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EFFECT OF COMPOSITION OF ATMOSPHERE INSIDE PACKAGING ON QUALITY OF MINIMALLY PROCESSED VEGETABLE SALAD BASED ON WHITE CABBAGE

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Key words: coleslaw mix, modified atmosphere, minimally processed food products

The aim of the study was to determine the effect of composition of atmosphere inside packaging on the sensory quality, selected physico-chemical properties and microbiological quality of coleslaw mix stored for 12 days at 4°C. Moreover, in the study changes in carbon dioxide and oxygen content were analysed in the atmosphere inside packaging with the product. In the analyses a coleslaw mix was used with the following composition: 80% white cabbage cv. Masada and Galaksa, and 20% carrot cv. Perfekcja.

Packaging of coleslaw mix, produced from cabbage cv. Galaksa in modified atmosphere with O_2 contents of 20% with a 5% or 25% addition of CO_2 resulted in an extension of its sensory acceptability. After 9-day storage its sensory attributes were considered typical. In the salad based on cabbage cv. Masada packaged in modified atmosphere (irrespective of its composition) intrinsic sensory attributes were retained for only 6 days. It was found that CO_2 content, increased to 25%, in the atmosphere used for the packaging of coleslaw mix (irrespective of the used cabbage cultivar), resulted in the inhibition of tissue respiratory processes. After 12-day storage no effect of composition of atmosphere inside packaging was found on the level of microbial contamination of the product.

INTRODUCTION

In recent years we may observe an increased demand for food exhibiting high nutritive value and short preparation time. Minimally processed vegetables and fruit are examples of such products. They are produced when raw material is cleaned, inedible pats are removed and next the raw material is shredded. Most frequently the product is packaged on trays covered with plastic film or in plastic bags. One of the more popular minimally processed products is coleslaw mix. It is composed of 80% sliced white cabbage and 20% carrots. It is a rich source of vitamins, minerals and biologically-active compounds. This product is widely used both in households and restaurants.

Preservation of natural nutritive value and assurance of safety and convenience of a minimally processed product requires the application of production techniques including mainly non-thermal methods. The most frequently used are modified atmosphere packaging (MAP) and cold storage.

It results from data published in literature worldwide that the most frequently recommended packaging atmosphere for minimally processed vegetables and fruit should contain 2%-5% O_2 and 5%-8% CO_2 [Jacxsens *et al*., 1999]. However, numerous studies are being conducted on the application of atmospheres with other gas contents to extend shelf-life of minimally processed vegetables and fruit. Packaging of endive in the atmosphere containing 1.5% oxygen, 20% carbon dioxide and 78.5% nitrogen is an example of such studies. The application of atmosphere with such a composition contributed to the preservation of good sensory quality of the product during 13-day storage [Bennick *et al*., 1996]. There are few publications concerning packaging conditions of coleslaw mix. Cliffe-Byrnes & O' Beirne [2005] investigated *e.g*. the effect of the cultivar, storage time and packaging plastic film on the quality of this product. They found that the use of microperforated film PA-160 for the packaging of coleslaw resulted in the preservation of its sensory acceptability for the period of 7 days, at oxygen and carbon dioxide contents of approx. 12%.

The aim of the study was to determine the effect of composition of atmosphere inside packaging on the sensory quality, selected physico-chemical properties and microbiological quality of coleslaw mix stored for 12 days at 4°C. Moreover, changes in the contents of carbon dioxide and oxygen were analysed in atmosphere inside packaging with the product.

MATERIAL AND METHODS

Material. In the investigations coleslaw mix was used, composed of 80% white cabbage (*Brassica oleracea*) cv. Masada and Galaksa and 20% carrot (*Daucus carota*) cv. Perfekcja. Raw material was purchased in retail. Three experiments were carried within this study. In experiment 1 coleslaw mix was produced from cabbage cv. Masada, while in experiments 2 and 3 the raw material was cabbage cv. Galaksa.

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Technological process. The raw material was washed, hand-peeled, washed again and dried on blotting paper, next shredded mechanically in a Robocie-Coupe (Vincennes, France). Prepared salad containing 80% cabbage and 20% carrot was packaged in batches of 100 g in bags of laminated plastic: oriented polyamide/polyethylene with layer thickness of 50/40 μm, of 15 x 21 cm and gas permeability (in $cm^3/m^2/24$ h at 23°C) of 100 for carbon dioxide and 45 for oxygen. The product was sealed using an A-300 packaging machine by Multivac (Jastków, Poland) in air atmosphere and in modified atmosphere with the following composition (% O_2/ % CO_2/ % N_2): 10/10/80; 20/5/75; 20/25/55, and next stored for 12 days at 4°C.

Product quality (sensory examination, pH, total acidity and extract) and changes in gas contents inside packaging (in experiments 1 and 2) were analysed after 1, 3, 6, 9 and 12 days of storage. In experiments 1 and 2 quality of fresh vegetable salad was examined at 0 day of storage. The microbial contamination level (total counts of mesophilic and psychrophilic bacteria, counts of moulds and mesophilic and psychrophilic yeasts, as well as counts of lactic acid bacteria), (in experiment 3) was assessed after 1, 6 and 12 days of product storage.

Sensory examination. Sensory examination was performed directly after opening packaging with coleslaw mix. Assessment was based on a 5-point scale, in three replications for each sample [Baryłko-Pikielna, 1975].

Measurement of oxygen and carbon dioxide contents. Assays were performed using a Gaspace 2 Systech Instruments BV (Oxon, UK). Three replications were performed for each sample.

Physico-chemical analysis. Active acidity [PN-90/A-75101/06] and total acidity [PN-90/A-75101/04], as well as soluble solid [PN-90/A-75101/02] were analysed.

Analysis of microbiological quality. Coleslaw mix (approx. 10 g) samples were transferred into a sterile stomacher bag (Merck, Poland) and 90 mL of a physiological salt/peptone solution (Difco, Poland) were added and mixed for 2 min in a DEVIMIX machine (De Ville Biotechnology, Raszyn, Poland). Ten-fold dilutions in the range from 10^{-1} to 10^{-7} were prepared from such prepared samples.

In the determination of total counts of mesophilic and psychrophilic bacteria, counts of mesophilic and psychrophililc moulds and yeasts, and counts of lactic acid bacteria a quantitative culture using the Koch plate method was applied [Burbianka *et al*., 1983]. Media in the case of total counts of mesophililc and psychrophilic bacteria were prepared according to Burbianka *et al.* [1983]. Medium used for the analysis of yeasts and moulds contained 5 g/L yeast extract, 20 g/L glucose, 0.1 g/L chloramphenicol, 15 g/L bacteriological agar, pH 6.6, (BTL, Łódź, Poland). Media in the case of counts of lactic acid bacteria were de Man, Rogosa and Sharpe (MRS) (BTL, Łódź, Poland). The analyses were carried out on duplicate agar plates. The following incubation parameters were adopted: mesophilic bacteria – incubation time of 48-72 h, incubation temperature of 30°C; psychrophilic bacteria – incubation time from 72 to 120 h, incubation temperature of 4°C. Incubation time for the determination of mould and yeast was 72 –96 h, while incubation temperature was 30°C - mesophilic mould and yeast and 15°C - psychrophilic mould and yeast. Incubation time in the case of counts of lactic acid bacteria was 72 h at 30°C.

TABLE 1. Effect of composition of atmosphere inside packaging on the sensory quality of coleslaw mix based on white cabbage cv. Masada and cv. Galaksa.

Sample packaged in atmosphere	Storage time (days)	Overall sensory quality	
		cv. Masada	cv. Galaksa
Raw material	0	5.0	5.0
Air	1	4.7^{a}	5.0
	3	4.3^{ac}	4.4^{ac}
	6	3.3^{ac}	3.7^{ac}
	9	2.4^{ac}	2.0^{ac}
	12	1.9^{ac}	1.9^{ac}
10% O_2/ 10%CO_2/80% N_2	1	5.0^{b}	5.0
	3	4.9^{b}	4.7^{abc}
	6	4.0^{abc}	3.9^{ac}
	9	2.5^{ac}	2.3^{abc}
	12	1.2^{abc}	2.0^{abc}
20% O_2/ 5% CO_2/75% N_2	1	4.6^{a}	5.0
	3	4.5^{a}	4.5^{abc}
	6	3.6^{abc}	4.1^{abc}
	9	2.0^{abc}	3.7^{abc}
	12	2.0^{ac}	2.8^{abc}
20% O_2/ 25%CO_2/55% N_2	1	4.6^{a}	5.0
	3	4.6^{ab}	5.0^{b}
	6	4.2^{abc}	4.4^{abc}
	9	2.1^{abc}	3.7^{abc}
	12	2.1^{ac}	2.8^{abc}

a – statistically significant differences ($p \leq 0.05$) between the score of samples packaged in air and modified atmosphere and the score of raw material; b - statistically significant differences ($p \leq 0.05$) between the score of samples packaged in modified atmosphere and the score of sample packaged in air after the same time storage; c- statistically significant differences ($p \leq 0.05$) between the score of sensory examination after 3, 6, 9 and 12 days of storage and the score after 1 day of storage within the sample.

Statistical analysis of results. Results were analysed with the analysis of variance (ANOVA) and Fisher's least significant difference (LSD) multicomparison test. Statistically significant differences were reported at $p \leq 0.05$. Statistical analysis was performed using computer software Statistica ver. 7.0 (StatSoft, Kraków, Poland).

RESULTS AND DISCUSSION

Coleslaw mix produced from cabbage cv. Masada (experiment 1) packaged in modified atmosphere (% O_2/ % CO_2/ % N_2: 10/10/80; 20/5/75; 20/25/55) exhibited typical sensory at-

TABLE 2. Effect of composition of atmosphere inside packaging on selected physico-chemical properties of coleslaw mix based on white cabbage cv. Masada and cv. Galaksa after 1 and 12 days of storage.

Sample packaged in atmosphere	Storage time (days)	pH	Total acidity (g citric acid/100g product)	Soluble solid (%)
cv. Masada				
Raw material	0	6.04	0.09	8.6
Air	1	6.35^{a}	0.08^{a}	8.2^{a}
	12	6.90^{ac}	0.07^{ac}	7.9^{a}
10% O_2/ 10%CO_2/80% N_2	1	6.41^{a}	0.09^{b}	8.5^{b}
	12	6.72^{abc}	0.08^{abc}	7.7^{abc}
20% O_2/ 5% CO_2/75% N_2	1	6.45^{a}	0.07^{ab}	8.2^{a}
	12	6.90^{ac}	0.07^{a}	8.1^{a}
20% O_2/ 25%CO_2/55% N_2	1	6.66^{ab}	0.07^{ab}	8.5^{b}
	12	6.41^{abc}	0.07^{a}	8.0^{ac}
cv. Galaksa				
Raw material	0	6.32	0.09	9.7
Air	1	6.43	0.08	8.8^{a}
	12	6.79^{ac}	0.06^{ac}	7.8^{ac}
10% O_2/ 10%CO_2/80% N_2	1	6.56^{ab}	0.08	9.8^{b}
	12	5.27^{abc}	0.14^{abc}	8.7^{abc}
20% O_2/ 5% CO_2/75% N_2	1	6.63^{ab}	0.08	9.5^{b}
	12	6.96^{abc}	0.07^{ac}	9.3^{ab}
20% O_2/ 25%CO_2/55% N_2	1	6.61^{ab}	0.08	9.5^{b}
	12	6.86^{ac}	0.07^{ac}	9.4^{b}

a – statistically significant differences ($p \leq 0.05$) between the value of selected physico-chemical properties of samples packaged in air and modified atmosphere and the value of selected physico-chemical properties of raw material; b - statistically significant differences ($p \leq 0.05$) between the value of selected physico-chemical properties of samples packaged in modified atmosphere and the value of selected physico-chemical properties of sample packaged in air after the same time storage; c- statistically significant differences ($p \leq 0.05$) between the value of selected physico-chemical properties after 3, 6, 9 and 12 days of storage and the value after 1 day of storage within the sample.

tributes up to the 6 day of storage (Table 1). Samples packaged in air atmosphere, after identical storage time, were considered medium typical. Packaging of coleslaw from cabbage cv. Galaksa (experiment 2) in modified atmosphere with 20% oxygen content and a 5% or 25% addition of carbon dioxide (balanced with nitrogen) resulted in the extension of the time of its sensory acceptability. After 9 days of storage it received scores of 3.7 points in the overall sensory examination (Table 1). These results confirm studies by McLaughlin & O'Beirne [1999], who obtained good sensory quality of coleslaw mix when storing it in modified atmosphere containing 21% O_2, 25% CO_2 and 54% N_2.

During storage in most analysed samples a statistically significant ($p \leq 0.05$) increase in pH and decrease in total acidity were recorded in comparison to those of fresh salad (Table 2). The value of the extract only in samples produced from cabbage cv. Galaksa packaged in atmosphere containing 20% oxygen with a 5% or 25% addition of carbon dioxide remained at the level reported for fresh salad (at 0 day storage) (Table 2). A higher level of soluble solid in minimally processed carrot packaged in atmosphere with a 10% to 40% addition of CO_2, in comparison to the soluble solid of samples packaged in air atmosphere was observed *e.g.* by Carlin *et al*. [1990].

Based on the measurement of changes in oxygen and carbon dioxide contents in packaging with the analysed coleslaw mix a statistically significant ($p \leq 0.05$) increase in CO_2 contents was recorded in all samples, irrespective of the applied cabbage cultivar and packaging conditions (Table 3). The lowest increase in carbon dioxide content was found in samples packaged in atmosphere containing 20% O_2, 25% CO_2 and 55% N_2. For coleslaw mix produced from cabbage cv. Masada it was 28.4%, while for salad based on cv. Galaksa it was 35%. In these samples a lower oxygen consumption was also recorded, the element being present in the atmosphere inside packaging after 3 days of product storage (Table 3). Fonseca *et al.* [2005], when applying for packaging of kale the atmosphere containing 21% O_2, and 10%; 15% or 20% CO_2 balanced with N_2, also found a reduction in the level of produced carbon dioxide with an increase in the content of this gas in the atmosphere used for product packaging. After 12-day storage carbon dioxide content in packaging with coleslaw mix analyzed in this study, packaged in modified atmosphere of 20% O_2, 25% CO_2 and 55% N_2, was highest due to the high initial concentration of CO_2. For the packaging of respiratory products, such as coleslaw mix, carbon dioxide concentrations of over 20% are generally not recommended. However, it results from a study by Fonseca *et al.* [2005] that vegetables exhibit varied tolerance of high concentrations of carbon dioxide and low concentrations of oxygen. An example in this respect may be good quality of carrot at carbon dioxide concentrations between 30% and 40% [Carlin *et al*., 1990]. In spite of the fact that in vegetable salad produced from cv. Galaksa the increase in carbon dioxide content during storage was higher than in samples based on cv. Masada, sensory quality of salad made from cabbage cv. Galaksa, packaged at O_2 content of 20% with a 5% or 25% addition of CO_2, was retained for a longer period. The effect of the cultivar on the extension of shelf-life of coleslaw mix was also reported by Cliffe-Byrnes & O'Beirne [2005]. They found that coleslaw produced from cabbage cv. Marathon retains its good quality

TABLE 3. Effect of storage time on changes in carbon dioxide and oxygen content in the atmosphere inside packaging with the coleslaw mix based on white cabbage cv. Masada and cv. Galaksa.

Sample packaged in atmosphere	Storage time (days)	Content of CO_2 (%)		Content of O_2 (%)	
		cv. Masada	cv. Galaksa	cv. Masada	cv. Galaksa
Air	1	17.2	15.8	0.0	0.0
	3	21.8^{c}	21.4^{c}	0.0	0.0
	6	34.7^{c}	40.8^{c}	0.0	0.0
	9	42.2^{c}	46.2^{c}	0.0	0.0
	12	46.7^{c}	53.0^{c}	0.0	0.0
10% O_2/ 10%CO_2/80% N_2	1	18.5	18.7^{b}	0.0	0.9^{b}
	3	21.7^{c}	22.4^{c}	0.0	0.0^{c}
	6	35.6^{c}	36.1^{bc}	0.0	0.0^{c}
	9	43.8^{c}	49.4^{bc}	0.0	0.0^{c}
	12	46.8^{c}	47.1^{bc}	0.0	0.0^{c}
20% O_2/ 5% CO_2/75% N_2				1.1^{bc}	
	1	19.4	15.9	0.0^{c}	5.0^{b}
	3	24.0^{c}	21.9^{c}	0.0^{c}	0.3^{c}
	6	34.8^{c}	35.4^{bc}	0.0^{c}	0.0^{c}
	9	41.6^{c}	45.1^{c}	0.0^{c}	0.0^{c}
	12	44.7^{c}	53.6^{c}		0.0^{c}
				0.0	
20% O_2/ 25%CO_2/55% N_2	1	29.8^{b}	26.0^{b}	7.9^{bc}	13.6^{b}
	3	34.0^{bc}	29.8^{bc}	4.2^{bc}	9.4^{bc}
	6	42.3^{bc}	47.0^{bc}	0.0^{c}	0.0^{c}
	9	49.1^{bc}	51.1^{bc}	0.0^{c}	0.0^{c}
	12	53.4^{bc}	60.0^{bc}	0.0^{c}	0.0^{c}

b - statistically significant differences ($p \leq 0.05$) between the content of O_2 or CO_2 of samples packaged in modified atmosphere and the content of O_2 or CO_2 of sample packaged in air after the same time storage; c- statistically significant differences ($p \leq 0.05$) between the content of O_2 or CO_2 after 3, 6, 9 and 12 days of storage and the content of O_2 or CO_2 after 1 day of storage within the sample.

longer than salad made from cv. Lennox, despite the observed higher intensity of tissue respiration in cv. Marathon.

Based on analyses of microbiological quality of coleslaw mix (experiment 3) it was found that in samples packaged in modified atmosphere of 20% O_2, 25% CO_2 and 55% N_2 after 6-day storage an inhibition of growth was reported for psychrophilic bacteria, as well as moulds and psychrophilic yeasts at the level of 10^3 U/g. After 12-day storage no effect of atmosphere inside packaging was recorded on the counts of most analyzed groups of microorganisms. Counts of mesophilic bacteria, moulds and mesophilic and psychrophilic yeasts increased from 10^3-10^4 U/g to10^5–10^6 U/g, psychrophilic bacteria were undetectable at decimal dilution of10^{-7}, while counts of lactic acid bacteria increased from 10^2 U/g to 10^4 U/g, after 12-day product storage.

CONCLUSIONS

1. Packaging of coleslaw mix produced from cabbage cv. Galaksa in modified atmosphere of 20% O_2, 25% CO_2 and 55% N_2 resulted in an extension of its sensory acceptability. After 9-day storage its sensory attributes were considered typical.

2. The quality of stored coleslaw mix is affected both by the composition of modified atmosphere in which the product was packaged, and by the used cabbage cultivar.

3. Content of CO_2 increased to 25% in the atmosphere used in packaging of coleslaw mix (irrespective of the used cabbage cultivar) resulted in an inhibition of tissue respiratory processes. In these samples the lowest increase in CO_2 content and a slower O_2 consumption were recorded during storage.

4. After 12-day storage no effect of the composition of atmosphere inside packaging was found at the level of microbial contamination of the product.

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WPŁYW SKŁADU ATMOSFERY WEWNĄTRZ OPAKOWANIA NA JAKOŚĆ MAŁO PRZETWORZONEJ SAŁATKI WARZYWNEJ NA BAZIE KAPUSTY BIAŁEJ

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Celem pracy było określenie wpływu składu atmosfery wewnątrz opakowania na jakość sensoryczną, wybrane cechy fizykochemiczne oraz jakość mikrobiologiczną sałatki warzywnej typu coleslaw przechowywanej przez 12 dni w temperaturze 4°C. W pracy zbadano również zmiany zawartości ditlenku węgla i tlenu w atmosferze wewnątrz opakowania z produktem. Do badań użyto mieszankę warzywną typu coleslaw o składzie: 80% kapusty białej odmian: Masada i Galaksa oraz 20% marchwi odmiany *Perfekcja*.

Zapakowanie sałatki warzywnej typu coleslaw, otrzymanej z kapusty białej odmiany *Galaksa*, w atmosferze modyfikowanej o zawartości O_2: 20% z 5% lub 25% dodatkiem CO_2 wpłynęło na przedłużenie jej akceptowalności sensorycznej. Po 9 dniach przechowywania jej cechy sensoryczne uznano za typowe. W sałatce na bazie kapusty białej odmiany *Masada* zapakowanej w atmosferze modyfikowanej (niezależnie od składu) typowe cechy sensoryczne utrzymywały się tylko przez 6 dni. Stwierdzono, że zwiększona do 25% zawartość CO_2 w atmosferze zastosowanej do pakowania sałatki warzywnej typu coleslaw (niezależnie od użytej odmiany kapusty), spowodowała zahamowanie procesów oddechowych tkanki. Po 12 dniach przechowywania nie stwierdzono wpływu składu atmosfery wewnątrz opakowania na poziom skażenia mikrobiologicznego produktu.