30 min under pressure (500 MPa), the authors observed increase in lightness, decrease in redness, and decrease or no change in yellowness. Fernández, Cofrades, Solas, Carballo, and Jiménez Colmenero (1998) also applied high pressure simultaneously with cooking at 70 °C to chicken batters, and reported decrease in lightness, redness and yellowness.

Table 1
Colour parameters[a] of heat-treated (80–85 °C for 40 min) and pressurised (500 MPa at 65 °C) cooked sausages

	L value[b]	a value[c]	b value[d]	ΔE[e]
Untreated	52.36	8.70	8.55	
Heat-treated	52.35	8.75	8.64	0.11
Pressurised (5 min)	51.61	8.78	8.72	0.77
Pressurised (15 min)	51.74	8.78	8.71	0.64

[a] $n = 12$.
[b] L value: lightness. Least significant difference (LSD) = 0.771.
[c] a value: redness. LSD = 0.315.
[d] b value: yellowness. LSD = 0.194.
[e] ΔE: total colour difference (between untreated and treated samples), $\Delta E = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2}$.

3.3. Texture

Springiness, adhesiveness and force at cutting did not differ significantly (Fig. 1). Cohesiveness [Fig. 1(b)] and hardness [Fig. 1(d)] statistically changed. Pressurised sausages were the most cohesive and heat-treated sausages were the firmest ones [*firm* is a preferred term to *hard* (Jowitt, 1974)]. Sausages pressurised for 15 min were less firm than untreated ones.

Heat and pressure processing did not affect most texture characteristics. This is because the previous industrial cooking caused gelation, and then only the exudation induced by the subsequent treatment can modify the texture. No studies similar to this one have been found in the literature. Fernández et al. (1998) found pressurised chicken batters less cohesive and firm. They suggested that this may be related to the less heat denaturation of meat proteins when pressurisation is applied simultaneously. In a previous study (Yuste et al., 1999), pressurised sausages also showed higher cohesiveness and lower hardness than, and similar force at cutting to heat-treated sausages; furthermore, pressurisation increased springiness.

In TPA, gumminess is defined as the product of hardness×cohesiveness, and chewiness as the product of hardness×cohesiveness×springiness. Therefore, gumminess and chewiness followed a similar pattern to hardness.

3.4. Sensory analysis

As colour of pressurised sausages was not differentiated from that of heat-treated sausages, neither by instrumental analysis nor with the naked eye, sensory analysis was performed in the regular light.

When heat-treated and 5 min pressurised sausages were contrasted, there were 16 (44.4%) correct judgements (Table 2), which is not significant at $P < 0.05$

Table 2
Results[a] from sensory analysis carried out to discriminate between heat-treated (80–85 °C for 40 min) and pressurised (500 MPa at 65 °C) cooked sausages

Triangle test	Correct judgements	Subject preferences
Heat-treated versus pressurised (5 min)	16[b]	Pressurised = 8 No preference = 5 Heat-treated = 3
Heat-treated versus pressurised (15 min)	22[c]	Pressurised = 11 No preference = 5 Heat-treated = 6

[a] $n = 36$ (18 subjects, two triads per subject).
[b] Not significant ($P < 0.05$).
[c] Significant ($P < 0.05$ and $P < 0.001$).

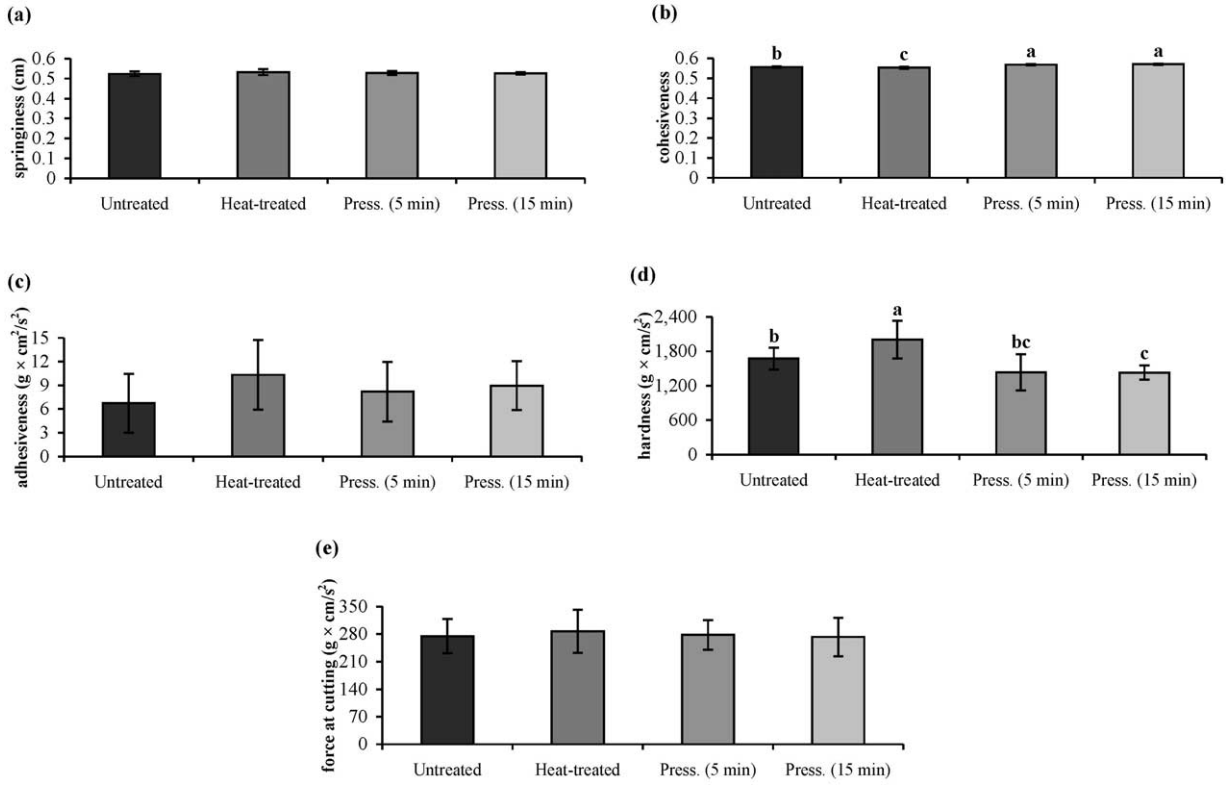

Fig. 1. Texture parameters ($n = 16$) of heat-treated (80–85 °C for 40 min) and pressurised (500 MPa at 65 °C) cooked sausages. (a) Springiness. Least significant difference (LSD) = 0.011. (b) Cohesiveness. LSD = 0.004. (c) Adhesiveness. LSD = 3.852. (d) Hardness. LSD = 240.530. (e) Force at cutting. LSD = 46.266. a–c: Means lacking a common letter differ significantly ($P < 0.05$).

(Stone & Sidel, 1993). In 50% of these 16 judgements the subjects preferred pressurised samples; and only in 18.8% cases heat-treated samples were liked more. When heat-treated and 15 min pressurised sausages were contrasted, there were 22 (61.1%) correct judgements (Table 2). This is significant at $P < 0.05$, and even at $P < 0.001$ (Stone & Sidel, 1993). Again, from these 22 judgements, pressurised samples were preferred in more cases (50%) than heat-treated ones (27.3%). Therefore, only 15 min pressurised sausages significantly differed from heat-treated ones.

In both triangle tests, preference to pressurised sausages was because of (1) the appearance: less gelatin on the surface (which is due to less formation of exudate rich in connective tissue proteins); (2) the taste: stronger and more pleasant, especially in 15 min pressurised sausages; and (3) the texture: more juicy, less grainy and more uniformly consistent.

3.5. Yield

Weight loss was significantly higher in heat-treated sausages than in pressurised ones (Table 3). The lower yield of heat-treated sausages is because at 80–85 °C + water loss is

Table 3
Weight loss[a] (%) of heat-treated (80–85 °C for 40 min) and pressurised (500 MPa at 65 °C) cooked sausages

	Heat-treated	Pressurised (5 min)	Pressurised (15 min)
Batch no. 1	1.438	1.166	1.230
	1.073	1.085	1.330
	1.276	1.100	1.231
	1.312	1.296	1.149
	1.550	1.297	1.327
	1.379	1.059	1.100
$\bar{x} \pm$S.D.	1.338 ± 0.163	1.168 ± 0.109	1.227 ± 0.091
Batch no. 2	2.267	0.970	0.796
	2.377	1.227	0.777
	2.033	1.159	0.651
	2.433	0.916	0.983
	2.006	1.025	0.605
	2.280	0.738	0.649
$\bar{x} \pm$S.D.	2.233 ± 0.176	1.007 ± 0.175	0.743 ± 0.140
Total mean	1.785a[b]	1.087b	0.985b

[a] Each measurement is the weight loss of the six sausages of a package.

[b] Total means lacking a common letter (a, b) differ significantly ($P < 0.05$). Least significant difference = 0.349.

greater and, furthermore, most connective tissue proteins become water-soluble. Thus, sausages treated with high pressure were less firm and more juicy, which was detected by both instrumental and sensory analyses.

No studies similar to this one have been found in the literature. Yield depends on the type of product and the intensity of treatment. Thus, for fresh meat and meat products, pressures above 200 MPa negatively affect water binding properties (Jiménez Colmenero, Carballo, Fernández, Barreto, & Solas, 1997; Mandava et al., 1994). Carballo, Fernández, Carrascosa, Solas, and Jiménez Colmenero (1997) did not find a clear effect of high pressure on water binding properties.

The differences between batches of the same product are mainly because the conditions applied to carry out the previous industrial cooking can vary slightly, which is usual at large-scale production.

4. Summary and conclusion

Colour attributes did not change. Pressurised sausages were more cohesive and less firm than heat-treated sausages. In some cases, the sensory panel did not detect differences between both types of sausages; and when there were differences, pressurised samples were preferred in more occasions because of their better appearance, taste and, especially, texture. Pressurisation induced higher yield than heat treatment. These are important aspects for any new technology to be accepted as a valid food processing method by both consumers and manufacturers.

In conclusion, and also considering the microbiological results of a previous study (Yuste et al., 2000), high pressure treatment at mild temperature can replace the second industrial heat treatment of cooked sausages.

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References

Bourne, M. C. (1978). Texture profile analysis. *Food Technology*, *32*(7), 62–66 , 72.

Carballo, J., Fernández, P., Carrascosa, A. V., Solas, M. T., & Jiménez Colmenero, F. (1997). Characteristics of low- and high-fat beef patties: effect of high hydrostatic pressure. *Journal of Food Protection*, *60*(1), 48–53.

Carlez, A., Veciana-Nogués, T., & Cheftel, J. C. (1995). Changes in colour and myoglobin of minced beef meat due to high pressure processing. *Lebensmittel-Wissenschaft und-Technologie*, *28*(5), 528–538.

Cheftel, J. C., & Culioli, J. (1997). Effects of high pressure on meat: a review. *Meat Science*, *46*(3), 211–236.

Fernández, P., Cofrades, S., Solas, M. T., Carballo, J., & Jiménez Colmenero, F. (1998). High pressure-cooking of chicken meat batters with starch, egg white, and iota carrageenan. *Journal of Food Science*, *63*(2), 267–271.

Goutefongea, R., Rampon, V., Nicolas, N., & Dumont, J. P. (1995). Meat color changes under high pressure treatment. In *Proceedings 41st International Congress of Meat Science and Technology* (pp. 384–385), 20–25 August 1995, San Antonio, TX.

Jiménez Colmenero, F., Carballo, J., Fernández, P., Barreto, G., & Solas, M. T. (1997). High-pressure-induced changes in the characteristics of low-fat and high-fat sausages. *Journal of the Science of Food and Agriculture*, *75*(1), 61–66.

Jowitt, R. (1974). The terminology of food texture. *Journal of Texture Studies*, *5*(3), 351–358.

Macfarlane, J. J. (1974). Pressure-induced solubilization of meat proteins in saline solution. *Journal of Food Science*, *39*(3), 542–547.

Macfarlane, J. J., McKenzie, I. J., Turner, R. H., & Jones, P. N. (1984). Binding of comminuted meat: effect of high pressure. *Meat Science*, *10*(4), 307–320.

Mandava, R., Fernandez, I., & Juillerat, M. (1994). Effect of high hydrostatic pressure on sausage batters. In *Proceedings 40th International Congress of Meat Science and Technology*, The Hague, Netherlands.

McNeal, J. E. (1990). Meat and meat products. In K. Helrich (Ed.), *Official methods of analysis* (15th ed.) (pp. 931–948). Arlington, VA: Association of Official Analytical Chemists (Vol. 2).

Okamoto, M., Kawamura, Y., & Hayashi, R. (1990). Application of high pressure to food processing: textural comparison of pressure- and heat-induced gels of food proteins. *Agricultural and Biological Chemistry*, *54*(1), 183–189.

Stone, H., & Sidel, J. L. (1993). *Sensory evaluation practices*. San Diego, CA: Academic Press.

Tauscher, B. (1995). Pasteurisation of food by hydrostatic high pressure: chemical aspects. *Zeitschrift für Lebensmittel-Untersuchung und-Forschung*, *200*(1), 3–13.

Yoshioka, K., Kage, Y., & Omura, H. (1992). Effect of high pressure on texture and ultrastructure of fish and chicken muscles and their gels. In C. Balny, R. Hayashi, K. Heremans, & P. Masson (Eds.), *High pressure and biotechnology (colloque INSERM Vol. 224)* (pp. 325–327). Montrouge, France: John Libbey Eurotext/Les Editions INSERM.

Yuste, J., Mor-Mur, M., Capellas, M., Guamis, B., & Pla, R. (1999). Mechanically recovered poultry meat sausages manufactured with high hydrostatic pressure. *Poultry Science*, *78*(6), 914–921.

Yuste, J., Pla, R., Capellas, M., Ponce, E., & Mor-Mur, M. (2000). High-pressure processing applied to cooked sausages: bacterial populations during chilled storage. *Journal of Food Protection*, *63*(8), 1093–1099.