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Alternative technology for beef meat shelf life

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Abstract

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Increasing consumer demands from food of animal origin are leading to an update on the methods of pasteurization of food through clean pressurized drinking water to deactivate pathogens and extend the shelf life without the use of heat, chemicals or additives.

The aim of the present study is related to the study of two muscles: *m. Longisimus dorsi* and m. *Semimembranosus* from the carcass of beef and the impact of their High Pressure Processing (HPP), as an alternative technology for storing a beef meat.

The saturated fatty acids in *Longissimus dorsi* muscle increase low significantly from 44.26 to 49.01 g/100 g fat ($P \leq 0.5$), the monounsaturated fatty acids increase as a result of processing from 35.62 to 39.02 g/100 g fat, at the expense of reducing the content of polyunsaturated fatty acids from 18.17 to 10.44 g/100 g. There was a slight increase in the content of trans and cis isomers of fatty acids and a slight decrease in branched fatty acids, which are an indicator of microbiological activity. Saturated fatty acids in *Semimembranosus* muscle decrease as a result of processing from 48.83 to 43.08 g/100 g fat, monounsaturated fatty acids increase from 40.99 to 42.54 g/100 g fat, and polyunsaturated fatty acids increase from 8.49 to 13.12 g/100 g fat.

There was a significant decrease in trans fatty acids from 2.33 to 1.80 g/100 g fat ($P \leq 0.01$), a slight increase in the content of cis isomers of fatty acids, and a slight decrease in branched fatty acids, which is an indicator of microbiological activity.

Keywords: beef meat; muscle; high pressure processing; fatty acids
Abbreviations: HPP – High-pressure processing, LD – *Longissimus dorsi,* Sm – *Semimembranosus*, SFA – saturated fatty acid, MUFA – monounsaturated fatty acid, PUFA – polyunsaturated fatty acid, CLA – conjugated fatty acid.

Introduction

Consumer's requirements for foodstuffs are fresh taste, free of additives, microbiologically safe, easy to use, extended storage and require minimal preparation time (Wilsona et al., 2008, Abera, 2019, Hugas et al., 2002, Raso & Barbosa-Cańovas, 2003) determine the characteristics of the ideal treatment method, namely not to inactivate spoilage and pathogens, to not affect the organoleptic and nutritional value of the product, to be cheap and convenient for use, to be acceptable to consumers and regulatory authorities.

High pressure processing (HPP) is a lightweight alternative technology used in recent decades to sterilize and pasteurize food matrices, including meat and seafood. HPP has the advantage of guaranteeing the reduction of pathogens and spoilage of foods and preserving the organoleptic characteristics of the product, which are compromised in traditional thermal treatments (Paciulli et al., 2019). However, high pressure alters the thermodynamic equilibrium of chemical reactions. This is the case with lipid oxidation, in which kinetics are accelerated in the presence of high hydrostatic pressure. In recent years, there has been an increas-

ing emphasis on the reaction of lipid components to HPP (Medina-Meza et al., 2014).

High-pressure processing (HPP) allows decontamination of foods with minimal impact on their nutritional and sensory characteristics. The use of HPP to reduce microbial load has great potential in the production of meat, poultry and seafood. HPP is widely used initially in the US and Canada to stabilize ready-to-eat meat and dried products (Campus, 2010, NFI, 2015). HPP processing is accompanied by a wide range of operations, including non-thermal decontamination of acidic foods, combined heat treatment to inactivate pathogenic bacteria, freezing and thawing under pressure, texturing and removing of mussels and crustaceans.

Kaur et al. (2016) in their studies on high pressure bovine meat (600 MPa) found that the product had the appearance and texture similar to cooked meat, after processing it had better digestibility (slightly high molecular weight peptides) and higher free amine-N content than untreated meat.

Cruz-Romero et al. (2008) found that the application of the HPP method (at 260 (three minutes), 500 (five minutes) or 800 (five minutes) MPa / 20°C) in the treatment of oysters did not change the profile of fatty acids compared to untreated oysters, while the n-3 / n-6 ratios were numerically higher but not statistically significant in high pressure oysters, i.e. increasing the content of human health n-3 PUFAs.

Barba et al. (2012) examined the effect of the HPP method on the preservation of milk fruit drink and found that PUFA content did not change due to pressure, while monounsaturated fatty acids increased and saturated fatty acids increased at 100 and 200 MPa but decreased at 300 and 400 MPa.

Rakotondramavo et al. (2019) treated vacuum-packed samples with high pressure cooked ham at 500 MPa for 5 minutes at 20°C and examined the fatty acid composition of the cooked ham and the treated, resulting in no significant differences in the content of the individual fatty acids and fatty acid groups between the untreated and pressure samples.

The application of high pressure processing in beef at a low pressure of 200 MPa results in a decrease in the ratio of polyunsaturated/saturated fatty acids and omega-3 / omega-6 fatty acids, as well as docosahexaenoic acid content (Wang et al., 2013; Nuora et al., 2015; Bolumar et al., 2014; Arshad et al., 2017). Lipid peroxidation of meat depends on the animal type, muscle type and anatomical location (Min & Ahn, 2005). Raw beef is much more susceptible to lipid peroxidation than raw pork and chicken (Min et al., 2008) and due to the higher iron and myoglobin content in beef muscle (Min et al., 2008; Estevez, 2015). Lipid oxidation increases significantly with increasing unsaturated groups (double bond).

PUFAs oxidize faster than monounsaturated fatty acids. Linoleic acid (C18: 2) is oxidized ten times faster than oleic acid (C18: 1), which in turn occurs 20 to 30 times slower than oxidation of linolenic acid (C18: 3) (Lima et al., 2013; Li & Liu, 2012). High levels of PUFA in animal feed are associated with an increase in the concentration of PUFA in meat muscle and oxidation of lipids in the body, leading to a decrease in lipid stability and an influence on the color stability of meat at certain concentrations. The concentration of linolenic acid (C18: 3ω-3) over 3% of the lipids causes an adverse effect of fatty acids on the oxidation and aroma of the meat. The muscles from pasture grass beef contain between two and three times more PUFA compared to those rearing indoor, which in turn lead to oxidative processes. Nutritional supplement with antioxidants is a common way of solving this problem (Li & Liu, 2012).

The aim of the present study is related to the study of two muscles: m. *Longisimus dorsi* and m. *Semimembranosus* from the carcass of beef and the impact of their High Pressure Processing (HPP), as an alternative technology for storing a beef meat.

Material and Methods

Two types of *Longissimus dorsi* and *Semimembranosus* beef muscles were used as feedstock for high pressure processing at the following parameters – 600 MPa for 3 min at 4°C and to monitor changes in the fatty acid composition of the bases (control) and treated (HPP) muscle. Each group consists of three individual samples.

Fatty acid analysis of meat performed – the total lipid extraction was performed by Bligh & Dyer (AOAC, 1959) with chloroform and methanol in a ratio of 1:2. The methyl esters of fatty acids (FAME) were analyzed using a Shimadzu-2010 gas chromatograph (Kyoto, Japan). The assay was performed with a CP7420 capillary column (100 m x 0.25 mm i.d., 0.2 m, Varian Inc., Palo Alto, CA), with carrier gas-hydrogen and make-up gas-nitrogen. A five-stape gas chromatographic oven program has been used.

The results were processed by the methods of variation statistics and presented in tables.

Results and Discussion

The saturated fatty acids in *Longissimus dorsi* muscle increase low significantly from 44.26 to 49.01 g / 100 g fat ($P \leq 0.5$), the monounsaturated fatty acids increase as a result of processing from 35.62 to 39.02 g/100 g fat, at the expense of reducing the content of polyunsaturated fatty acids from 18.17 to 10.44 g/100 g. There was a slight increase in the content of trans and cis isomers of fatty acids and a slight decrease in branched fatty acids, which are an indicator of microbio-

Table 1.Fatty acid groups (g/100g fat) in *Longissimus dorsi* and *Semimembranosus* muscle from beef meat

Fatty acid groups	*Longissimus dorsi* (LD)				*Semimembranosus* (Sm)			
	Control		HPP		Control		HPP	
	X	SD	X	SD	X	SD	X	SD
SFA	44.26*	1.98	49.01	1.81	48.83	5.14	43.08	3.21
MUFA	35.62	3.53	39.02	7.20	40.99	3.13	42.54	0.87
PUFA	18.17	3.12	10.44	5.73	8.49	3.85	13.12	4.13
∑ C-18:1Trans-FA	1.32	0.24	1.56	0.72	2.33**	0.14	1.80	0.13
∑CLA	0.46	0.21	0.24	0.04	0.31	0.07	0.26	0.05
C-16:0/C-18:1cis9	0.80	0.14	0.67	0.10	0.74	0.07	0.72	0.06
C-16:0/C-18:1 ges.	0.74	0.11	0.63	0.07	0.68	0.06	0.66	0.05
∑n-3	7.08	1.80	3.24	2.00	2.68	1.41	4.33	1.51
∑n-6	10.75	1.53	7.12	3.75	5.73	2.54	8.74	2.67
∑MCT(C-10 > C-14)	7.79	3.60	1.68	0.28	6.82	4.35	2.84	0.80
CLA 9c,11t	0.28	0.18	0.09	0.04	0.13	0.05	0.13	0.04
∑n-6/Σn-3	1.55**	0.21	2.27	0.21	2.37	0.70	2.04	0.09
∑ C-18:1cis-FA	25.80	4.38	34.56	7.26	33.83	2.89	35.04	0.87
Branched FA	1.95	0.70	1.53	0.14	1.70	0.42	1.22	0.18

* $P \leq 0.05$, ** $P \leq 0.01$

logical activity. The total content of CLA is reduced twice, but not statistically significant as a result of technological processing. The CLA9c, 11t isomer is reduced threefold as a result of the application of the high pressure process (HPP). The total content of omega-3 fatty acids is reduced twice from 7.08 to 3.24 g/100 g fat after processing, while omega-6 fatty acids are reduced from 10.75 to 7.12 g/100 g fat in the *Longissimus dorsi* muscle. A statistically significant increase ($P \leq 0.01$) of the omega-6 / omega-3 fatty acid ratio was observed as a result of HPP processing from 1.55 to 2.27 (Table 1).

Saturated fatty acids in *Semimembranosus* muscle decrease as a result of processing from 48.83 to 43.08 g/100 g fat, monounsaturated fatty acids increase from 40.99 to 42.54 g/100 g fat, and polyunsaturated fatty acids increase from 8.49 to 13.12 g/100 g fat. There was a significant decrease in trans fatty acids from 2.33 to 1.80 g/100 g fat ($P \leq 0.01$), a slight increase in the content of cis isomers of fatty acids, and a slight decrease in branched fatty acids, which is an indicator of microbiological activity. The total CLA content of the *Semimembranosus* muscle decreased from 0.31 to 0.26 g/100

Table 2.Saturated fatty acid (g/100g fat) in *Longissimus dorsi* and *Semimembranosus* muscle from beef meat

SFA	*Longissimus dorsi* (LD)				*Semimembranosus* (Sm)			
	Control		HPP		Control		HPP	
	X	SD	X	SD	X	SD	X	SD
C-12:0	4.73	0.47	0.23	0.08	4.52	0.56	0.54	0.29
C-13:0	0.06	0.05	0.01	0.00	0.01	0.01	0.01	0.00
C-14:0	2.30	1.14	1.32	0.25	2.11	0.94	2.19	0.56
C-15:0	0.04	0.04	0.00	0.00	0.12	0.08	0.02	0.01
C-16:0	19.96	1.17	22.54	1.96	24.59	1.34	24.75	2.48
C-17:0	0.87	0.08	1.05	0.17	0.77	0.09	0.66	0.05
C-18.0	15.23*	1.46	23.41	3.87	16.13	2.71	14.60	0.33
C-20:0	0.23	0.13	0.16	0.05	0.09	0.03	0.08	0.02
C-21:0	0.08	0.10	0.09	0.03	0.06	0.03	0.09	0.02
C-22:0	0.32	0.13	0.06	0.02	0.12	0.05	0.05	0.03
C-23:0	0.03	0.02	0.00	0.00	0.02	0.03	0.00	0.00
C-24:0	0.11	0.14	0.10	0.05	0.15	0.14	0.07	0.03
C-25:0	0.08	0.07	0.01	0.01	0.04	0.05	0.00	0.00
C-26:0	0.08	0.09	0.01	0.00	0.03	0.03	0.00	0.00

* $P \leq 0.05$

g fat, while that of the CLA9c, 11t isomer remains constant – 0.13 g/100 g fat as a result of the processing (Tables 1 and 4). The total content of omega-3 fatty acids in *Semimembranosus* muscle increases from 2.68 to 4.33 g/100 g fat, similarly omega-6 fatty acids increase from 5.73 to 8.74 g/100 g fat, but the ratio between omega-6/ omega-3 fatty acids decreased as a result of the processing from 2.37 to 2.04 (Table 1).

The main representatives of saturated fatty acids are lauric, palmitic and stearic acid in both beef muscles. Lauric acid (C-12: 0) decreases from 4.73 to 0.23 g/100 g fat after technological treatment in the *Longissimus dorsi* muscle and from 4.52 to 0.54 g/100 g fat in the *Semimembranosus* muscle. Palmitic acid (C- 16: 0) increases with the HPP method over the control of the *Longissimus dorsi* muscle from 19.96 to 22.54 g/100 g fat, while in the *Semimembranosus* muscle it remains relatively constant after technological treatment. Stearic acid (C-18: 0) increases in low confidence ($P \leq 0.05$) after application of the high pressure process from 15.23 to 22.54 g/100 g fat in the *Longissimus dorsi* muscle, whereas in the *Semimembranosus* muscle it decreases as a result of technological treatment from 16.13 to 14.60 g/100 g fat (Table 2).

Oleic acid is the most abundant monounsaturated fatty acid and accounts for about 40% of fatty acids in beef (Hwang et al. 2017).

Monounsaturated fatty acids are mainly represented by oleic acid (C-18: 1c9), which in the test muscles increases slightly after technological treatment from 25.53 to 34.20 g/100 g fat in the *Longissimus dorsi* muscle and from 33.23 to 34, 52 g/100 g fat per *Semimembranosus* muscle. Vaccenic acid (C-18: 1t11) in *Longissimus dorsi* muscle increases from 0.10 g /100 g fat in control samples to 0.24 g/100 g fat in high pressure processing, whereas in *Semimembranosus* muscle it decreases significantly by 0.55 to 0.26 g/100 g fat (Table 3).

Table 3. Monounsaturated fatty acid (g/100g fat) in *Longissimus dorsi* and *Semimembranosus* muscle from beef meat

MUFA	*Longissimus dorsi* (LD)				*Semimembranosus* (Sm)			
	Control		HPP		Control		HPP	
	X	SD	X	SD	X	SD	X	SD
C-10:1	0.10	0.06	0.02	0.00	0.00	0.01	0.00	0.00
C-12:1n1	0.02	0.03	0.00	0.00	0.02	0.01	0.00	0.00
C-14:1n5	0.04	0.03	0.03	0.01	0.03	0.01	0.02	0.01
C-15:1n5	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.00
C-16:19tr	0.32	0.20	0.13	0.01	0.17	0.06	0.13	0.01
C-16:1n7	2.04	0.50	1.50	0.54	2.34	0.81	2.59	0.41
C-16:2n4	0.09	0.15	0.00	0.00	0.01	0.01	0.00	0.00
C-17:1n7	4.88**	0.59	0.48	0.07	1.61	1.24	2.00	0.37
C-16:3n4	0.04	0.06	0.03	0.02	0.02	0.01	0.02	0.00
C-18:1t4	0.03	0.01	0.00	0.00	0.02	0.03	0.00	0.00
C-18:1t5/6/7	0.10	0.07	0.04	0.03	0.10	0.04	0.07	0.05
C-18:1t9	0.07	0.07	0.14	0.09	0.23	0.06	0.14	0.08
C-18:1t10	0.09	0.14	0.23	0.20	0.17	0.03	0.15	0.04
C-16:4n1	0.22	0.38	0.00	0.00	0.00	0.00	0.00	0.00
C-18:1t11	0.10	0.11	0.24	0.18	0.55*	0.12	0.26	0.16
C-18:1c9/C-18:1t12/13/	25.53	4.33	34.20	7.27	33.23	2.84	34.52	0.82
C-18:1t15	0.41	0.18	0.36	0.07	0.33	0.05	0.35	0.08
C-18:1c11	0.85	0.28	0.80	0.28	1.10	0.10	1.06	0.17
C-18:1c12	0.11	0.12	0.17	0.03	0.23	0.03	0.22	0.01
C-18:1c13	0.06	0.04	0.11	0.05	0.19	0.07	0.16	0.03
C-18:1t16	0.07	0.05	0.10	0.08	0.16*	0.02	0.11	0.02
C-18:1c14	0.04	0.02	0.05	0.02	0.05	0.01	0.04	0.02
C-18:1c15	0.05	0.05	0.04	0.03	0.13	0.04	0.10	0.04
C-20:1n9	0.04	0.05	0.14	0.04	0.05	0.07	0.13	0.01
C-22:1n11	0.03	0.04	0.06	0.05	0.02	0.01	0.02	0.02
C-22:1n9	0.19	0.16	0.11	0.09	0.20	0.13	0.37	0.13
C-24:1n9	0.07**	0.11	0.06	0.05	0.03	0.03	0.05	0.02

* $P \leq 0.05$, ** $P \leq 0.01$

Table 4.Polyunsaturated fatty acid (g/100g fat) in *Longissimus dorsi* and *Semimembranosus* muscle from beef meat

PUFA	*Longissimus dorsi* (LD)				*Semimembranosus* (Sm)			
	Control		HPP		Control		HPP	
	X	SD	X	SD	X	SD	X	SD
C-18:2t9,12	0.01**	0.01	0.12	0.02	0.05	0.04	0.02	0.02
C-18:2c9,12/19:0	10.42	1.61	6.59	3.67	5.14	2.54	8.25	2.60
gC-18:3n6	0.14	0.14	0.10	0.02	0.07	0.02	0.05	0.01
aC-18:3n3	0.47	0.30	0.31	0.21	0.41	0.16	0.63	0.09
CLA9c,11t	0.28	0.18	0.09	0.04	0.13	0.05	0.13	0.04
CLA10t,12c	0.10	0.05	0.01	0.00	0.00	0.00	0.02	0.00
C-18:4n3	0.05	0.05	0.01	0.00	0.06	0.04	0.00	0.00
CLA9c,11c	0.04	0.03	0.07	0.02	0.14*	0.05	0.06	0.01
CLA9t,11t	0.04	0.08	0.07	0.02	0.04	0.05	0.06	0.01
C-20:2n6	0.05	0.05	0.10	0.05	0.08	0.05	0.12	0.04
C-20:3n6	0.00	0.00	0.05	0.02	0.05	0.02	0.07	0.03
C-20:4n6	0.00	0.01	0.01	0.00	0.02	0.02	0.01	0.00
C-20:3n3	5.51*	1.31	2.40	1.36	1.67	1.05	2.89	1.19
C-20:5n3	0.01	0.01	0.00	0.00	0.01	0.02	0.00	0.00
C-22:2n6	0.01	0.01	0.00	0.00	0.08	0.14	0.00	0.00
C-22:5n3	0.88	0.58	0.48	0.39	0.47	0.24	0.72	0.22
C-22:6n3	0.17	0.14	0.05	0.04	0.06	0.03	0.09	0.03

* $P \leq 0.05$

The two major polyunsaturated fatty acids in meat are linoleic and linolenic and are integral to membranes (Hwang et al. 2017).

Linoleic acid reduced from 10.42 g/100 g fat in the *Longissimus dorsi* muscle control group compared to high pressure treatments (HPP) to 6.59 g/100 g fat, whereas the opposite was found in *Semimembranosus muscles* (Table 4). Gamma linolenic acid is relatively stable in both muscle types after HPP. Alpha linolenic acid decreases after technological treatment on the *Longissimus dorsi* muscle from 0.47 to 0.31 g/100 g fat, while the *Semimembranosus* muscle has the opposite effect of increasing from 0.41 to 0.63 g/100 g fat.

Changes also occur in the content of omega-3 and omega-6 fatty acids. Eicosatrienoic (C-20: 3n3) fatty acid significantly reduced ($P \leq 0.05$) from 5.51 to 2.40 g/100 g fat after technological treatment with the *Longissimus dorsi* muscle and increased slightly from 1.67 to 2.89 g/100 g fat when treated with *Semimembranosus* muscle. Docosopentaenoic (C-22: 5n3) acid has identical manifestations in the application of high pressure processing in both muscles as in eicosotrienoic (Table 4).

Our results converge and correspond to the results obtained by Arshad et al. (2017) and Hwang et al. (2017).

Conclusion

High pressure processing (HPP) of two muscle types from *Longissimus dorsi* and *Semimembranosus* of beef provides significant information on changes in fatty acid composition with respect to groups and specific scale acids. An increase in saturated fatty acids has been found, which is an indicator of lipid oxidation in the processing of *Longissimus dorsi* muscles, whereas in *Semimembranosus* muscle, it leads to an improvement in fatty acid composition with respect to saturated and trans fatty acids.

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