Quality of meat products packaged and stored under vacuum and modified atmosphere conditions

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Abstract The experimental materials comprised cooked coarsely-ground and finely-ground sausages. The sausages were packaged in vacuum (V) and in modified atmospheres with the following composition: 20 % CO₂, 80 % N₂ (A1); 50 % CO₂, 50 % N₂ (A2); 80 % CO₂, 20 % N₂ (A3). The samples were stored at around 4 °C for 15 days. The measurements were repeated 8 times: at the completion of the production process and at 3-day intervals (day 0, 3, 6, 9, 12, 15) during storage. Drip loss changes in the package were analyzed during storage. Meat products were subjected to a sensory evaluation. The obtained results show that changes in the quality of meat products packaged under modified atmosphere are significantly influenced by the composition of the applied atmosphere. A wider range of quality changes were noted in vacuum-packaged products. Changes in the quality of modified atmosphere packaged products were less significant.

Keywords Meat products · Modified atmosphere · Packaging · Drip loss · Organoleptic evaluation

Introduction

Quality attributes determine the processing suitability and consumer perception of meat products. The quality characteristics

of the end product are affected by the quality of the raw materials used for production, the applied production technology, packaging method and storage conditions. The quality attributes of meat products include pH values, color parameters, texture parameters, malonaldehyde content, microbiological quality and organoleptic properties.

The methods of storing meat are being continuously improved so as to extend the shelf-life and preserve the desirable quality attributes of meat products. Modified atmosphere packaging (MAP) is a modern preservation method used for prolonging the shelf-life of fresh and minimally processed foods. Modified atmosphere packaging has evolved from the vacuum packaging technique which has been in use for many years. In this process, the internal atmosphere surrounding a product is modified with a selection of gases. The use of protective gas mixtures has a beneficial effect on the microbial and chemical stability of meat. This solution enhances the quality of the end product. Compared with more traditional packaging methods, modified atmosphere packaging modifies the quality parameters of meat to a lesser degree, mostly due to lower weight loss. MAP provides also protection against lipid oxidation and undesirable changes in color (Czerniawski and Sarzyński 1996; Gajewska Szczербal 2005; Hansen et al. 2007; Lee 2010; McMillin et al. 1999; McMillin 2008; Seydim et al. 2006; Soldatou et al. 2009;).

Various meat packaging technologies have been widely discussed in literature, whereas scant information is available on the modified atmosphere packaging of meat products. Since modified atmosphere packaging has a steadily growing number of applications, the aim of this study was to determine the effect of storage time and the composition of modified atmosphere on changes in selected quality attributes of scalded sausages, including drip formed inside the package and organoleptic properties.

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Materials and methods

The experimental materials comprised scalded sausages with varying degrees of coarseness and various processing parameters to differentiate the rate of gas diffusion from the outside to the inside of the product. The sausages were produced from class I pork (lean, non-stringy, with a fat content of up to 15 %), class IIA pork (with a fat content of up to 25 %), class III pork (with a fat content of up to 35 %), class I beef (lean, non-stringy, with a fat content of up to 15 %), class II beef (with a fat content of up to 25 %). The meat was diced into 50 mm/50 mm cubes, dry cured for 24 h at a temperature of $4\text{ }^{\circ}\text{C}\pm 1$ with the addition of 2 % curing salt mixture with the following composition: 99.4 % NaCl, 0.6 % NaNO₂.

Coarsely-ground sausages (CG) had the following composition: class I pork—60 %, class I beef—15 %, class III pork—15 %, class II beef—5 %, cutting fat—5 %, water—9 %, spices: natural pepper—0.10 %, coriander—0.01 %, nutmeg—0.01 %, sugar—0.20 %.

Finely-ground sausages (FG) had the following composition: class IIA pork—15 %, class III pork—20 %, class I beef—30 %, pork chap without skin—30 %, skin—5 %, water—32 %, spices: natural pepper—0.08 %, nutmeg—0.04 %, sugar—0.20 %.

The following process parameters were applied in the production of coarsely-ground sausages: class I pork was diced into 40 mm/40 mm cubes, class I beef was ground in a grinder, mesh size 20 mm, and the remaining raw materials were ground in a grinder, mesh size 3 mm. The following process parameters were applied in the production of finely-ground sausages: meat was ground in a grinder, mesh size 3 mm. The ingredients were mixed with spices and were cooled with water. Artificial protein casings which provided optimal steam, meat juice, smoke and air permeability were filled with the stuffing using a piston stuffer to produce bars with a diameter of 85 mm and a length of 300 mm (coarsely-ground sausages), and with a diameter of 18 mm and a length of 140 mm (finely-ground sausages).

The sausages were hung at $25\text{ }^{\circ}\text{C}\pm 5\text{ }^{\circ}\text{C}$ for around 45 min, hot smoked at $50\text{ }^{\circ}\text{C}\pm 10\text{ }^{\circ}\text{C}$ for around 75 min (coarsely-ground sausages) and for around 15 min (finely-ground sausages), and scalded at $75\text{ }^{\circ}\text{C}$ until the inside of the bar reached a temperature of $72\text{ }^{\circ}\text{C}\pm 1$ (coarsely-ground sausages). At the next stage of the production process, the sausages were cooled under cold water until the inside of the bar reached a temperature of $20\text{ }^{\circ}\text{C}$. After 24 h of cooling at around $4\text{ }^{\circ}\text{C}\pm 1\text{ }^{\circ}\text{C}$, the products were packaged under modified atmosphere with the following composition:

- P—vacuum,
- A1—20 % CO₂, 80 % N₂,
- A2—50 % CO₂, 50 % N₂,
- A3—80 % CO₂, 20 % N₂.

The sausages were packaged in polyamide and polyethylene bags with the following permeation rates: oxygen— $35\text{ cm}^3/(\text{m}^2\times 24\text{ h}\times\text{Pa})$, nitrogen— $6\text{ cm}^3/(\text{m}^2\times 24\text{ h}\times\text{Pa})$, carbon dioxide— $158\text{ cm}^3/(\text{m}^2\times 24\text{ h}\times\text{Pa})$, water steam— $15\text{ g}/(\text{m}^2\times 24\text{ h})$. The products were packaged with the use of the Multivac A300 (Wolfertschwenden, Germany) device and were stored at around $4\text{ }^{\circ}\text{C}$ for 15 days.

Tests were performed in eight replications. Three samples were collected and analyzed each time. Sausage samples were collected at 3-day intervals: on the day of packaging (day 0) and after 3, 6, 9, 12 and 15 days of storage.

Drip inside the package (Pikul 1993) The drip formed inside the package (M) was determined as described by Pikul (1993), using the formula:

$$M = M_1 - M_2 - M_3$$

where:

- M drip inside the package (g)
- M₁ weight of the product including the package (g)
- M₂ weight of a dried product excluding the package (g)
- M₃ weight of a dried package (g).

Organoleptic evaluation (PN – ISO 6658: 1998; PN – ISO 4121: 1998; PN – ISO 6564: 1999) The organoleptic properties of sausages were evaluated by five trained panelists on a six-point scale. The following quality attributes were assessed: external appearance, color, consistency, juiciness and taste.

Statistical analyses The results were processed statistically by determining basic statistical measures (arithmetic mean $\bar{X}$, standard error of the mean—SEM). The effect of atmosphere type, storage time and interaction (atmosphere $\times$ time) on changes in the qualitative attributes of the studied products was determined by two-way ANOVA (Fisher's *F* test). Mean values were compared using the Newman-Keuls test at a significance level of $\alpha=0.05$. Calculations were performed with the use of STATISTICA 6.0 PL software (Stanisz 1998).

Results and discussion

Changes in the drip loss from sausages during modified atmosphere storage An increase in the drip formed inside the package was observed over storage in different modified atmospheres. Drip loss was greater in vacuum-packaged products than in sausages packaged under gas atmospheres. The drip loss from sausages packaged in gas atmospheres (A1, A2 and A3) was at a similar level throughout storage. During the same storage period, drip loss was approximately five-fold and six-fold greater in vacuum-packaged coarsely-

ground and finely-ground sausages, respectively, than in sausages packaged in various gas atmospheres (Table 1).

A two-way analysis of variance showed that the type of the applied atmosphere and storage time had a significant effect on changes in the drip loss from experimental sausages. There was also a significant interaction between these two factors (Table 1). The observed weight loss validates the results of our previous studies. Greater drip loss from vacuum-packaged sausages resulted from the effect of underpressure on the products (Krala 1998; Liaros et al. 2009; O'Sullivan et al. 2011; Pikul 2001).

There was no correlation between the carbon dioxide content of modified atmospheres and the drip formed inside the package. Czerniawski (1998) found that the packaging of meat products in a modified atmosphere with high concentrations of carbon dioxide may increase drip loss in the package. In our study, drip loss increased in all samples during storage, irrespective of the packaging method.

Changes in the organoleptic properties of sausages during modified atmosphere storage Before packaging, the analyzed ground sausages received five points for external appearance. After 3 days of storage, coarsely-ground sausages received 5.0 points (the highest score) for visual appearance in all types of packaging, while finely-ground

sausages packaged under modified atmosphere A1 and A2 received 4.7 points (the lowest score). On day 15, the score for the external appearance of coarsely-ground and finely-ground sausages was by 0.4 and 0.4–0.6 points lower, respectively, compared with that on day 0 (Table 2). Changes in the external appearance of sausages were most probably due to the drip formed inside the package and slight color fading on the surface.

The smallest changes in the external appearance of finely-ground sausages were noted in vacuum-packaged products, which corroborates the findings of Cilla et al. (2006). The patterns of changes in the appearance of coarsely-ground sausages were similar in all samples after 15 days of storage, regardless of the packaging method. Changes in the visual appearance of coarsely-ground sausages were significantly affected by storage time, while atmosphere type and storage type had a significant influence on changes in the appearance of finely-ground sausages (Table 2).

Before packaging, coarsely-ground and finely-ground sausages received 5.3 and 5.0 points for color, respectively. On the last day of storage, the color of coarsely-ground and finely-ground sausages changed insignificantly, and the final score for this quality attribute was by 0.5–0.6 and 0.3–0.5 points lower, respectively, than the initial score

Table 1 Changes in the drip formed inside the package during the storage of experimental sausages (%)

Packaging method	Storage (4 °C) period (days)				
	3	6	9	12	15
Coarsely-ground sausages					
P	1.2±0.05 ^{Ba}	1.3±0.04 ^{Ba}	1.3±0.02 ^{Ba}	1.4±0.02 ^{Bb}	1.6±0.01 ^{Bc}
A1	0.24±0.017 ^{Ac}	0.28±0.008 ^{Aa}	0.31±0.008 ^{Aab}	0.33±0.009 ^{Ab}	0.36±0.010 ^{Ad}
A2	0.22±0.006 ^{Aa}	0.25±0.007 ^{Aa}	0.28±0.008 ^{Ac}	0.31±0.012 ^{Ab}	0.34±0.015 ^{Ab}
A3	0.23±0.008 ^{Ab}	0.26±0.007 ^{Aa}	0.28±0.007 ^{Aa}	0.32±0.006 ^{Ac}	0.35±0.006 ^{Ad}
Results of analysis of variance (F)	Atmosphere	<i>F</i> =4217.30		<i>p</i> <0.001	
	Time	<i>F</i> =66.81		<i>p</i> <0.001	
	Interaction	<i>F</i> =11.05		<i>p</i> <0.001	
Finely-ground sausages					
P	1.6±0.02 ^{Ba}	1.6±0.02 ^{Ba}	1.7±0.02 ^{Bab}	1.7±0.03 ^{Bb}	1.8±0.03 ^{Bc}
A1	0.28±0.008 ^{Ad}	0.33±0.014 ^{Aa}	0.36±0.015 ^{Aab}	0.40±0.015 ^{Abc}	0.43±0.011 ^{Ac}
A2	0.29±0.015 ^{Aa}	0.31±0.017 ^{Aa}	0.35±0.012 ^{Ac}	0.39±0.010 ^{Ab}	0.43±0.012 ^{Ab}
A3	0.30±0.009 ^{Aa}	0.32±0.009 ^{Aab}	0.34±0.013 ^{Abc}	0.37±0.014 ^{Ac}	0.40±0.016 ^{Ad}
Results of analysis of variance (F)	Atmosphere	<i>F</i> =7470.51		<i>p</i> <0.001	
	Time	<i>F</i> =56.70		<i>p</i> <0.001	
	Interaction	<i>F</i> =3.16		<i>p</i> <0.001	

Arithmetic mean±SEM—standard error of the mean ($n=8$)

A, B—mean values in columns denoted with different letters are statistically significantly different ($\alpha=0.05$)

a, b—mean values in lines denoted with different letters are statistically significantly different ($\alpha=0.05$)

P—vacuum, A1—atmosphere containing 20 % CO₂, 80 % N₂, A2—atmosphere containing 50 % CO₂, 50 % N₂, A3—atmosphere containing 80 % CO₂, 20 % N₂

Table 2 Changes in the external appearance of experimental sausages during storage

Packaging method	Storage (4 °C) period (days)					
	0	3	6	9	12	15
Coarsely-ground sausages						
P	5.0±0.01	5.0±0.05	5.0±0.03	4.9±0.15	4.7±0.21	4.6±0.24
A1	5.0±0.01	5.0±0.01	5.0±0.03	4.8±0.08	4.8±0.19	4.6±0.24
A2	5.0±0.01	5.0±0.01	5.0±0.05	4.8±0.12	4.7±0.18	4.6±0.24
A3	5.0±0.01	5.0±0.05	5.0±0.10	4.9±0.13	4.6±0.30	4.6±0.24
Results of analysis of variance (F)		Atmosphere	<i>F</i> =0.20		<i>p</i> =0.897	
		Time	<i>F</i> =4.67		<i>p</i> <0.001	
		Interaction	<i>F</i> =0.07		<i>p</i> =0.999	
Finely-ground sausages						
P	5.0±0.01	4.8±0.17	4.8±0.16	4.8±0.21	4.1±0.06	4.6±0.08
A1	5.0±0.01	4.7±0.10	4.6±0.06	4.6±0.06	4.6±0.07	4.5±0.01
A2	5.0±0.01	4.7±0.04	4.7±0.01	4.7±0.01	4.7±0.01	4.4±0.05
A3	5.0±0.01	5.0±0.01	4.9±0.06	4.9±0.12	4.6±0.13	4.5±0.04
Results of analysis of variance (F)		Atmosphere	<i>F</i> =5.12		<i>p</i> =0.004	
		Time	<i>F</i> =16.45		<i>p</i> <0.001	
		Interaction	<i>F</i> =0.76		<i>p</i> =0.715	

Mean values in the Table are not significantly different ($\alpha=0.05$)

Arithmetic mean±SEM—standard error of the mean ($n=8$)

P—vacuum, A1—atmosphere containing 20 % CO₂, 80 % N₂, A2—atmosphere containing 50 % CO₂, 50 % N₂, A3—atmosphere containing 80 % CO₂, 20 % N₂

(Table 3). The above was due to a slight increase in color lightness. The observed changes are consistent with the results of previous studies (Martinez et al. 2005; Pexara et al. 2002). The color of meat products is more stable during storage in gas mixtures, compared with vacuum (Ho et al. 2003; Narasimha Rao and Sachindra 2002).

A two-way analysis of variance revealed that storage time had a significant effect on changes in the color parameters of coarsely-ground and finely-ground sausages (Table 3).

On the day of packaging, coarsely-ground and finely-ground sausages received 5.0 and 4.2 points for consistency, respectively. On the last day of storage, the consistency of coarsely-ground and finely-ground sausages changed insignificantly, and the final score for this quality parameter was by 0.4–0.6 and 0.1–0.2 points lower than the initial score (Table 4). Changes in the consistency of sausages resulted from the drip formed inside the package which contributed to an increase in their hardness. A statistical analysis demonstrated that storage time had a significant influence on the consistency of coarsely-ground sausages, whereas neither storage time nor the applied atmosphere caused significant changes in the consistency of finely-ground sausages (Table 4).

Another quality attribute evaluated in the study was juiciness. Modified atmosphere packaging resulted in an

insignificant decrease in juiciness. After 15 days of storage, the juiciness of coarsely-ground and finely-ground sausages decreased by 0.7–0.9 and 0.5–1.0 points, in comparison with the initial value (Table 5). Similarly as in the case of external appearance and consistency, changes in juiciness resulted most probably from the drip formed inside the package. An increase in drip loss over storage was followed by a decrease in juiciness. Changes in the juiciness of experimental sausages were significantly affected by storage time (Table 5).

At the beginning of storage, coarsely-ground and finely-ground sausages received 5.3 and 4.3 points for taste, respectively. No significant changes in taste were noted over storage. Towards the end of storage (day 12 and 15) the products were characterized by a slightly sour taste, most probably due to the excessive growth of lactic acid bacteria. On the last day of storage, the score for the taste of coarsely-ground and finely-ground sausages was by approximately 0.4 and 0.3–0.4 points lower, respectively, in all types of packaging than on the day of packaging (Table 6).

Vacuum-packaged finely-ground sausages received a higher score for taste than MAP sausages. Cilla et al. (2006) also found that the flavor of pork sausages was better preserved under vacuum than in a modified atmosphere composed of 80 % N₂, 20 % CO₂.

The decrease in scores for flavor could result from the growth of lactic acid bacteria or slow oxidation. Our results

Table 3 Changes in the color parameters of experimental sausages during storage

Packaging method	Storage (4 °C) period (days)					
	0	3	6	9	12	15
Coarsely-ground sausages						
P	5.3±0.11	5.1±0.16	5.0±0.10	5.0±0.03	4.8±0.18	4.7±0.26
A1	5.3±0.11	5.1±0.13	5.1±0.06	5.0±0.05	4.9±0.33	4.8±0.09
A2	5.3±0.11	5.1±0.06	5.0±0.17	4.9±0.10	4.8±0.08	4.7±0.31
A3	5.3±0.11	5.1±0.13	5.1±0.21	5.0±0.13	4.9±0.13	4.8±0.06
Results of analysis of variance (F)	Atmosphere		<i>F</i> =0.45		<i>p</i> =0.720	
	Time		<i>F</i> =6.05		<i>p</i> <0.001	
	Interaction		<i>F</i> =0.08		<i>p</i> =0.999	
Finely-ground sausages						
P	5.0±0.1	5.0±0.01	4.9±0.06	4.9±0.08	4.7±0.21	4.7±0.15
A1	5.0±0.01	5.0±0.01	4.9±0.08	4.8±0.17	4.8±0.15	4.5±0.31
A2	5.0±0.01	5.0±0.01	5.0±0.01	4.8±0.17	4.8±0.30	4.7±0.15
A3	5.0±0.01	5.0±0.04	4.8±0.17	4.8±0.30	4.7±0.28	4.6±0.21
Results of analysis of variance (F)	Atmosphere		<i>F</i> =0.28		<i>p</i> =0.839	
	Time		<i>F</i> =3.18		<i>p</i> =0.015	
	Interaction		<i>F</i> =0.09		<i>p</i> =0.999	

Mean values in the Table are not significantly different ($\alpha=0.05$)

Arithmetic mean±SEM—standard error of the mean ($n=8$)

P—vacuum, A1—atmosphere containing 20 % CO₂, 80 % N₂, A2—atmosphere containing 50 % CO₂, 50 % N₂, A3—atmosphere containing 80 % CO₂, 20 % N₂

Table 4 Changes in the consistency of experimental sausages during storage

Packaging method	Storage (4 °C) period (days)					
	0	3	6	9	12	15
Coarsely-ground sausages						
P	5.0±0.01	5.0±0.01	4.7±0.24	4.6±0.24	4.5±0.27	4.4±0.24
A1	5.0±0.01	4.9±0.06	4.9±0.08	4.9±0.08	4.8±0.19	4.5±0.29
A2	5.0±0.01	5.0±0.01	4.9±0.13	4.9±0.13	4.9±0.13	4.6±0.24
A3	5.0±0.01	5.0±0.01	4.9±0.13	4.7±0.16	4.7±0.16	4.6±0.21
Results of analysis of variance (F)	Atmosphere		<i>F</i> =1.47	<i>p</i> =0.231		
	Time		<i>F</i> =5.14	<i>p</i> <0.001		
	Interaction		<i>F</i> =0.25	<i>p</i> =0.998		
Finely-ground sausages						
P	4.2±0.17	4.1±0.13	4.1±0.13	4.1±0.11	4.0±0.01	4.0±0.01
A1	4.2±0.17	4.2±0.17	4.1±0.11	4.1±0.08	4.0±0.01	4.0±0.01
A2	4.2±0.17	4.1±0.13	4.1±0.11	4.1±0.08	4.00±0.01	4.0±0.01
A3	4.2±0.17	4.2±0.17	4.2±0.17	4.1±0.11	4.1±0.08	4.1±0.08
Results of analysis of variance (F)	Atmosphere		<i>F</i> =0.22	<i>p</i> =0.883		
	Time		<i>F</i> =1.20	<i>p</i> =0.323		
	Interaction		<i>F</i> =0.03	<i>p</i> =1.000		

Mean values in the Table are not significantly different ($\alpha=0.05$)

Arithmetic mean±SEM—standard error of the mean ($n=8$)

P—vacuum, A1—atmosphere containing 20 % CO₂, 80 % N₂, A2—atmosphere containing 50 % CO₂, 50 % N₂, A3—atmosphere containing 80 % CO₂, 20 % N₂

Table 5 Changes in the juiciness of experimental sausages during storage

Packaging method	Storage (4 °C) period (days)					
	0	3	6	9	12	15
Coarsely-ground sausages						
P	5.0±0.18	4.5±0.22	4.4±0.06	4.2±0.16	4.2±0.14	4.1±0.19
A1	5.0±0.18	4.8±0.12	4.7±0.20	4.5±0.41	4.4±0.35	4.3±0.10
A2	5.0±0.18	4.8±0.19	4.8±0.23	4.5±0.22	4.4±0.32	4.3±0.31
A3	5.0±0.18	4.9±0.17	4.8±0.16	4.6±0.12	4.3±0.22	4.3±0.11
Results of analysis of variance (F)		Atmosphere	<i>F</i> =1.83		<i>p</i> =0.150	
		Time	<i>F</i> =7.59		<i>p</i> <0.001	
		Interaction	<i>F</i> =0.15		<i>p</i> =0.999	
Finely-ground sausages						
P	5.0±0.01	4.9±0.08	4.8±0.17	4.8±0.14	4.6±0.22	4.5±0.14
A1	5.0±0.01	4.8±0.22	4.6±0.06	4.6±0.22	4.4±0.29	4.0±0.01
A2	5.0±0.01	4.8±0.17	4.6±0.22	4.4±0.30	4.4±0.05	4.2±0.17
A3	5.0±0.01	4.8±0.22	4.6±0.22	4.4±0.29	4.4±0.20	4.1±0.11
Results of analysis of variance (F)		Atmosphere	<i>F</i> =1.81		<i>p</i> =0.159	
		Time	<i>F</i> =10.53		<i>p</i> <0.001	
		Interaction	<i>F</i> =0.20		<i>p</i> =0.999	

Mean values in the Table are not significantly different ($\alpha=0.05$)

Arithmetic mean±SEM—standard error of the mean ($n=8$)

P—vacuum, A1—atmosphere containing 20 % CO₂, 80 % N₂, A2—atmosphere containing 50 % CO₂, 50 % N₂, A3—atmosphere containing 80 % CO₂, 20 % N₂

Table 6 Changes in the taste of experimental sausages during storage

Packaging method	Storage (4 °C) period (days)					
	0	3	6	9	12	15
Coarsely-ground sausages						
P	5.3±0.08	5.1±0.13	5.1±0.22	4.9±0.24	4.9±0.24	4.8±0.23
A1	5.3±0.08	5.1±0.25	5.1±0.18	4.9±0.20	4.9±0.05	4.8±0.25
A2	5.3±0.08	5.1±0.25	5.1±0.18	4.9±0.24	4.9±0.22	4.8±0.33
A3	5.3±0.08	5.1±0.21	5.1±0.12	4.9±0.25	4.9±0.22	4.8±0.25
Results of analysis of variance (F)		Atmosphere	<i>F</i> =0.75		<i>p</i> =0.524	
		Time	<i>F</i> =3.74		<i>p</i> =0.005	
		Interaction	<i>F</i> =0.47		<i>p</i> =0.947	
Finely-ground sausages						
P	4.3±0.33	4.2±0.15	4.2±0.12	4.2±0.12	4.0±0.03	4.0±0.01
A1	4.3±0.33	4.2±0.22	4.1±0.07	4.0±0.03	4.0±0.09	4.0±0.11
A2	4.3±0.33	4.2±0.22	4.1±0.10	4.1±0.22	4.0±0.04	4.0±0.10
A3	4.3±0.33	4.2±0.17	4.0±0.01	4.0±0.29	4.0±0.01	3.9±0.24
Results of analysis of variance (F)		Atmosphere	<i>F</i> =0.20		<i>p</i> =0.898	
		Time	<i>F</i> =2.00		<i>p</i> =0.094	
		Interaction	<i>F</i> =0.04		<i>p</i> =1.000	

Mean values in the Table are not significantly different ($\alpha=0.05$)

Arithmetic mean±SEM—standard error of the mean ($n=8$)

P—vacuum, A1—atmosphere containing 20 % CO₂, 80 % N₂, A2—atmosphere containing 50 % CO₂, 50 % N₂, A3—atmosphere containing 80 % CO₂, 20 % N₂

are consistent with literature data (Bjørn and Solveig 2010; Czerniawski and Sarzyński 1996; Martinez et al. 2005; Pexara et al. 2002; Summo et al. 2010; Xiong 2000; Zakrys-Waliwander et al. 2010).

As demonstrated by a two-way analysis of variance, changes in the taste of coarsely-ground sausages were significantly affected by storage time, while none of the experimental factors significantly influenced the taste of finely-ground sausages (Table 6).

The results of an evaluation of the organoleptic properties of experimental sausages show that the values of the analyzed parameters varied slightly over storage. Modified atmosphere packaging had an insignificant effect on the organoleptic properties of sausages.

Parra et al. (2010) who investigated the effect of different modified atmospheres on dry-cured Iberian ham slices stored at 4 ± 1 °C for 120 days found that the aroma and taste of ham remained unchanged throughout storage. According to other authors, the flavor intensity of meat products tends to decrease over storage (Cilla et al. 2006). Fernández-Fernández et al. (2002) reported that vacuum and modified atmosphere packaging had a similar effect on the organoleptic properties of dry-cured sausages—no statistically significant differences were noted in the analyzed parameters during storage.

Vestergaarda et al. (2007) studied the sensory quality of a meat product (pork meat pizza topping) stored in a gas mixture composed of 25 % CO₂ and 75 % N₂ at 7 °C for 1, 5, 7, 9, 14 and 19 days. A rancid flavor was detected after 9 days. The sensory quality of the pizza topping was affected by lipid oxidation and microbial growth. In a study by Martinez et al. (2005), fresh pork sausages were stored in a modified atmosphere composed of oxygen, carbon dioxide and nitrogen in various proportions, for 20 days, in darkness, at 2 ± 1 °C. The above authors found that increasing concentrations of CO₂ promoted lipid oxidation and microbial growth, and they concluded that the color and aroma of fresh pork sausages could be better preserved in a modified atmosphere containing low CO₂ concentrations (20 %) rather than high (60 %). Krala and Kułagowska (2005) demonstrated that modified atmosphere packaging and storage (vacuum or 20 % CO₂, 80 % N₂) for 50 days at 4 ± 2 °C caused small changes in the color, juiciness, taste and flavor of meat products.

Conclusions

Owing to the effect of underpressure on the products, drip loss was found to be greater in vacuum-packaged sausages than in sausages packaged under modified atmospheres. The results of an assessment of the organoleptic properties of semi-coarsely ground sausages suggest that modified atmosphere storage has no significant negative effect on the

quality of meat products. Modified atmosphere packaging combined with improvements in the chill chain contribute to prolonging the storage life of meat products.

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