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DYNAMICS OF WATER ACTIVITY CHANGES IN PORTIONED MEAT PRODUCTS PACKED IN MULTILAYER FOILS

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Abstract. Water activity (a_w) is one of the primary quality parameters basing on which the storage stability of meat products can be determined. A_w value undergoes fluctuations during product storage. The aim of the study was to determine and compare the dynamics of water activity changes (a_w), pH value and selected chemical parameters in sausages with different storage stability, vacuum packed in direct packagings and stored under cooling conditions. Salami (beef, pork) as well as Lunch meat (pork) was the experimental material. Sausage portions were packed in two kinds of foil packagings: vacuum PA/PE bags and 4-layer bags with thermoshrinkable features, which gives a "strained skin" effect. Chemical composition, water activity and pH value were determined in samples, and the protein and water content quotient (*b/w*) was estimated. Basing on the results obtained, it was observed that examined sausages differ in basic chemical composition, pH value, water activity, as well as in protein content and water quotient *(b/w)*. Both sausages in each of five phases of storage in thermoshrinkable as well as in vacuum packagings, were characterized with higher water activity than before packaging, and each of these sausages showed different a_w and its change dynamics. Analysis of variance, performed in this study with the use of the Fisher-Snedecor test, showed statistically significant influence of sausage type and experiment phase on the water activity of the samples investigated, packed in multilayer foils with different characteristics.

Keywords: meat products, packaging units, water activity

INTRODUCTION

With the expansion of the network of self-service shops and big markets, industrial portioning and meat products packaging is becoming more and more important. Appropriate packaging is one of the ways of extending the stability time of food products. Packaging should prevent, among others: over-drying of product surface, oxidation of muscle pigments, development of microorganisms, mass losses, as well as sublimation during the freezing process. It is a protection for the product, so it causes quality maintenance during storage, allows significant extension of consumption usefulness, extension of disposability during distribution, and improvement of presentation conditions in cooling counters. The following three criteria are the basis for packaging selection:

- degree of product protection from oxygen and vapour access,
- efficient closing,
- fulfilling the regulations of law and the health requirements.

Taking into consideration all these assumptions, easily spoiling food, like meat products, is packed into multilayer packagings. Organic polymers, such as PE (polyethylene), PA (polyamide), EVOH (ethylo-vinylic alcohol), PVC (vinyl polychloride, PVDC (vinyliden polychloride) and PET (polyester), are the main materials used for their production. Polymeric foil layers connected to each other form multilayered packaging materials with special physical features, offering the possibility of usage for specific products. For example, polyethylene is susceptible to welding and makes a perfect barrier for water vapour, however polyamide is characterized by good barrier properties for gases as well as by providing good thermal stability of packaging. EVOH [1] foil makes even better protection against gas exchange with the surroundings.

Vacuum packaging technique is being used on a wide scale. It is based on air evacuation, most often in 95%, from packagings closed hermetically by welding and made from materials with sufficient barrier properties, and it is profitable taking prices under consideration. This technique needs quite little packaging material. Vacuum packaging in welded foil bags as well as in thermoshrinkable packagings is common both in large, as well as in medium size meat processing plants [3].

Water content in food products is presented in percentages in relation to mass of the whole wet product which is assumed as 100%, or in dry matter percentages. Free, biologically active, structural and bound, are terms used for determination of form and state of water occurring in living tissues. Division into free water and water with reduced activity is being used taking into consideration food products. Free water is water that shows vapour pressure equal to pure water vapour pressure. It makes a bigger part of water contained in food unprocessed or processed without removing it. Bound water, that does not freeze or does not have properties to dissolve or to react, also exists. Water activity is one of basic quality parameters being a basis for the determination of meat products storage stability. The problem of water activity (a_w), introduced in 1957 by Scott, determines its arrangement and degree of connection with other food components. It is an indicator of availability of water contained in food for microorganisms. Taking into consideration that each material humidity in equilibrium state meets particular partial pressure of water vapour (Equilibrium Relative Humidity – *ERH*), this value is determined as a ratio of water vapour pressure over material (p) to water vapour pressure over pure water (p_o) under the same conditions [6]. It was observed that, for example, meat and meat products pH value as well as protein and water content quotient *b/w* [4,5] have a significant influence on water activity. Basing on the a_w value of meat products, as well as on their hydrogen ions concentration, meat products were classified into three groups:

- easily spoiling: $a_w > 0.95$ and pH > 5,2 – products that need cooling at +5°C,
- spoiling: $a_w \leq 0.95$ and pH ≤ 5.2, products that need cooling at +10°C,
- qualified for storage: $a_w \leq 0.95$ and pH ≤ 5.2 or only $a_w \leq 0.91$ or pH ≤ 5.2, products that do not need cooling [7].

THE AIM OF THE STUDY

The aim of the study was to determine the dynamics of water activity changes (a_w), pH value and selected chemical characteristics in portioned sausages packed under vacuum in direct packagings made of multilayer foils and stored under cooling conditions.

MATERIAL AND METHODS

Two kinds of sausages, differing both in technological process as well as in stability, were the raw material used for this study:

- Salami cooked (beef, pork),
- Lunch meat (pork).

Experimental sausages were divided into nine equal parts (portions) before the tests, from which one was a control sample, and the other eight were separately packed into polymeric foil bags with the use of a vacuum chamber seamer. Four of the samples were packaged in 2-layer foil bags from PA/PE (polyamide / polyethylene) foil with the following parameters:

- thickness: 90 μm (20/70),
- oxygen penetrability: 50 cm^3/ m^2/24 h,
- carbon dioxide penetrability: 140 cm^3/m^2/24 h,
- water vapour penetrability: 6-8 g /m^2/24 h.

However, the remaining four samples were packed into 4-layer bags with thermoshrinkable features, made by the Cryovac company, shrunk bi-axially, which gives a “strained skin” effect, with the characteristics given below:

- thickness: 59 μm,
- oxygen penetrability: 30 cm^3/m^2/24 h,
- carbon dioxide penetrability: 150 cm^3/m^2/24h,
- water vapour penetrability: 20g/m^2/24 h,
- shrinking temperature: 85-88°C during 1-2 s.

After closing in individual packaging, samples were stored in a cooler at +4^{o}C at a relative humidity of 60%. The tests were carried out on the day of packaging (control sample – term 1) and after the following number of weeks of storage: for Salami – after 2, 3, 4, and 5 storage weeks, and for pork Lunch meat – after 1, 2, 3 and 4 storage weeks. The differences in the examination terms were caused by different sausage stability periods declared by the producer. The terms of examination were indicated as experiment phases from 2 to 5 for both portioned sausages.

An automatic apparatus of the Aquaspector–1 type, determining parameter value after setting the equilibrium relative humidity in measurement chamber upon examined sample, was used for water activity measurement. Besides, water content in sausages was determined using the dryer method, and protein quantity (N x 6,25) with the Kjeldahl method, with the use of a Kjeltec unit. Fat level was determined using the extraction-weight method, with the Soxtec apparatus using paraffin oil ether as the extraction agent [2]. Basing on the water content, dry matter in sausages was calculated, and after subtracting from it the fat content, the amount of fat free dry matter was obtained. The pH value was determined with an Accumet –15 apparatus, using a glass-chloro-silver joint electrode towards three standards. Hydrogen ions concentration and water activity were estimated inside the portions of sausages examined. Besides, the values of protein and water content quotient (*b/w*) in the sausages examined were also determined in each phase of the study.

The results obtained were subjected to analysis of variance using the „F” test. Three variability factors were taken under consideration: type of sausage (A), packaging type (B) and experiment phase (C). The significance of differences between mean values of each of the indicated parameters were estimated for a significance level of $p \leq 0.05$, basing on the Least Significant Difference (LSD).

RESULTS AND DISSCUSSION

Table 1 shows the values of parameters characterizing the basic composition of the experimental sausages examined.

Basing on the results obtained, it was observed that before packaging Salami contained about 25% less water and 0.7% less fat free dry matter than Lunch meat. However, it also contained about 4% more protein. Portions of both sausages packed in thermoshrinkable foil in the last experiment phase had less water than those packed in vacuum packaging, which was a result of higher penetrability to water vapour of first foil, as well as of gradual increase in water content with protein leak into the inside of packaging and the occurrence of jelly, especially in the case of Lunch meat. Fat free dry matter content changed during the storage of packed samples. A higher amount of it was observed in the case of

Salami than in the case of Lunch meat. Probably, the high water temperature during the shrinking of foil bags on sausage portions resulted in quite a high level of fat free dry matter in Salami sausage packed in thermoshrinkable foil. However, the jelly leak from the sausage, which was still intensifying till the forth week of storage, was the cause of a gradual decrease in the fat free dry matter content in Lunch meat.

Table 1. Characteristics of the chemical composition of the sausages examined (%)

Sausage type (A)	Packaging type (B)	Parameter	Experiment phase (C)				
			1	2	3	4	5
Salami	thermoshrinkable	water	49.72	47.99	51.03	46.88	45.86
	vacuum			48.77	51.29	48.10	49.60
Lunch meat	thermoshrinkable		73.49	74.65	76.00	75.60	74.18
	vacuum			74.92	75.72	75.76	75.12
Salami	thermoshrinkable	protein	16.72	16.72	16.13	15.50	15.11
	vacuum			15.89	15.78	16.20	15.29
Lunch meat	thermoshrinkable		12.96	12.75	11.77	11.50	11.04
	vacuum			11.81	11.30	10.92	11.11
Salami	thermoshrinkable	fat free dry matter	18.59	19.95	17.19	21.45	22.51
	vacuum			18.74	16.71	20.77	17.94
Lunch meat	thermoshrinkable		19.30	17.04	14.84	13.46	17.15
	vacuum			17.12	15.05	13.54	16.25

Statistical analysis of the results showed that the type of portioned sausage, packaging type as well as storage time, had statistically significant influence on water and protein content in sausages packed in polymeric foils with different characteristics, stored under cooling conditions (Tab. 2). No statistically signify-cant influence of the type of packaging foil used on the amount of fat free dry matter in the sausages examined was observed.

The pH value of portioned sausages was changing during the whole period of their storage (Fig. 1). Before packaging, it was, on average, equal to 5.11 for Salami sausage and to 6.32 for Lunch Meat. The range of hydrogen ions concentration changes during storage was bigger in Lunch meat than in Salami. The pH values decreased from the initial value of 6.32 to 5.42 and 5.55, in thermoshrinkable and vacuum packaging, respectively, as observed in the final phase of the study.

Table 2. Analysis of variance for the basic composition parameters of the experimental sausages

Parameter	Variability factor	$F_{obl.}$	$F_{tab.}$	$LSD_{0.05}$
Water	A – sausage type	3247.47	**3.90**	0.89
Protein		236.60	**3.90**	0.51
Fat free dry matter.		31.09	**3.90**	1.00
Water	B – packaging type	7.69	**3.90**	0.89
Protein		4.32	**3.90**	0.51
Fat free dry matter.		2.26	3.90	1.00
Water	C – experiment phase	4.54	**2.43**	1.40
Protein		10.19	**2.43**	0.80
Fat free dry matter.		4.36	**2.43**	1.58
Water	interaction A x B	0.11	3.90	1.25
Protein		5.24	3.90	0.72
Fat free dry matter		1.24	3.90	1.41
Water	interaction A x C	2.62	**2.43**	1.98
Protein		2.23	2.43	1.13
Fat free dry matter.		7.70	3.90	2.24
Water	interaction B x C	2.78	**2.43**	1.98
Protein		1.38	2.43	1.13
Fat free dry matter		0.96	2.43	2.24
Water	interaction A x B x C	0.14	2.43	2.80
Protein		0.80	2.43	1.60
Fat free dry mater		0.51	2.43	3.16

*values written in bold type show statistically significant influence of a variability factor on the parameter examined.

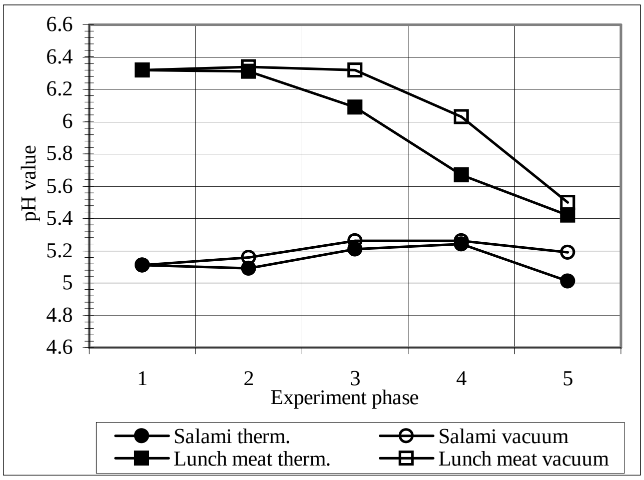

Fig. 1. Changes in the pH value in examined sausages during storage

In both portioned sausages, hydrogen ions concentration did not change after the first week of storage. However, after a longer period of time, differences occurred in pH value, depending on the type of packaging used. In each phase of the experiment, the pH value was higher in the sausage packed in the vacuum packaging than in the thermoshrinkable one. In the case of Salami, the difference occurred in the second period of the study and was equal to 0.09 of pH unit, and in the fifth – 0.18 pH unit. The biggest hydrogen ions concentration changes were observed between the second and third period and were equal to 0.12 in the thermoshrinkable packaging and 0.1 in the vacuum packaging, respectively. A similar phenomenon was observed in Lunch meat samples where, however, a stronger influence of the packaging type and the experiment phase was noticed. The pH value underwent the quickest redu-ction in samples packed in the thermoshrinkable packaging rather than in the vacuum one where it was slower, especially in the third period – by about 0.23, and in the fourth period – by about 0.36 unit.

Table 3. Analysis of variance of pH values, water activity, as well as protein and water content quotient *b/w*

Parameter	Variability factor	$F_{obl.}$	$F_{tab.}$	$LSD_{0.05}$
pH	A – sausage type	838.02	**3.90**	0.06
water activity		75.84	**3.94**	0.003
b/w		1311.49	**3.90**	0.009
pH	B – packaging type	11.66	**3.90**	0.06
water activity		2.94	3.94	0.003
b/w		6.17	**3.90**	0.009
pH	C – experiment phase	33.16	**2.43**	0.09
water activity		21.77	**2.46**	0.005
b/w		7.82	**2.43**	0.015
pH	interaction A x B	1.53	3.90	0.08
water activity		0.08	3.94	0.004
b/w		1.43	3.90	0.013
pH	interaction A x C	31.95	**2.43**	0.13
water activity		5.12	2.46	0.007
b/w		2.89	**2.43**	0.021
pH	interaction B x C	1.33	2.43	0.13
water activity		1.31	2.46	0.007
b/w		0.48	2.43	0.021
pH	interaction A x B x C	1.94	2.43	0.19
water activity		0.41	2.46	0.010
b/w		0.95	2.43	0.029

*values written in bold type show statistically significant influence of a variability factor on the parameter examined.

The results of pH values obtained in the study underwent an analysis of variance, and on this basis it was observed that they depended in a statistically significant way on the type of sausage examined, on the type of individual packaging used, as well as on the storage time. Statistically significant was also the influence of interactions between the type of sausage and the experimental phase (Tab. 3).

It was found that sausages, like in the case of pH, demonstrated different water activities (Fig. 2), which was reflected in the mean values of a_w equal to 0.932 for Lunch meat and 0.957 for Salami. Basing on the evaluation of pH and a_w of sausages stored in multilayer foils with different characteristics, the values of these parameters increased, and were higher for vacuum packed samples than for samples packed in foil with thermocontractile properties. One of the reasons for this was probably the higher water vapour penetrability of the first foil type. Maximum water activity in Salami was observed in the second period of the study, irrespective of the packaging type; on average, it increased by about 0.024 in thermoshrinkable packaging and about 0.029 in vacuum packaging.

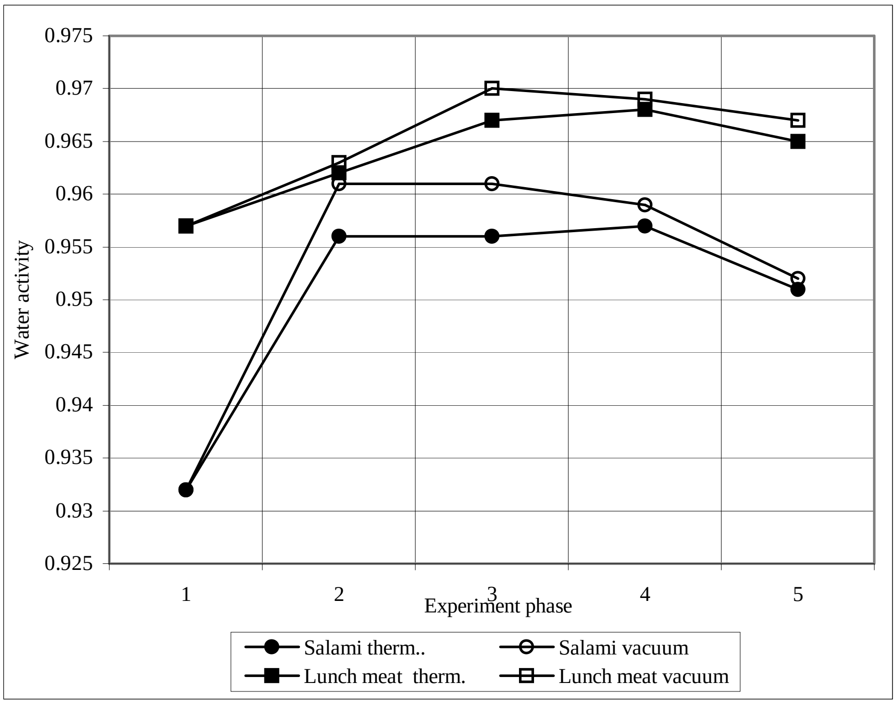

Fig. 2. Water activity changes in examined sausages during storage

In the Lunch meat, the most dynamic increase of a_w value was observed in the third period of the study and it was, on average, equal to 0.010 in the thermo-shrinkable packaging and 0.013 in vacuum packaging in comparison with the values observed before sausage packaging. In subsequent phases of the experiment, the water activity in the sausage samples decreased without achieving previous values, i.e. those which occurred before packaging (Fig. 3).

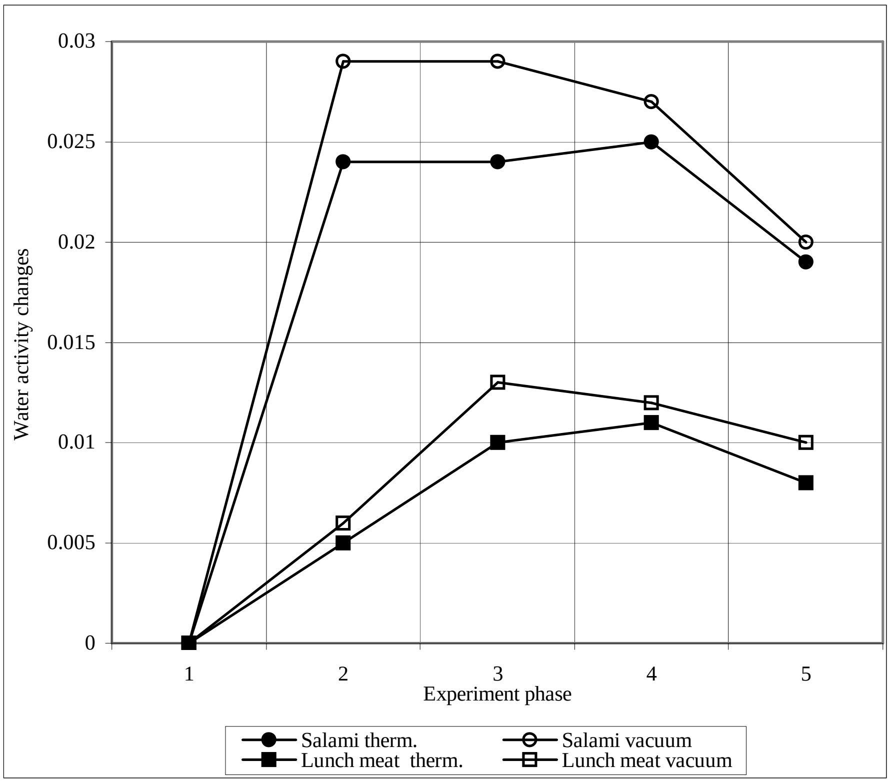

Fig. 3. Water activity changes in stored sausages in comparison to values before packaging

The decrease was higher and more acute in Salami samples than in the Lunch meat, where the decrease of water activity occurred gradually. It is well shown in the figure comparing water activity changes in each phase of the study in relation to the preceding phase of the experiment (Fig. 4).

In the case of Lunch meat, the α_w value was higher in each next phase of the experiment, with the exception of the fifth phase; however, in the case of Salami, the third phase of the study initiated a reduction of water activity in relation to the initial level. Analysis of variance, carried out in this study, showed statistically significant influence of the sausage type and of the experiment phase on the water activity of the examined sausages packed in multilayer foils with different characteristics (Tab. 3).

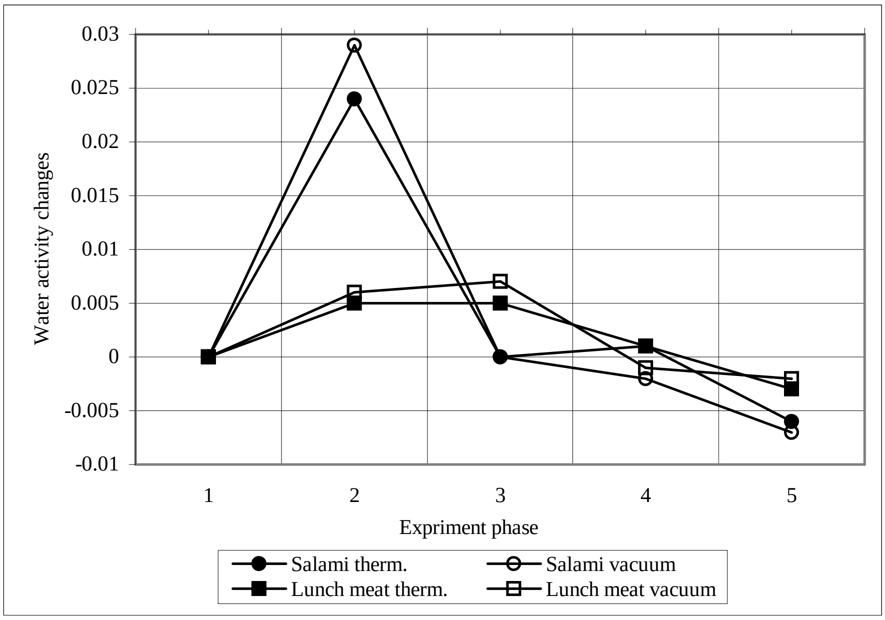

Fig. 4. Water activity changes in examined sausages in comparison with previous experiment phase

During the experiment, an inversely proportional dependence between the water activity and the protein and water content quotient *b/w* was found [4,5] (Fig. 5).

The values of the *b/w* quotient for the sausages before packaging was different and equal to 0.34 for Salami and 0.17 for Lunch meat. During their storage in multilayer foils, a gradual decrease of those values was observed. Lower values were found for the vacuum packed samples in comparison to samples in the thermoshrinkable packaging. The lowest values of the *b/w* quotient were determined in the third step of the experiment: 0.31 and 0.14 for Salami and Lunch meat, respectively. In the final phase of the experiment, the quotient values in Lunch meat samples in both types of packaging became equalized, however in Salami samples the difference was equal to 0.02.

Analysis of variance, performed with the use of the Fisher-Snedecor test, confirmed statistically significant influence of the sausage type, packaging type, as well as the experiment phase, on the value of the *b/w* quotient. A statistically significant influence of interactions between the sausages type and the experiment phase was also observed.

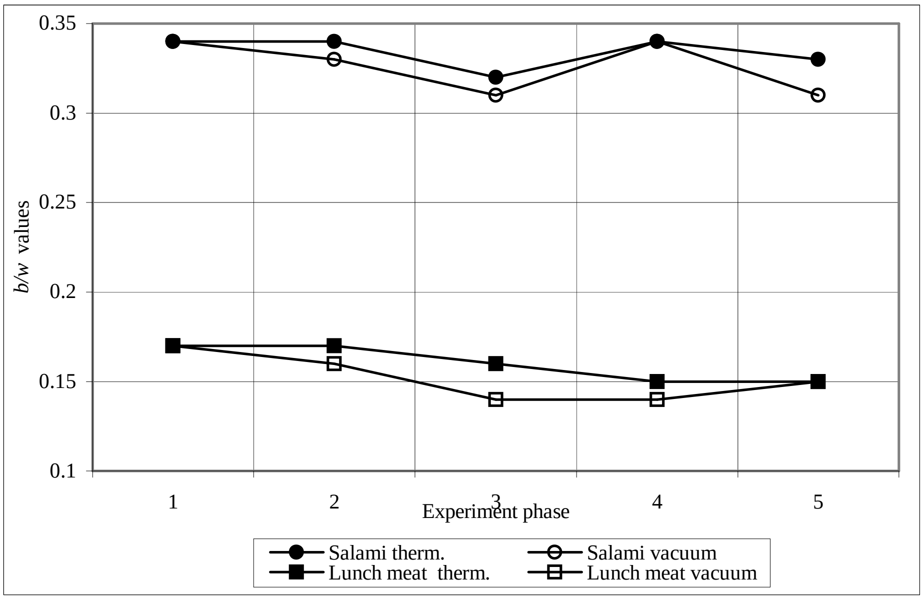

Fig. 5. Changes of *b/w* values in examined sausages during storage

CONCLUSIONS

1. Sausages in each storage phase, both in thermoshrinkable and in vacuum packaging, were characterized with higher water activity than before packaging.

2. The portioned sausages examined were characterized by different water activity as well as by different dynamics of its changes. A statistically significant influence of the sausage type and the experiment phase on the water activity of the sausage samples studied, packed in multilayer foils with different characteristics, was observed.

3. No statistically significant influence of the type of packaging foil used on the fat free dry matter amount in the sausages examined was observed.

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DYNAMIKA ZMIAN AKTYWNOŚCI WODY W PORCJOWANYCH WYROBACH MIĘSNYCH PAKOWANYCH W FOLIE WIELOWARSTWOWE

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Streszczenie. Jednym z podstawowych parametrów jakości, na podstawie którego określa się trwałość przechowalniczą wyrobów mięsnych, jest aktywność wody (a_w). Wartość a_w ulega wahaniom podczas przechowywania przetworów. Celem doświadczenia było określenie i porównanie dynamiki zmian aktywności wody, wartości pH i wybranych wyróżników chemicznych w wędlinach o zróżnicowanej trwałości, zapakowanych w atmosferze próżni w opakowania bezpośrednie i przechowywanych w warunkach chłodniczych. Materiałem doświadczalnym było salami wołowo-wieprzowe oraz mielonka wieprzowa. Porcje wędlin zapakowano w dwa rodzaje woreczków foliowych: próżniowe PA/PE oraz czterowarstwowe o cechach termokurczliwości, dające efekt „naciągniętej skórki”. W próbach oznaczano skład chemiczny, aktywność wody i wartość pH oraz obliczano iloraz zawartości białka i wody *b/w*. Na podstawie uzyskanych wyników stwierdzono, że badane wędliny różniły się pod względem podstawowego składu chemicznego, wartości pH, aktywności wody oraz ilorazu zawartości białka i wody *b/w*. Obie wędliny w każdej z pięciu faz przechowywania, zarówno w opakowaniach termokurczliwych jak i próżniowych, charakteryzowały się większą aktywnością wody niż przed zapakowaniem, a każda z nich wykazała się odmienną aktywnością wody oraz dynamiką jej zmian. Analiza wariancji, wykonana w pracy z zastosowaniem testu Fishera-Snedecora, wykazała statystycznie istotny wpływ rodzaju wędliny i fazy doświadczenia na aktywność wody badanych prób wędlin, zapakowanych w folie wielowarstwowe o zróżnicowanej charakterystyce.

Słowa kluczowe: produkty mięsne, opakowania jednostkowe, aktywność wody