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SELECTED QUALITY ATTRIBUTES OF PROCESSED MEAT PRODUCTS STORED IN MODIFIED ATMOSPHERE

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Key words: processed meat products, storage, modified atmosphere, pH, colour parameters

The experimental materials comprised two kinds of cooked sausages, *i.e.* coarsely-ground ham sausage and finely-ground sausage. The sausages were packed in modified atmosphere with the following composition: vacuum; 50% N_2, 50% CO_2; 80% N_2, 20% CO_2; 20% N_2, 80% CO_2. The samples were stored at about 4°C for 15 days. Measurements were made in three-day intervals (day 0, 3, 6, 9, 12, 15). Changes in the pH and colour of meat products were monitored during packaging. The colour attributes L*, a*, b* were determined in the CIE system, and the colour stability coefficient E* was calculated. It was found that storage in modified atmosphere with a higher concentration of carbon dioxide caused a considerable decrease in pH. The type of modified atmosphere packaging had no significant effect on changes in the colour parameters L*, a*, b* in meat products. Slight changes in colour attributes observed at the end of storage were most probably caused by chemical changes. There was a correlation between the colour of processed meats and pH values.

ABBREVIATIONS

P – vacuum; A1 – atmosphere containing 20% CO_2, 80% N_2; A2 – atmosphere containing 50% CO_2, 50% N_2; A3 – atmosphere containing 80% CO_2, 20% N_2; K. Gr. – coarsely-ground sausage; K. Dr. – finely-ground sausage

INTRODUCTION

In order to assure high quality and longer shelf lives for processed meat products, new methods of packaging have been developed. Traditional packaging should reduce the access of oxygen, water vapor, light and microbiological contaminations. Up-to-date packaging technologies, including modified atmosphere packaging (MPA), serve more functions that affect the extension of processed meat product quality. Modified atmosphere entails either a reduction of oxygen access (vacuum packages) or introduction of a mixture of gases to a package (nitrogen, oxygen, carbon dioxide). Practically, the complete removal of oxygen is not possible, even in the case of vacuum-packaging. In a number of cases, leaving even a negligible amount of oxygen in a package has a detrimental effect on the product's quality (acidification of medium, change of color, oxidation of lipids, growth of microorganisms) [Feldman, 1992; Czerniawski, 1999].

Colour is one of the key quality attributes of meat and processed meat products. It is a visual sensation induced mainly by the presence of pigments in meat, but also dependent on its tissue composition and structure.

A red colour is caused mainly by myoglobin, which constitutes *ca.* 90% of all pigments, and by haemoglobin constituting *ca.* 10% of meat pigments. In addition, cell hemes: cytochromes and blood plasma pigment, flavines, bilirubin as well as pigments of some fatty tissues are likely to occur in minimal amounts. The amount of myoglobin may fluctuate, thus resulting in changes in the intensity of the red colour. The most important factors that determine the colour quality of processed meat products are, among others, recipe, contents of nutrients, pH, molecular pressure of oxygen, water activity, packaging method, storage temperature, air humidity, access of light and oxygen, type of package used, and permeability of gases. In cured raw materials, colour is formed by nitrosylmyoglobin which upon heating transforms into a yellow-colored compound – nitrosylmyochromogen. The presence of air hinders the formation of desired colour, as the pink colour of processed meat products is not stable in the environment of atmospheric pressure. Therefore, the processed meat products are packed under modified atmosphere to extend the period of colour stability, thus protecting meat against growing grey. The application of packages with low oxygen permeability enables minimizing changes in the colour of meat products [Ahvenainen, 1989; Arihara *et al.*, 1993; Pikul, 1993; Brewer & Novakofski, 1999; Kłossowska & Olkiewicz, 2000; Pikul, 2002; Jankiewicz, 2004].

This study was aimed at evaluating the relationships between the storage time of model processed meat products, with different degrees of comminution, in various atmospheres and colour parameters and pH values of the products examined. Based on the results obtained, an attempt was made to determine which of the storage methods applied exerts the most favourable effect on the selected quality attributes of sausages.

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EXPERIMENTAL MATERIAL

Materials. The raw material for the production of sausages was dry-cured meat (2% of curing salt with the following composition: 99.4% NaCl, 0.6% $NaNO_2$).

The recipe of coarsely-ground sausage was as follows: pork meat of I class – 60%, beef meat of I class – 15%, pork meat of III class – 15%, beef meat of II class – 5%, fine fat –5%, water – 9%. Seasonings: natural pepper – 0.10%, coriander – 0.01%, nutmeg – 0.01%, and sugar – 0.20%.

The recipe of finely-ground sausage was as follows: pork meat of II class – 15%, pork meat of III class – 20%, beef meat of I class – 30%, skinned jowl – 30%, cured rind 5%, water – 32%. Seasonings: natural pepper – 0.08%, nutmeg – 0.04%, and sugar – 0.20%.

The course of the technological process. Comminution of raw material for the production of coarsely-ground sausage proceeded as follows: pork meat of I class was cut into cubes of 50 mm x 50 mm, beef meat of I class was comminuted in a grinder with screen mesh diameter of 20 mm, the other raw material was comminuted through a screen with mesh diameter size of 3 mm.

Comminution of raw material for the production of finely-ground sausage. The raw material was comminuted in a grinder with screen mesh diameter of 3 mm. The ground material was mixed with seasonings and chilled water. After mixing, the batter was stuffed into artificial casings with the use of a manual sausage stuffer: the coarsely-ground sausage – 35–45 cm long chubs, the finely-ground sausage – 12–14 cm long chubs.

Technological parameters of sausages. Settling at a temp. of 30–40°C for ca. 45 min, hot smoking at a temp. of 60–75°C for *ca.* 75 min. The coarsely-ground sausage was scalded at a temp. of 72–75°C to reach a temp. of 68–70°C inside the chub. After 24-h chilling at a temp. of *ca.* 4°C±2°C, the sausages were packed under modified atmosphere with various composition – vacuum; 20% CO_2, 80% N_2; 50% CO_2, 50% N_2; 80% CO_2, 20% N_2. The processed meat products were packed in foil bags made of polyamide and polyethylene and permeability of: 35 cm^3 / (m^2 × 24 h × atm) for oxygen, 6 cm^3 / (m^2 × 24 h × atm) for nitrogen, 158 cm^3 / (m^2 × 24 h × atm) for carbon dioxide, and 15 g / (m^2× 24 h) for water vapor. Samples were stored at a temp. of *ca.* 4°C for 15 days. Six measurements were carried out in 3-day intervals (0, 3, 6, 9, 12, 15). The processed meat products were packed with the use of a Multivac A 300 packing machine. Analyses were carried out in four replications.

Quality assessment methods. The quality of the stored meat products was assessed based on results of the following analyses: (1) pH, with a pH-meter 340/ION – SET, a combined electrode SenTix 21; (2) measurement of colour attributes was done with the reflection method using a Spectro – color apparatus. Colour attributes: L* – lightness, a* – redness, b* – yellowness, were determined in the CIE system, and colour stability coefficient ΔE* was calculated according to the formula [Clydesdale, 1978]:

$$\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$$

Statistical analysis. The results obtained were elaborated statistically. Means were compared with the Duncan's test. Calculations were made with STATISTICA 6.0 PL software.

RESULTS AND DISCUSSION

In the initial period of storage, the pH value of the coarsely-ground sausage accounted for 6.37, whereas that of the finely-ground one was 6.34 (Table 1). Over the entire storage period, the pH values tended to decline in both types of sausages. After 15 days of storage, the pH values of sausages were the highest in a package with modified atmosphere A1 and reached: 6.35 in the coarsely-ground sausage (K. Gr.) and 6.36 in the finely-ground sausage (K. Dr.). The K. Dr. sausage was characterised by lower pH values than the K. Gr. one. Changes in the pH values of sausages stored in modified atmosphere were negligible and depended on the type of atmosphere applied. A greater pH drop was observed in the modified atmosphere with a lower concentration of CO_2. The observed changes in pH values are consistent with previous results published by other authors [Mingardi & Desenzani, 1993; Oddvin *et al.*, 2004].

TABLE 1. Changes in pH values during storage of experimental sausages.

Type of sausage	Packaging method	Storage period (days)					
		0	3	6	9	12	15
K. Gr.	P	6.37^{Aa}	6.36^{Aa}	6.35^{Aa}	6.40^{Aa}	6.37^{Aa}	6.33^{Aa}
	A1	6.37^{Aa}	6.32^{Aa}	6.34^{Aa}	6.37^{Aab}	6.35^{Aa}	6.35^{Aa}
	A2	6.37^{Aa}	6.34^{Aa}	6.35^{Aa}	6.36^{Aab}	6.34^{Aa}	6.31^{Aa}
	A3	6.37^{Aa}	6.32^{Aa}	6.32^{Aa}	6.33^{Ab}	6.34^{Aa}	6.31^{Aa}
K. Dr.	P	6.34^{Aa}	6.30^{Aa}	6.30^{Aa}	6.34^{Aa}	6.32^{Aa}	6.25^{Aa}
	A1	6.34^{Aa}	6.30^{Aa}	6.29^{Aa}	6.33^{Aa}	6.33^{Aa}	6.36^{Aa}
	A2	6.34^{Aa}	6.32^{Aa}	6.28^{Aa}	6.29^{Aa}	6.29^{Aa}	6.16^{Aa}
	A3	6.34^{Aa}	6.24^{Aa}	6.29^{Aa}	6.30^{Aa}	6.25^{Aa}	6.32^{Aa}

A – mean values in lines denoted with different letters are statistically significantly different ($p<0.05$); a, b – mean values in columns denoted with different letters are statistically significantly different ($p<0.05$)

TABLE 2. Changes in color lightness (L*) during storage of experimental sausages.

Type of sausage	Packaging method	Storage period (days)					
		0	3	6	9	12	15
K. Gr.	P	59.26^{Aab}	58.41^{Aab}	57.98^{Aab}	57.97^{Aab}	57.52^{Aab}	60.99^{Aa}
	A1	59.26^{Aab}	58.35^{Aab}	55.96^{Aab}	57.31^{Aab}	58.61^{Aab}	55.61^{Ab}
	A2	59.26^{Aab}	57.26^{Aab}	58.16^{Aab}	58.16^{Aab}	59.49^{Aab}	58.81^{Aab}
	A3	59.26^{Aab}	59.03^{Aab}	56.75^{Aab}	59.19^{Aab}	55.39^{Aab}	58.04^{Aab}
K. Dr.	P	57.84^{Aab}	60.71^{Aa}	59.74^{Aab}	60.11^{Aab}	60.48^{Aab}	60.23^{Aab}
	A1	57.84^{Aab}	60.64^{Aa}	60.06^{Aab}	57.22^{Aab}	59.76^{Aab}	57.48^{Aab}
	A2	57.84^{Aab}	60.07^{Aa}	60.46^{Aab}	59.35^{Aab}	59.77^{Aab}	58.90^{Aab}
	A3	57.84^{Aab}	54.58^{Ab}	58.32^{Aab}	58.51^{Aab}	59.83^{Aab}	56.90^{Aab}

A – mean values in lines denoted with different letters are statistically significantly different ($p<0.05$); a, b – mean values in columns denoted with different letters are statistically significantly different ($p<0.05$)

The next stage of the study involved the determination of changes in colour attributes.

The initial values of colour lightness (L*) reached 59.26 units in the coarsely-ground sausage and 57.84 units in the finely-ground one (Table 2). After 3 days of storage, the colour lightness of the K. Gr. sausage was observed to decrease in all types of atmosphere applied. In this type of sausages, the L* values were the lowest in the package with A2 atmosphere – 57.26 units, and the highest – in the package with A3 atmosphere – 59.03 units. In the case of the finely-ground sausage, the values of the L* attribute were observed to decline in the package with A3 atmosphere – 54.58 units. In the other types of atmosphere, the values of L* coordinate appeared to increase, with the highest value reported in the vacuum package, *i.e.* 60.71 units. In the consecutive period of storage of both products, the values of colour lightness were subject to slight fluctuations in all types of atmosphere. After 15 days of storage, a negligible increase was observed in the lightness of both types of sausages stored in the vacuum package, namely 60.99 units in the coarsely-ground sausage and 60.23 units in the finely-ground one. In packages with gas atmosphere, the colour lightness of the products examined was reported to decrease slightly. A minute increase in the L* values was most likely due to pH decline. A correlation was found between the pH value of processed meat products and colour lightness. Higher pH values corresponded with lower values of colour lightness and, lower pH values were accompanied by higher values of colour lightness.

At the initial stage of the storage period, values of colour "redness" (a*) accounted for 8.01 units in the coarsely-ground sausage and for 7.01 units in the finely-ground sausage (Table 3). After 3-day storage of the coarsely-ground sausage, a slight increase in the "redness" value was observed in the vacuum package – 8.43 units and in the package with A2 atmosphere – 8.18 units, whereas a slight decrease in "redness" was reported for packages with atmosphere A1 and A3. In the case of the finely-ground sausage, the values of "redness" attribute increased in all types of atmosphere, with the greatest increase found in the package with A3 atmosphere – 8.87 units, and the smallest one in the package with atmosphere A1, *i.e.* 7.60 units. The "redness" of the samples examined was subject to negligible changes during subsequent storage in all types of packages. A statistically insignificant decrease in "redness" of the coarsely-ground sausage stored in the vacuum package was probably due to the production of brown methmyoglobin as affected by oxygen residues in the package. On the last day of storage, the values of "redness" appeared to be the highest in the package with A1 atmosphere, reaching 8.59 units in the coarsely-ground sausage and 9.75 units in

TABLE 3. Changes in color redness (a*) during storage of experimental sausages.

Type of sausage	Packaging method	Storage period (days)					
		0	3	6	9	12	15
K. Gr.	P	8.01^{Aa}	8.43^{Aa}	7.87^{Aa}	8.52^{Aa}	8.35^{Aa}	7.46^{Aa}
	A1	8.01^{Aa}	7.87^{Aa}	7.77^{Aa}	7.45^{Aa}	7.68^{Aa}	8.59^{Aa}
	A2	8.01^{Aa}	8.18^{Aa}	7.79^{Aa}	7.98^{Aa}	8.04^{Aa}	8.27^{Aa}
	A3	8.01^{Aa}	7.72^{Aa}	7.45^{Aa}	7.06^{Aa}	9.01^{Aa}	7.47^{Aa}
K. Dr.	P	7.01^{Aa}	8.22^{ABa}	8.77^{ABa}	8.54^{ABa}	8.75^{ABa}	9.40^{Ba}
	A1	7.01^{Aa}	7.60^{ABa}	8.93^{ABa}	8.82^{ABa}	8.79^{ABa}	9.75^{Ba}
	A2	7.01^{Aa}	8.38^{Aa}	8.10^{Aa}	7.99^{Aa}	8.68^{Aa}	8.37^{Aa}
	A3	7.01^{Aa}	8.87^{Aa}	9.16^{Aa}	9.03^{Aa}	8.94^{Aa}	9.69^{Aa}

A – mean values in lines denoted with different letters are statistically significantly different ($p<0.05$); a, b – mean values in columns denoted with different letters are statistically significantly different ($p<0.05$)

TABLE 4. Changes in color yellowness (b*) during storage of experimental sausages.

Type of sausage	Packaging method	Storage period (days)					
		0	3	6	9	12	15
K. Gr.	P	12.14^{Aa}	12.90^{Aa}	13.43^{Aa}	13.29^{Aa}	13.24^{Aa}	12.26^{Aa}
	A1	12.14^{Aa}	12.59^{Aa}	14.83^{Aa}	14.06^{Aa}	13.16^{Aa}	13.67^{Aa}
	A2	12.14^{Aa}	12.17^{Aa}	13.58^{Aa}	13.65^{Aa}	12.99^{Aa}	13.49^{Aa}
	A3	12.14^{Aa}	12.87^{Aa}	13.85^{Aa}	14.28^{Aa}	13.93^{Aa}	13.29^{Aa}
K. Dr.	P	18.16^{Aa}	17.77^{Aa}	17.38^{Aa}	16.64^{Aa}	17.34^{Aa}	17.36^{Aa}
	A1	18.16^{Aa}	16.21^{Aa}	17.96^{Aa}	19.04^{Aa}	18.43^{Aa}	19.21^{Aa}
	A2	18.16^{Aa}	17.45^{Aa}	17.36^{Aa}	17.76^{Aa}	18.46^{Aa}	16.91^{Aa}
	A3	18.16^{Aa}	19.79^{Aa}	17.94^{Aa}	18.86^{Aa}	18.66^{Aa}	20.92^{Aa}

A – mean values in lines denoted with different letters are statistically significantly different ($p<0.05$); a, b – mean values in columns denoted with different letters are statistically significantly different ($p<0.05$)

TABLE 5. Changes in color stability coefficient (ΔE*) during storage of experimental sausages.

Type of sausage	Packaging method	Storage period (days)					
		0	3	6	9	12	15
K. Gr.	P	6.87^{Aa}	1.82^{Aa}	1.80^{Aa}	2.09^{Aa}	1.82^{Aa}	7.46^{Aa}
	A1	1.02^{Aa}	4.26^{Aa}	2.79^{Aa}	1.25^{Aa}	4.00^{Aa}	8.59^{Aa}
	A2	2.01^{ABa}	1.83^{Aa}	1.87^{Ba}	0.88^{ABa}	1.45^{ABa}	8.27^{Aa}
	A3	0.82^{Aa}	3.09^{Aa}	2.34^{Aa}	3.96^{Aa}	1.76^{Aa}	7.47^{Aa}
K. Dr.	P	3.14^{Aa}	2.70^{Aa}	3.13^{Aa}	3.27^{Aa}	3.47^{Aa}	9.40^{Ba}
	A1	3.46^{Aa}	2.94^{Aa}	2.11^{Aa}	2.63^{Aa}	2.96^{Aa}	9.75^{Ba}
	A2	2.71^{Aa}	2.95^{Aa}	1.84^{Aa}	2.57^{Aa}	2.13^{Aa}	8.37^{Aa}
	A3	4.09^{Aa}	2.21^{Aa}	2.24^{Aa}	2.82^{Aa}	3.96^{Aa}	9.69^{Aa}

A – mean values in lines denoted with different letters are statistically significantly different ($p<0.05$); a, b – mean values in columns denoted with different letters are statistically significantly different ($p<0.05$)

the finely-ground one. Over the storage period of the processed meat products, the "redness" values were observed to slightly increase, which could have been caused by an increase in nitrosylmyoglobin responsible for the red colour of processed meat products.

Prior to packaging the experimental sausage, the values of "yellowness" reached: 12.14 units in the coarsely-ground sausage and 18.16 units in the finely-ground product (Table 4). After 3 days of storage, a slight increase in the "yellowness" value was reported in the coarsely-ground sausage in all types of atmosphere. The greatest increase in its value occurred in the vacuum package – 12.90 units, whereas the smallest one was in the package with A1 atmosphere – 12.17 units. The finely-ground sausage was characterised by a slight decline in the value of "yellowness" in three types of packages (P, A1, A2), and by an increase in its value observed in the package with A3 atmosphere. Over the 15-day storage of the processed meat products in modified atmosphere, the "yellowness" was not subject to any statistically significant changes. A small decrease in its value was observed in the finely-ground sausage stored under vacuum – 17.36 units, and in the package with modified atmosphere A 2 – 16.91 units. The decrease was probably caused by the fact that during storage there is an intensive growth of microorganisms utilizing oxygen as a result of lactic fermentation, which affects a reduction in the content of oxymyoglobin and, consequently, decreases the values of "yellowness".

To provide more explicit presentation of colour change in the processed meat product, the colour stability coefficient ΔE* was calculated for the experimental sausages (Table 5). At the initial stage of storage of the sausages, the highest values of the color stability coefficient were observed for the coarsely-ground vacuum-packed sausage – 6.87 units, and in the finely-ground sausage stored in the package with modified atmosphere A3 – 4.09 units. In the consecutive days of storage, slight fluctuations in the coefficients values were reported in all samples examined.

After 15 days of storage, the highest values of the colour stability coefficient occurred in the coarsely-ground sausage stored in the package with A1 atmosphere – 4.00 units, and in the finely-ground sausage stored in the package with atmosphere A3 – 3.96 units. The lowest values of that coefficient were noted in the package with A2 atmosphere, namely 1.45 units in the coarsely-ground sausage and 2.13 units in the finely-ground product. The increase value of the colour stability coefficient indicates deterioration of colour over the storage period, which is likely to result from the photo-oxidation process proceeding upon the access of light [Kłossowska & Olkiewicz, 2000].

CONCLUSIONS

1. A greater decrease in pH values was observed in the processed meat products stored in modified atmosphere with a higher concentration of carbon dioxide.

2. A correlation was found between pH values and colour lightness, *i.e.*: the higher the pH value, the lower the colour lightness, and *vice versa*.

3. The processed meat products examined were characterised by slight changes in colour attributes L*, a*, b* over the entire period of storage in all types of atmosphere.

4. On the basis of changes observed for the colour stability coefficient ΔE*, it was demonstrated that storage of processed meat products in protective atmosphere has a positive effect on maintaining a stable colour.

5. Modified atmosphere packaging of processed meat products is a beneficial method of storage, as it does not deteriorate the quality attributes.

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WYBRANE CECHY JAKOŚCIOWE PRODUKTÓW MIĘSNYCH PRZECHOWYWANYCH W MODYFIKOWANEJ ATMOSFERZE

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Materiałem badawczym były kiełbasy parzone: grubo rozdrobniona (kiełbasa szynkowa), drobno rozdrobniona (parówki). Kiełbasy po zakończeniu procesu technologicznego umieszczano w opakowaniach próżniowych lub wypełnionych: 20% CO_2, 80% N_2; 50% CO_2, 50% N_2; 80% CO_2, 20% N_2. Zapakowane wyroby przechowywano w temp. ok. 4°C przez 15 dni. Oznaczenia prowadzono w odstępach 3 dniowych (0, 3, 6, 9, 12, 15). W czasie przechowywania badano zmiany wartości pH i barwę przetworów mięsnych. Określono parametry barwy L*, a*, b*, w systemie CIE, oraz wyliczono współczynnik trwałości barwy ΔE*. Wykazano, że przechowywanie przetworów mięsnych w atmosferze modyfikowanej o wyższej zawartości dwutlenku węgla powoduje istotne zmniejszenie wartości pH. Stwierdzono, że rodzaj użytej atmosfery w czasie przechowywania przetworów mięsnych nie miał istotnego wpływu na zmiany parametrów barwy L*, a*, b*. Nieznaczne zmiany parametrów barwy pod koniec przechowywania były spowodowane najprawdopodobniej zachodzącymi przemianami chemicznymi. Stwierdzono zależność między barwą przetworów mięsnych, a wartościami pH.