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THE EFFECT OF MODIFIED ATMOSPHERE PACKAGING CONDITIONS ON QUALITY OF MINIMALLY PROCESSED KALE*

Summary. The aim of the study was to determine the effect of packaging conditions on quality of minimally processed kale during 12-day storage at a temperature of 4°C. In the experiment the packaging material was film with oxygen permeability of 1.5 and 35 cm^3/m^2 during 24 h, microperforation of packaging material and modified atmosphere with a high oxygen content (30, 55 and 80%) were applied. Packaging in air atmosphere was also used. Samples packaged in air and in atmosphere consisted of 80% O_2 / 10% CO_2 / 10% N_2, using packaging film microperforation received the highest scores in sensory examination during storage. Values of these scores after 12-day storage ranged from 4.6 to 5.0. Samples packaged using packaging material without microperforation, irrespective of its permeability, were evaluated as sensorily acceptable up to the 9th day of storage. Further storage, as a result of too little permeability of the packaging material, resulted in the appearance of unpleasant aroma and disqualification of the sample.

Key words: modified atmosphere packaging, kale, sensory quality

Introduction

Modified atmosphere packaging (MAP) is not a new technology. It was developed in the early 1970's, but its rapid development occurred as late as the 1990's. MAP consists in the application of an appropriate gas composition inside packaging, differing from the natural atmosphere.

The technology of modified atmosphere packaging is applied first of all in the storage of fresh vegetables prepared for consumption, i.e. washed, peeled and frequently cut. The aim of modified atmosphere packaging is to form an adequately balanced gas

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composition inside a packaging, which would facilitate the biggest possible reduction of physiological activity of the product. Moreover, the level of oxygen and carbon dioxide in the packaging may not have a negative effect on the product (PRETEL et AL. 2000). Initial concentration of gas in products packaged in modified atmosphere has a considerable influence on their metabolic rates, and thus also the rate of quality changes in packaged raw materials. Numerous studies have been conducted on the selection of modified atmosphere packaging conditions for different minimally processed vegetables and fruits. Most authors suggest the proportion of 1-3% oxygen and 3-10% carbon dioxide (AGAR et AL. 1999, LEE et AL. 1996). The latest studies have been directed at the application of high-oxygen atmosphere in packaging of unprocessed and minimally processed fruits and vegetables. According to literature data high concentrations of oxygen (70-100%) may cause the so-called oxidative shock, which slows down tissue respiratory processes, prevents anaerobic respiration and inhibits the development of microorganisms (JACXSENS et AL. 2001).

Kale (*Brassica oleracea* var. *acephala*), sometimes called feathered cabbage, is one of the oldest crops of the cabbage family, morphologically closest to wild cabbage. This raw material is a particularly valuable vegetable among those of the cabbage family, at the same time insufficiently popular or appreciated in Poland. In contrast, kale, due to its high nutritive value, is very popular in Scandinavia, Portugal and Turkey. It is delicious and rich in valuable biological substances. The application of minimal processing in combination with modified atmosphere packaging, at the selection of its adequate composition and appropriate packaging material, may extend shelf-life of kale after harvest and its availability (SIWULSKI 1993).

This study evaluated the effect of packaging in modified atmosphere with a high oxygen content on sensory quality and selected physico-chemical properties of minimally processed kale.

Material and methods

Studies were conducted on leaves of kale cv. 'Refleks'. Raw material for analyses came from a horticultural farm in Pamiątkowo near Szamotuły.

Kale leaves after sorting and removal of stalks were washed under cold running water. After draining they were immersed in an ascorbic acid solution (0.5%) for approximately 10 min, and next they were drained again and dried on blotting paper. Such prepared raw material in batches of 50 g was placed on PP trays with the dimensions of 205/160/60 (mm) and oxygen permeability of 7-8 cm^3/m^2 during 24 h and sealed using a T 200 sealing machine (Multivac) equipped with a gas mixer and a microperforation device. Trays with kale were sealed using two types of packaging films: VAC HB 180my (PAEVOH/PE) with oxygen permeability of 1.5 cm^3/m^2 during 24 h and Opalen HB 55my AF (OPA/PE) with oxygen permeability of 35 cm^3/m^2 during 24 h. Moreover, the packaging material was microperforated using rings with a diameter of 7 cm equipped with 10 piercing needles at the circumference. The diameter of perforating needles was 0.7 μm. Application of one ring (1·10) yielded 10 holes (±1) at the width of the tray with the product, while three rings (3·10) gave 30 holes (±3).

The packaged product was stored at a temperature of 4°C for 12 days. Quality was evaluated and the product analyses were performed after 1, 3, 6, 9 and 12 days of storage.

The study comprised two experiments. In experiment 1 kale was packaged using film with oxygen permeability of 1.5 cm^3/m^2 during 24 h and the following compositions of atmosphere: air, 30% O_2 / 10% CO_2 / 60% N_2, 55% O_2 / 10% CO_2 / 35% N_2 and 80% O_2 / 10% CO_2 / 10% N_2. Experiment 2, in which samples were packaged using film with oxygen permeability of 35 cm^3/m^2 during 24 h, included the following packaging variants:

- air
- 55% O_2 / 10% CO_2 / 35% N_2,
- 80% O_2 / 10% CO_2 / 10% N_2,
- air, film microperforation (1·10),
- air, film microperforation (3·10),
- 55%O_2 / 10% CO_2 / 35% N_2, film microperforation (1·10),
- 55% O_2 / 10% CO_2 / 35% N_2, film microperforation (3·10),
- 80% O_2 / 10% CO_2 / 10% N_2, film microperforation (1·10),
- 80% O_2 / 10% CO_2 / 10% N_2, film microperforation (3·10).

Evaluation and analysis of samples

Active acidity (pH) was determined according to Standard PN-90/A-75101/06 (1990) using a 710A pehameter (Orion). Contents of solids were determined according to Standard PN-90/A-75101/02 (1990). Prior to physico-chemical analyses kale samples were homogenized.

Contents of oxygen and carbon dioxide in packaging with kale were measured using an Oxybaby apparatus by WITT-Gastechnik. Three replications (measurement in three packagings performed twice) were made for each sample.

Sensory examination was conducted using a 5-point scale with the application of a specially developed sensory examination chart. The product was evaluated by a 5--member panel immediately after the opening of the packaging after 1, 3, 6, 9 and 12 days of storage. The evaluated parameters included colour (type-weighting coefficient 4, uniformity WE 3), taste (WE 3), aroma (WE 5), consistency (WE 4) and the presence of drip in the packaging (WE 1). Moreover, samples of fresh kale (unprocessed) were also evaluated.

Statistical analysis of results was conducted based on the analysis of variance and the LSD Fisher's test (at the level of significance $p \leq 0.05$). Analysis was conducted using Statistica ver. 8.0 software (StatSoft, Cracow, Poland).

Results and discussion

Sensory quality of samples

Raw material used for analyses was characterised by a very good quality and received an overall sensory score of 5.0 (Table 1).

Table 1. The effect of atmosphere composition on sensory quality of kale packaged in film with oxygen permeability of 1.5 cm^3/m^2 during 24 h (experiment 1)
Tabela 1. Wpływ składu atmosfery na jakość sensoryczną jarmużu zapakowanego w folię o przepuszczalności tlenu 1,5 cm^3/m^2 w czasie 24 h (doświadczenie 1)

Packaging conditions	Storage time (days)	Attributes				
		colour	aroma	taste	consistency	overall score
Fresh kale	0	5.0	5.0	5.0	5.0	5.0
Air	1	5.0	5.0	5.0	5.0	5.0
	3	5.0	4.5 b	4.5 b	4.5 b	4.6
	6	5.0	3.7 ab	4.7 b	4.5 b	4.5 b
	9	4.8 b	1.0 b	4.0 b	4.0 b	3.7 b
	12	–	–	–	–	–
30% O_2 / 10% CO_2 / 60% N_2	1	5.0	5.0	5.0	5.0	5.0
	3	5.0	4.5 b	5.0 a	4.8 ab	4.7
	6	5.0	4.0 ab	4.0 ab	4.0 ab	4.2 ab
	9	4.8 b	3.5 ab	4.0 b	4.0 b	4.1 ab
	12	5.0	1.0 ab	–	3.4 ab	2.5 ab
55% O_2 / 10% CO_2 / 35% N_2	1	5.0	5.0	5.0	5.0	5.0
	3	5.0	4.7 b	4.5 b	4.5 b	4.4 b
	6	5.0	4.0 ab	4.0 ab	4.0 ab	4.4 ab
	9	5.0 a	4.5 ab	4.0 ab	4.0 b	4.5 ab
	12	5.0	1.0 ab	–	4.0 b	3.3 ab
80% O_2 / 10% CO_2 / 10% N_2	1	5.0	5.0	5.0	5.0	5.0
	3	5.0	4.7 b	4.3 b	4.7 b	4.4 b
	6	5.0	4.0 ab	4.0 ab	4.0 ab	4.4 ab
	9	5.0 a	3.5 ab	3.0 ab	4.0 b	4.1 ab
	12	5.0	1.0 ab	–	4.0 b	3.3 ab

a – statistically significant difference ($p \leq 0.05$) between a selected attribute in evaluation of samples packaged in modified atmosphere and the examined value for reference sample (air-packaged sample), after identical storage time.

b – statistically significant difference ($p \leq 0.05$) between a selected attribute in evaluation after 3, 6, 9 and 12 days of storage and the value of examined parameter after 1-day storage.

In both experiments after 1 and 3 days of storage scores for overall sensory examination for all samples were very high, ranging from 4.7 to 5.0 (Tables 1, 2).

In experiment 1, where packaging material with oxygen permeability of 1.5 cm^3/m^2 during 24 h was used, after 1-day storage all samples packaged in modified atmosphere received maximum scores for overall sensory examination. During further storage these values decreased. After 6 days of storage samples received good scores, ranging from 4.2 to 4.5 (Table 1). After 12 days of storage MAP samples with the atmosphere composition of 55% O_2 / 10% CO_2 / 35% N_2 and 80% O_2 / 10% CO_2 / 10% N_2 were charac-

Table 2. The effect of atmosphere composition on sensory quality of kale packaged in film with oxygen permeability of 35 cm^3/m^2 during 24 h (experiment 2)
Tabela 2. Wpływ składu atmosfery na jakość sensoryczną jarmużu zapakowanego w folię o przepuszczalności tlenu 35 cm^3/m^2 w czasie 24 h (doświadczenie 2)

Packaging conditions	Storage time (days)	Attributes				
		colour	aroma	taste	consistency	overall score
1	2	3	4	5	6	7
Fresh kale	0	5.0	5.0	5.0	5.0	5.0
Air	1	5.0	5.0	5.0	5.0	5.0
	3	5.0	4.5	5.0	5.0	4.9 b
	6	5.0	3.0 b	4.0	4.0 b	4.2 b
	9	5.0	1.0 b	1.0	4.0 b	3.5 b
	12	5.0	–	–	–	–
55% O_2 / 10% CO_2 / 35% N_2	1	5.0	5.0	5.0	5.0	5.0
	3	5.0	5.0	5.0	5.0	5.0
	6	4.5	4.5 a	5.0	5.0 a	4.7 ab
	9	4.0	3.2 ab	4.5	4.5 ab	4.0 ab
	12	4.0	1.0 b	4.0	4.5 b	2.8 b
80% O_2 / 10% CO_2 / 10% N_2	1	5.0	5.0	5.0	5.0	5.0
	3	5.0	5.0	5.0	5.0	5.0
	6	4.5	4.0 ab	5.0	5.0 a	4.8 ab
	9	4.0	2.0 ab	4.5	4.5 ab	3.8 ab
	12	4.0	2.0 b	4.0	4.5 b	3.0 b
Air, film micro-perforation 1·10	1	5.0	5.0	5.0	5.0	5.0
	3	5.0	4.5	5.0	5.0	4.9 b
	6	5.0	4.0 ab	4.0	4.0 b	4.8 ab
	9	5.0	4.0 ab	4.0	4.0 b	4.5 ab
	12	5.0	4.0 b	4.0	4.0 b	4.7 b
Air, film micro-perforation 3·10	1	5.0	5.0	5.0	5.0	5.0
	3	5.0	4.5	5.0	5.0	4.7 a
	6	5.0	4.0 ab	4.0	4.0 b	4.4 ab
	9	5.0	4.0 ab	4.0	4.0 b	4.5 ab
	12	5.0	4.0 b	4.0	4.0 b	4.7 ab
55% O_2 / 10% CO_2 / 35% N_2, film micro-perforation 1·10	1	5.0	5.0	5.0	5.0	5.0
	3	5.0	5.0	5.0	5.0	5.0
	6	4.5	5.0 a	5.0	5.0 a	4.8 ab
	9	4.0	3.3 ab	4.5	4.5 ab	4.0 ab
	12	3.5	3.3 b	4.0	4.5 b	3.9 b

Table 2 – cont. / Tabela 2 – cd.

1	2	3	4	5	6	7
55% O_2 / 10% CO_2 / 35% N_2, film micro-perforation 3·10	1	5.0	5.0	5.0	5.0	5.0
	3	5.0	5.0	5.0	5.0	5.0
	6	4.5	5.0 a	5.0	5.0 ab	4.8 ab
	9	4.0	4.0 ab	4.5	4.5 ab	4.2 ab
	12	3.5	3.7 b	4.0	2.7 b	3.3 b
80% O_2 / 10% CO_2 / 10% N_2, film micro-perforation 1·10	1	5.0	5.0	5.0	5.0	5.0
	3	5.0	4.5	5.0	5.0	4.9 b
	6	5.0	4.0 ab	4.0	4.0 b	4.4 ab
	9	5.0	4.0 ab	4.0	4.0 b	4.5 ab
	12	5.0	4.0 b	4.0	4.0 b	4.6 b
80% O_2 / 10% CO_2 / 10% N_2, film micro-perforation 3·10	1	5.0	5.0	5.0	5.0	5.0
	3	5.0	4.5	5.0	5.0	4.9 b
	6	5.0	4.0 ab	4.0	4.0 b	4.4 ab
	9	5.0	4.0 ab	4.0	4.0 b	4.5 ab
	12	5.0	4.0 b	4.0	4.0 b	4.6 ab

a – statistically significant difference ($p \leq 0.05$) between a selected attribute in evaluation of samples packaged in modified atmosphere and the examined value for reference sample (air-packaged sample), after identical storage time.

b – statistically significant difference ($p \leq 0.05$) between a selected attribute in evaluation after 3, 6, 9 and 12 days of storage and the value of examined parameter after 1-day storage.

terised by scores of overall sensory examination of 3.3, while the sample packaged in modified atmosphere of 30% O_2 / 10% CO_2 / 60% N_2 received a score of 2.5 (Table 1). These samples, despite overall scores after 12-day storage of approximately 3 points, were characterized by a very unpleasant aroma (score 1.0). The sample packaged in air atmosphere after 12-day storage was not valuated due to its very poor sensory quality (Table 1). Taste of kale leaves changed significantly only in samples packaged in air atmosphere. In the other samples, despite changes in aroma, scores given for taste ranged from 4 to 5. In samples packaged in the atmosphere with 30, 55 and 80% contents of oxygen in experiment 1 after 12 days of storage due to the intensive, extrinsic aroma, their aroma was not evaluated (Table 1).

Consistency of kale stored in modified atmosphere to a slight extent affected a deterioration of scores for overall sensory examination. Throughout the entire storage period kale leaves were firm and crisp and their scores ranged from 5.0 after 1 day of storage to 4.0 after 12 days of storage (Table 1).

Colour of kale during storage until the completion of the experiment was evaluated as very good (score given 5.0). Only in case of samples packaged in air and gas atmosphere of 30% O_2 / 10% CO_2 / 60% N_2 after 9 days of storage a slightly white coating was observed, which resulted in the deterioration of scores given for colour only to values ranging from 4.7 to 4.8 (Table 1).

In the second experiment, where film with oxygen permeability of 35 cm^3/m^2 during 24 h was used (with no microperforation and applying microperforation of 1·10 and 3·10) air packaging was applied and identical compositions of modified atmosphere as those in experiment 1, except for the sample with a 30% oxygen content, which among high-oxygen atmosphere received the lowest scores in sensory examination. Moreover, anaerobic conditions formed in the packaging with this sample after 12 days of storage.

In experiment 2 samples packaged using film with no microperforation, in air atmosphere and in modified atmosphere with the following compositions: 55% O_2 / 10% CO_2 / 35% N_2 and 80% O_2 / 10% CO_2 / 10% N_2 received the lowest scores. Similarly as in the first experiment, permeability of film with no microperforation was too low, which resulted in the appearance of unpleasant aroma in these samples, despite the application of high oxygen concentrations in the atmosphere. As a consequence, these samples were not classified as sensorily acceptable after 12 days of storage (Table 2). Application of the following packaging conditions: air atmosphere, microperforation (1·10) and (3·10) as well as atmosphere of 80% O_2 / 10% CO_2 / 10% N_2 with film microperforation of (1·10) and (3·10) made it possible to obtain a product of highest quality. Values of sensory examination scores of these samples throughout 12 days of storage ranged from 4.6 to 5.0. All attributes included in overall sensory examination (i.e. aroma, taste, colour and consistency) in these samples received high scores amounting to 4.0-5.0 (Table 2).

In both experiments the biggest effect on the deterioration of overall sensory examination for samples packaged using packaging material without microperforation was found for scores given for aroma. During storage the aroma of these samples received poorer and poorer scores. In the sample packaged in air atmosphere a significant deterioration of aroma was recorded as early as after 6 days of storage. On the 9th day in the air-packaged sample a very intensive sulfur aroma appeared, characteristic for vegetables of the *Cruciferae* family, disqualifying the sample, while in the other samples aroma was intrinsic, typical of kale. After 12 days in all samples a deterioration of aroma was observed and scores did not exceed 1, which is also equivalent to the disqualification of the sample due to this attribute of sensory examination, despite good scores given in the examination of the other attributes.

Physico-chemical analysis

The value of pH in fresh kale was 6.3. The lowest initial pH values were recorded in all samples in the first experiment (Table 3) and in samples from experiment 2 packaged in air, in air with microperforation of packaging material and in atmosphere of 80% O_2 / 10% CO_2 / 10% N_2 with packaging film microperforation (Table 4). A decrease in pH of samples after 1-day storage could have resulted from the application of ascorbic acid for rinsing of kale leaves. After 3-day storage values of pH for all analysed samples increased to values ranging from 6.1 to 6.5 and remained similar up to the 12th day of storage (Tables 3, 4).

Solids content in fresh kale leaves was 12.4%. A significant decrease in solids content during storage was recorded only in experiment 1 in the sample packaged in modified atmosphere of 55% O_2 / 10% CO_2 / 35% N_2 (Table 3). A decrease in solids content in samples could have caused the appearance of microorganisms in the product.

Table 3. The effect of atmosphere composition on solid content, pH and changes in O_2 and CO_2 contents in the atmosphere inside packaging with kale packaged in film with oxygen permeability of 1.5 cm^3/m^2 during 24 h (experiment 1)
Tabela 3. Wpływ składu atmosfery na zawartość ekstraktu, pH oraz zmiany zawartości O_2 i CO_2 w atmosferze wewnątrz opakowania z jarmużem zapakowanym w folię o przepuszczalności tlenu 1,5 cm^3/m^2 w czasie 24 h (doświadczenie 1)

Packaging conditions	Storage time (days)	Solids (%)	pH	O_2 content (%)	CO_2 content (%)
Fresh kale	0	12.4	6.3	–	–
Air	1	10.8	5.5 c	14.6	6.4 b
	3	11.0	6.2 c	6.9 ab	13.4 b
	6	12.3	6.1 c	0.2 b	19.5 b
	9	10.2 c	6.2 c	0.0 b	22.1 b
	12	10.8	6.4 b	0.0 b	22.5 b
30% O_2 / 10% CO_2 / 60% N_2	1	11.9	5.5 c	23.4 ab	13.4 ab
	3	13.2 a	6.1 bc	17.2 ab	18.7 ab
	6	11.1	6.1 bc	10.1 ab	24.4 ab
	9	12.2 a	6.3 ab	2.6 ab	30.1 ab
	12	10.6	6.5 b	0.1 b	30.2 ab
55% O_2 / 10% CO_2 / 35% N_2	1	13.2 a	5.5 c	48.4 ab	13.4 ab
	3	13.1 a	6.1 bc	4.3 ab	20.1 ab
	6	14.5 ac	6.2 bc	32.0 ab	26.0 ab
	9	11.5	6.2 bc	25.5 ab	31.0 ab
	12	10.7 b	6.5 bc	22.7 ab	33.0 ab
80% O_2 / 10% CO_2 / 10% N_2	1	11.2	5.5 c	72.8 ab	15.0 ab
	3	11.3	6.2 bc	65.2 ab	30.3 ab
	6	12.4	6.2 bc	56.5 ab	26.1 ab
	9	13.0 a	6.2 bc	49.4 ab	31.5 ab
	12	11.4	6.4 b	43.9 ab	35.7 ab

a – statistically significant difference ($p \leq 0.05$) between a selected attribute in evaluation of samples packaged in modified atmosphere and the examined value for reference sample (air-packaged sample), after identical storage time.

b – statistically significant difference ($p \leq 0.05$) between a selected attribute in evaluation after 3, 6, 9 and 12 days of storage and the value of examined parameter after 1-day storage.

c – statistically significant difference ($p \leq 0.05$) between a selected attribute in evaluation after 1, 3, 6, 9 and 12 days of storage and the value of examined parameter for fresh kale.

Analysis of gas contents in packaging

In samples packaged in air atmosphere, irrespective of permeability of the applied packaging material, after 6 days of storage oxygen content was approximately 0.2%, while anaerobic conditions were formed after 9 and 12 days of storage. In samples

Biegańska-Marecik R., Radziejewska-Kubzdela E., 2009. The effect of modified atmosphere packaging conditions on quality of minimally processed kale. Nauka Przyr. Technol. 3, 4, #135.

Table 4. The effect of atmosphere composition on solid content, pH and changes in O_2 and CO_2 contents in the atmosphere inside packaging with kale packaged in film with oxygen permeability of 35 cm^3/m^2 during 24 h (experiment 2)
Tabela 4. Wpływ składu atmosfery na zawartość ekstraktu, pH oraz zmiany zawartości O_2 i CO_2 w atmosferze wewnątrz opakowania z jarmużem zapakowanym w folię o przepuszczalności tlenu 35 cm^3/m^2 w czasie 24 h (doświadczenie 2)

Packaging conditions	Storage time (days)	Solids (%)	pH	O_2 content (%)	CO_2 content (%)
1	2	3	4	5	6
Fresh kale	0	12.4	6.3	–	–
Air	1	10.8	5.5 c	16.2	4.5
	3	10.7 c	6.1 bc	8.9 b	10.5 b
	6	9.8 b	6.1 bc	0.2 b	19.9 b
	9	10.1 c	6.3 b	0.0 b	23.1 b
	12	–	–	0.0 b	22.3 b
55% O_2 / 10% CO_2 / 35% N_2	1	11.8	6.2 ac	47.0 a	15.4 a
	3	10.6 c	6.3 ab	29.9 ab	18.9 ab
	6	10.5 ac	6.3 ab	28.1 ab	29.4 ab
	9	10.1 bc	6.2 ac	22.2 ab	40.9 ab
	12	10.8 b	6.1 bc	12.6 ab	52.2 ab
80% O_2 / 10% CO_2 / 10% N_2	1	12.9 a	6.2 a	70.8 a	17.7 a
	3	11.8 a	6.2 abc	62.3 ab	16.2 a
	6	11.5	6.1 a	57.3 ab	32.5 ab
	9	10.8 ab	6.1 abc	46.5 ab	42.9 ab
	12	10.2 bc	6.2 bc	43.8 ab	46.9 ab
Air, film micro-perforation 1·10	1	10.7 c	5.4 ac	17.7	3.9 a
	3	10.3 c	6.2 bc	17.0 a	4.9 a
	6	11.0 b	6.3 bc	16.1 a	5.7 a
	9	10.5 c	6.2 abc	17.2 a	4.9 a
	12	10.0 c	6.1 b	17.4 a	4.9 a
Air, film micro-perforation 3·10	1	10.7 c	5.4 c	18.6	3.2
	3	10.8 c	6.1 bc	18.6 a	2.6 a
	6	12.3	6.1 bc	17.7 a	3.6 a
	9	11.4 b	6.2 abc	18.4 a	2.9 a
	12	8.4 c	6.3 b	18.8 a	2.8 a
55% O_2 / 10% CO_2 / 35% N_2, film micro-perforation 1·10	1	12.4	6.2 ac	43.3 a	10.0 a
	3	12.3	6.0 abc	18.0 ab	4.7 ab
	6	12.0 a	6.1 bc	15.8 ab	4.2 ab
	9	11.0 c	6.1 abc	18.0 ab	1.6 ab
	12	11.6	6.0 bc	18.7 ab	2.0 ab

Table 4 – cont. / Tabela 4 – cd.

1	2	3	4	5	6
55% O_2 / 10% CO_2 / 35% N_2, film micro-perforation 3·10	1	11.1	6.3 a	31.6 a	11.1 a
	3	10.8	6.1 bc	17.6 ab	3.7 ab
	6	11.4 abc	6.2 abc	18.4 ab	1.4 ab
	9	9.8	6.2 abc	19.3 ab	0.2 ab
	12	10.6	6.0 bc	18.1 ab	3.0 ab
80% O_2 / 10% CO_2 / 10% N_2, film micro-perforation 1·10	1	11.6	5.4 c	78.9 a	8.7 a
	3	11.5	6.3 ab	19.3 ab	4.6 ab
	6	11.1	6.1 bc	16.8 ab	4.3 ab
	9	10.9	6.2 abc	16.8 ab	4.3 ab
	12	10.4	6.3 b	16.4 ab	4.7 ab
80% O_2 / 10% CO_2 / 10% N_2, film micro-perforation 3·10	1	11.3	5.5 ac	71.8 a	5.9
	3	11.4 abc	6.3 ab	18.0 ab	4.4 a
	6	11.3 a	6.2 bc	18.5 ab	1.8 ab
	9	11.0	6.2 abc	18.1 ab	2.0 ab
	12	11.6	6.4 b	18.5 ab	2.6 ab

a – statistically significant difference ($p \leq 0.05$) between a selected attribute in evaluation of samples packaged in modified atmosphere and the examined value for reference sample (air-packaged sample), after identical storage time.

b – statistically significant difference ($p \leq 0.05$) between a selected attribute in evaluation after 3, 6, 9 and 12 days of storage and the value of examined parameter after 1-day storage.

c – statistically significant difference ($p \leq 0.05$) between a selected attribute in evaluation after 1, 3, 6, 9 and 12 days of storage and the value of examined parameter for fresh kale.

packaged in modified atmosphere with an initial oxygen content of 55 and 80% a decrease was recorded in oxygen content by 40 to 50% (Table 4). In turn, in the sample packaged in atmosphere of 30% O_2 / 10% CO_2 / 60% N_2 on the 12th day of storage oxygen concentration decreased to 0.1% (Table 3).

In all samples packaged with the use of microperforated film a decrease in oxygen content was recorded only up to the 3rd day of storage, while further storage did no longer cause significant changes in the content of the analysed gas. From the 3rd to the 12th day of storage the content of oxygen in examined samples ranged from 17.6 to 19.3% (Table 4).

In all samples packaged without microperforation of the packaging material a significant increase was observed in the concentration of carbon dioxide in packaging with the product during storage.

All samples packaged using perforated packaging material were characterised by a decrease in the content of carbon dioxide in packaging during storage to the value ranging from 1 to 5%, irrespective of the composition of atmosphere applied in packaging and the type of perforation (Table 4).

Concluding remarks

Samples packaged in air and in atmosphere with an 80% content of oxygen, using film microperforation of 1·10 and 3·10 received the highest scores in sensory examination during storage. Values of these scores after 12 days of storage ranged from 4.6 to 5.0. JACXSENS et AL. (1999) stated that when using equilibrium modified atmosphere only the application of packaging with high oxygen permeability affects sensory quality of packaged spinach, including also its aroma.

Samples packaged in material without microperforation, irrespective of its permeability, were classified as sensorily acceptable until the 9th day of storage. Further storage, as a result of too little permeability of the packaging material, resulted in the appearance of unpleasant aroma and disqualification of the sample due to this attribute of sensory examination. Among samples packaged in film without microperforation the worst quality was found in samples packaged in air atmosphere and in atmosphere with a 30% oxygen content, in those samples also towards the end of the 12-day storage period anaerobic conditions were formed. JACOBSSON et AL. (2004) applied oriented polypropylene, polyvinyl chloride and low-density polyethylene in modified atmosphere packaging of broccoli. Among applied materials only LDPE, characterized by high oxygen permeability, made it possible to obtain good quality vegetables stored for 7 days.

According to ALLENIE et AL. (2004) the application of high oxygen content in packaging alleviates effects of tissue wounding and has an advantageous effect on overall quality of products. Packaging in atmosphere with a high oxygen concentration effectively prevents anaerobic respiration and inhibits growth of aerobic and anaerobic bacteria (JACXSENS et AL. 2001).

In all samples a significant increase was recorded in pH value during storage, as well as a significant decrease in solids content. A similar increase in pH values was recorded by BABIC and WATADA (1996) for spinach packaged in controlled atmosphere and stored at 5°C.

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WPŁYW WARUNKÓW PAKOWANIA W ATMOSFERZE MODYFIKOWANEJ NA JAKOŚĆ JARMUŻU O MAŁYM STOPNIU PRZETWORZENIA

Streszczenie. W pracy określono wpływ warunków pakowania na jakość jarmużu o małym stopniu przetworzenia w czasie 12 dni przechowywania w temperaturze 4°C. Zastosowano materiał opakowaniowy o przepuszczalności dla tlenu 1,5 i 35 cm^3/m^2 w ciągu 24 h, z zastosowaniem mikroperforacji, oraz atmosferę modyfikowaną o dużej zawartości tlenu (30, 55 i 80%). Zastosowano również pakowanie w atmosferze powietrza Próby pakowane w powietrzu i atmosferze o składzie 80% O_2 / 10% CO_2 / 10% N_2 z zastosowaniem mikroperforacji materiału opakowaniowego uzyskały najwyższe noty oceny sensorycznej w czasie przechowywania.. Wartości tych not po 12 dniach przechowywania mieściły się w zakresie od 4,6 do 5,0. Próby zapakowane z zastosowaniem folii opakowaniowej bez mikroperforacji, niezależnie od jej przepuszczalności, uzyskiwały akceptowalność sensoryczną do 9. dnia przechowywania Dalsze przechowywanie, na skutek zbyt małej przepuszczalności materiału opakowaniowego, powodowało pojawienie się nieprzyjemnego zapachu i dyskwalifikację prób.

Słowa kluczowe: pakowanie w atmosferze modyfikowanej, jarmuż, jakość sensoryczna

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