EFFECT OF SPICE EXTRACTS IN COMBINATION WITH PACKAGING MATERIALS AND TREATMENTS ON THE STABILITY OF GROUND BUFFALO MEAT PRODUCT STORED UNDER FROZEN CONDITIONS

M. A. Kenawi, H. A. Abdel-Aal, S. S. Latif

Abstract: Proximate analysis, expressible water (EP), water holding capacity (WHC), pH value, total acidity, free fatty acids (FFA), thiobarbituric acid values (TBA), color evaluation, and microbiological examination were determined in order to evaluate the effect of spice extracts in combination with packaging materials and treatments on the stability of ground buffalo meat product stored under frozen conditions up to six months. The samples were treated by spice extracts and packaged in two packaging materials: low density polyethylene (LDPE) bags without vacuum and laminated polyethylene/nylon bags under vacuum. The results indicated that all the samples had lost moisture during storage, and the loss was higher in samples packaged in (LDPE), also the (EP) values increased, whereas, (WHC) values decreased with time during storage for all samples.

The samples indicated a reduction in the pH values and an increase in the acidity values especially for the first four months of storage and these changes were associated with an increase in the (FFA) values as a result of storage. The increment in the pH value was the lowest in the control samples and this indicated the effect of natural antioxidants to retard the formation of FFA. The (TBA) values for the control samples were higher than those packaged under vacuum or treated by spice extracts. The storage time had a negative effect on the total bacterial counts and the coliform group for all samples. The rate of reduction was much higher in the vacuum packaged samples and the spice extracts treated samples as well especially those treated by black cumin extracts than the untreated or samples packaged without vacuum. The color measurements showed a decrease in the redness value for all samples during storage period. The rate of reduction was much higher in the control samples than the treated ones.

Key words: packaging, spice extracts, buffalo meat, frozen storage.

Introduction

During production, processing, distribution, and storage, food undergoes deterioration from chemical and microbiological processes (Wong et al., 1995). Oxidation is a major cause of that deterioration because of its negative effects on organoleptic qualities (flavor, color, etc.). Oxidation of lipids can also have a marked negative effect on nutritional value, and could be responsible for the production of toxic compounds (Sevanian and Peterson, 1986; Kubow, 1990: Naniki, 1990; Araoama, 1994; Guardiola et al., 1996; Ghirette et al., 1997; and Hsu et al., 2002).

Meat products, due to fat content are highly susceptible to lipid oxidation. Moisture,
prooxidant pigments. Storage, handling and display conditions contribute to lipid oxidation of meat products (Hettiarachchy et al., 1996). Due to detrimental effects of lipid oxidation on color, flavor, texture, and nutritional value of foods, addition of synthetic antioxidants such as BHT and BHA has been effective because of their low cost, high stability, and effectiveness (Namiki, 1990). However, the use of such compounds has been related to health risks resulting in strict regulations over their use in food products and this has stimulated research for alternative antioxidant sources (Hettiarachchy et al., 1996).

In the last few years, there has been an increasing interest in the use of natural additives in preference to synthetic substances for the stabilization of fat-containing food stuff. Among the natural antioxidants, extracts of herbs such as rosemary and sage have played an important role (Schwarz and Ernst, 1996; and Park et al., 2002). The use of antioxidants like vitamin C and E had a significant effect in reducing oxidation of lipids and pigments of meat during storage (Okayama et al., 1987; Mitsumoto et al., 1991; and Sahoo and Anjanyulu, 1997).

Natural antioxidants often have multiple modes of action that have not been fully clarified but the main functions have been identified (Ghirette et al., 1997). In view of the fact that natural spices are widely used in a variety of food products, it is important to know the effects they have on the keeping qualities of such products. A number of studies have been made on the bactericidal and bacteriostatic properties of spices to evaluate their effectiveness in preventing or retarding spoilage caused by microorganisms in addition to the antioxidant effect of spices on fats in certain foods (Pruthi, 1980).

Several natural antioxidants have been tested in meat systems; black pepper, propolis and extract of rosemary. Ground fresh leaves of rosemary and sage have also been reported to inhibit lipid oxidation in beef hamburgers (Dessouki et al., 1980; Resurreccion and Reynolds, 1990; Cuvelier et al., 1994; Shahidi et al., 1992; Abd el-Alim et al., 1999; and Nam et al., 2002).

Since frozen meat is highly susceptible to dehydration as a result of moisture losses and temperature fluctuations, the protection of frozen meat and its products against fluctuations in temperature during storage is important from the standpoint of quality retention. (Zuritz and Sastry, 1986). Jav et al., (1962); and Seidman et al., (1976) reported that vacuum packaging of meat may prolong the shelf life of retail cuts compared with those packaged in oxygen-permeable film. Zamora and Zuritshky (1985) found that, when meat is vacuum-packaged and the contaminating flora is exposed to an atmosphere containing high levels of carbon dioxide and a low percentage of oxygen, the growth of aerobic microorganisms is depressed. Vacuum packaging helped in reducing TBA value of beefsteaks during refrigerated storage (Unda et al., 1990; Fu et al., 1992).

The main purpose of this investigation was to investigate the protective effects of three spice extracts individually or in a mixture with combination of two packaging materials with or without vacuum on the subjective quality characteristics of buffalo meat products during frozen storage.

**Materials and methods**

**Antioxidant extracts:**
Dried spices (cardamom, nutmeg, and black cumin) were obtained from a local market, then powdered using a mortar and pestle. Powdered spice every 2g was extracted
with (10 ml) ethanol solution (50%) on a lab line orbit shaker at 60Xg for 2hrs. The solution was centrifuged at 1800Xg followed by filtration using Whatman No 1 filter paper. The final concentration of the stock solution was 20 g/100 ml.

Preparation of buffalo meat product:
The buffalo meat (bottom round, 10 Kg) used in this study was obtained from a local market in El-Minia, Egypt, one hour after slaughter. The sample was trimmed, packed in low density polyethylene bags and held at 4±1 °C for 24 hours, cut into cubes and minced with a meat grinder using 8 mm (coarse) and 3 mm (fine) plates simultaneously to obtain ground buffalo meat.

Buffalo meat product was prepared according to the following recipe in (table 1). All the ingredients were mixed well and divided into five equal portions. Spice extracts (individually or in mixture) were added to the first four portions in the ratio of (1ml/ 10g sample), whereas, the fifth portion was left without any additive as control. Each portion was divided into small balls 10±2 g each, then formed in a finger-like shape 10±1 cm long, and packaged in single layer using two different packaging materials with or without vacuum. The samples were frozen at -40°C for 6 hours, then stored frozen at -18°C for 6 months as shown in (Fig.1).

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Amount (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground meat</td>
<td>4800</td>
</tr>
<tr>
<td>Minced fat</td>
<td>1200</td>
</tr>
<tr>
<td>Bread crumb</td>
<td>900</td>
</tr>
<tr>
<td>Eggs</td>
<td>375</td>
</tr>
<tr>
<td>Potato starch powder</td>
<td>150</td>
</tr>
<tr>
<td>Salt</td>
<td>75</td>
</tr>
<tr>
<td>Black pepper powder</td>
<td>7.5</td>
</tr>
</tbody>
</table>

Table 1. Formulation of buffalo meat product
Tabela 1. Formulacija proizvoda od bivoljeg mesa

Packaging materials and treatments:
Commercial low density polyethylene (LDPE) 2 mil bags (1 mil = 0.001 inch) from Packaging Concepts and Design, Madison Heights, MN., USA., and 5 mil laminated polyethylene/nylon bags from Cryovac Co., USA. were used. Each portion of the buffalo meat product was divided into two equal parts. One part was packaged in a single layer in (LDPE) bags, then heat sealed under atmospheric pressure, while the other part was packed in laminated polyethylene/nylon bags and heat sealed under vacuum using a Deni Freshlock vacuum sealer.

Analytical methods:
Moisture, crude protein, crude fat, ash, and carbohydrate contents were determined according to the methods of the (AOAC, 1995).

Determination of expressible water (EP) and water holding capacity (WHC):
Expressible water (EP) was determined according to Alvarez et al., (1992). Whereas, the water holding capacity (WHC) was calculated.

pH measurement:
A slurry was prepared by blending the (5g /50ml distilled water). The pH of this
slurry was measured by using the glass-electrode method according to the AOAC method (1975).

Figure 1. Flow diagram of production and storing of buffalo meat product in two different packaging materials and treatments under frozen storing condition.

Slika 1. Dijagram postupka proizvodnje i skladištenja proizvoda od bivolje mesa korišćenjem dva različita materijala za pakovanje i tremana u uslovima zamrzavanja

**Determination of total acidity:**
The acidity was determined by titration according to (Keeton and Melton, 1978).

**Determination of free fatty acids (FFA):**
Free fatty acids (FFA), as measurement of enzymatic rancidity was assessed by the method described by Woyewoda et al., (1986).

**Thiolobarbituric acid (TBA) value:**
Frozen packaged samples were tested separately. TBA-reactive substances were measured using the method of Harold et al., (1981). Colorimetric absorbance at 530 nm was measured using a Spectronic 710 Spectrophotometer. Readings were converted to mg malonaldehyde /1000g meat product and reported as TBA values (mg TBA/1000g meat product).
Microbiological test:
Total aerobic count, total anaerobic count, coliform, and psychrophilic count of buffalo meat product were made as (CFU/g) according to the methods described in the standard methods of (APHA, 1985; and Vanderzant and Spittswesser, 1992).

Color evaluation:
Hunter color values (L* a*b*) were measured for buffalo meat product at zero time and during storage period with a colorimeter (color Tec PCM color Meter, color Tec. NJ. USA). Four random measurement spots on each sample were made and the average data were recorded according to (C.I.E., 1976; Park, 1995; and Killinger et al., 2000).

Statistical analysis:
Data were analyzed by analysis of variance (ANOVA) to determine if treatments were significantly different (Gill, 1981).

Results and discussion

Table 2 illustrates the chemical composition of the treated and untreated buffalo meat product. The data showed that there was no variation between the samples except for moisture content which was higher in the treated samples than the controlled ones and this might be due to the effect of the addition of the spice extract solutions which contain about 50% water. Packaging of food products in polymeric films is a technique designed to prevent moisture losses. Figure 2 illustrates the relationship between the storage time and the moisture content for the control and the treated buffalo meat product in two different packaging materials and treatments under frozen condition. It is shown from the results that all the samples have lost moisture during the storage period. The loss was higher in samples packaged in LDPE bags than the ones packaged in laminated PE/Nylon bags under vacuum, and this was due to the higher rate of the water vapor permeability through LDPE compared to the laminated PE/Nylon bags.

The effect of storage time and packaging materials and treatments on the expressible water (EP) and water holding capacity (WHC) for buffalo meat product was shown in (Figs. 3&4). The data revealed that the EP values increased along with storage period for all samples (control and treated with spice extracts), whereas, WHC values decreased with time during frozen storage.

The increment of EP values were higher in samples packaged in LDPE without vacuum than
Table 2. Chemical composition of untreated and treated buffalo meat product (g/100g on dry matter basis).*

Tabela 2. Hemitski sastav netretiranog i tretiranog proizvoda od bivaljeg mesa i g/100g na bazi suve materije).*

<table>
<thead>
<tr>
<th>Samples/Uzorci</th>
<th>Moisture content/ Sadržaj vlage</th>
<th>Crude protein/ Sirovi protein</th>
<th>Crude fat/ Sirova mast</th>
<th>Ash/Pepeo</th>
<th>Carbohydrate/ Ugleni hidrati</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control-Kontrola</td>
<td>58.09±0.18</td>
<td>17.09±0.21</td>
<td>16.97±0.08</td>
<td>2.08±0.03</td>
<td>5.77±0.08</td>
</tr>
<tr>
<td>Cardamom ext./ ek. kardamoma</td>
<td>60.24±0.10</td>
<td>16.95±0.08</td>
<td>16.04±0.12</td>
<td>1.93±0.06</td>
<td>4.84±0.11</td>
</tr>
<tr>
<td>Nutmeg ext./ ek. Muskatnog oraha</td>
<td>60.09±0.18</td>
<td>17.06±0.15</td>
<td>16.41±0.21</td>
<td>1.97±0.01</td>
<td>4.47±0.08</td>
</tr>
<tr>
<td>Black cumin ext/ ek. Crnog kumina</td>
<td>60.11±0.17</td>
<td>17.11±0.21</td>
<td>16.21±0.18</td>
<td>1.91±0.10</td>
<td>4.66±0.12</td>
</tr>
<tr>
<td>Mixture/ Mesavina</td>
<td>59.98±0.24</td>
<td>17.31±0.09</td>
<td>16.17±0.12</td>
<td>1.92±0.06</td>
<td>4.62±0.06</td>
</tr>
</tbody>
</table>

*Means of three determinations = Standard Error/ Srednje vrednosti tri određivanja = standardna greška


Figure 2. Effect of storage time. Packaging materials and treatments on moisture content of untreated and treated buffalo meat product

Slika 2. Uticaj trajanja skladištenja, materijala za pakovanje i tretmana na sadržaj vlage kod tretiranih i netretiranih proizvoda od bivaljeg mesa.

the others packaged under vacuum in laminated bags. The data show that the vacuum treatment reduced the rate of decline in WHC. It is obvious that the increase in the EP values were likely related to the loss of WHC as a result of dehydration and denaturation of muscle proteins, or interaction of auto-oxidation breakdown products with proteins (Brewer and Harbers, 1991), or could be due to the cells which were punctured by ice crystals and volatile moisture loss through vapor permeability of packaging materials.

Figures (5&6) clearly illustrate the effect of packaging materials and treatments in combination with spice extracts as a natural antioxidant on the pH changes and percentage
acidity (as lactic acid) in frozen buffalo meat product. The data demonstrate that there is a slight decrease in the pH values and an increase in the acidity values for all samples along with storage time during the first four months of storage as a result of the increase of free fatty acids due to rancidity. The decrease in the pH values was lower in the control samples than the treated ones due to the effect of natural antioxidants which retarded the formation of free fatty acids. It is also obvious that the values of pH for the product were higher than that of the pH values of meat and this could be due to the interaction effect of the other ingredients which were added during the processing of meat products. Free fatty acids (FFA) and TBA values for the control and the treated samples packaged in two different packaging materials and treatments were illustrated in Figs.(7 & 8). The data showed that the (FFA) values for the control sample (packaged in two different packaging materials and treatments) were significantly (p<0.05) increased along with the storage period. It is also shown that the addition of spice extracts delayed the formation of free fatty acids specially with the use of nutmeg extract for the first four months of storage, then the samples suffered much more increase in its (FFA) values, and the values were much lower in the samples packed under vacuum which means that vacuum is considered as the second line of protection by retarding the formation of free fatty acids.

![Graph](image1)

**Figure 3. Effect of storage time, packaging materials and treatments on expressible water (EP) of untreated and treated buffalo meat product**

**Slika 3. Uticaj trajanja skladištenja, materijala za pakovanje i tretmana na EP tretiranih i netretiranih proizvoda od bivoljeg mesa**

![Graph](image2)

**Figure 4. Effect of storage time, packaging materials and treatments on water holding capacity (WHC) of untreated and treated buffalo meat product**

**Slika 4. Uticaj trajanja skladištenja, materijala za pakovanje i tretmana na sposobnost zadržavanja vode (WHC) kod tretiranih i netretiranih proizvoda od bivoljeg mesa**
TBA values increased over time for all samples. The increment was rapid for the control samples and the greatest change occurring between the fourth and the sixth month of storage. The values for the control samples increased significantly (p<0.01) during frozen storage, whereas the changes in the TBA values for the samples treated by spice extracts were not significantly different (p<0.05). Within each treatment the same trend was shown as in figure (7) where the samples packaged under vacuum had the lowest TBA values compared to the other samples.

Meat and meat products stored in air is rapidly spoiled by bacteria which are responsible for discoloration and off odor, causing its rejection. Vacuum packaging exerts an important effect on the micro-organisms. Vacuum packaged meat is generally very stable in the cold with the low temperature and limited quantity of oxygen inhibiting bacterial growth (Labadie, 1999). Figure 9 illustrates the effect of storage time, and packaging materials and treatments on the total aerobic count of untreated products.
Figure 7. Effect of storage time, packaging materials and treatments on free fatty acids content (F.F.A) as μ mole/g of untreated and treated buffalo meat product
Slika 7. Uticaj trajanja skladištenja, materijala za pakovanje i tretmana na sadržaj slobodnih masnih kiseline kao μ mol/g kod tretiranih i nenetiranih proizvoda od bivoljeg mesa

Figure 8. Effect of storage time, packaging materials and treatments on TBA value (mg malonaldehyde/kg meat) of untreated and treated buffalo meat product
Slika 8. Uticaj trajanja skladištenja, materijala za pakovanje i tretmana na TBA vrednost (mg malonaldehyde/kg mesa) kod tretiranih i nenetiranih proizvoda od bivoljeg mesa

Figure 9. Effect of storage time, packaging materials and treatments on the total aerobic plate count (CFU/g) of untreated and treated buffalo meat product
Slika 9. Uticaj trajanja skladištenja, materijala za pakovanje i tretmana na ukupni broj aerobnih bakterija (CFU/g) kod tretiranih i nenetiranih proizvoda od bivoljeg mesa

and treated buffalo meat product. The data showed a negative relationship between the time of storage and the bacterial count for all samples. The rate of reduction was
much higher in the vacuum packaged samples and the spice extracts treated samples as well especially those treated by black cumin extracts than the others. This is particularly evident for the inhibiting effect of vacuum packaging and the spice extracts on the growth of aerobic microorganism (Labadie, 1999). The same trend of reduction was observed for the anaerobic total count for the treated and the untreated samples during the storage period as shown in (Fig.10). The reduction was lower for the vacuum packaged samples compared with the samples packaged without vacuum.

The effect of storage time in combination with packaging materials and treatments was clear on the total coliform count as shown in (Fig. 11). The data illustrated that the number of coliform decreased along with the storage period for all samples, and this effect was clear for the spice extracts treated samples and the vacuum packaged samples. The data also showed that some of the spice extracts treated samples have no coliform bacteria starting from the fourth month of storage which indicates the inhibiting effect of spice on the growth of coliform flora.

Total psychrophilic counts of all samples showed a reduction for the first four months of storage under frozen condition. The reduction was significant (p<0.05) for the samples vacuum packaged or treated by spice extracts. After the first four months of storage the number of the psychrophilic counts start to increase again as shown in (Fig.12).

Figure 10. Effect of storage time, packaging materials and treatments on the total anaerobic plate count (CFU/g) of untreated and treated buffalo meat product
Slika 10. Uticaj trajanja skladištenja, materijala za pakovanje i tretmana na ukupni broj anaerobnih bakterija (CFU/g) kod tretiranih i netretiranih proizvoda od bivoljeg mesa

Figure 11. Effect of storage time, packaging materials and treatments on the total coliform count (CFU/g) of untreated and treated buffalo meat product
Slika 11. Uticaj trajanja skladištenja, materijala za pakovanje i tretmana na ukupni broj koliformnih bakterija (CFU/g) kod tretiranih i netretiranih proizvoda od bivoljeg mesa
The influence of spice extracts in combination with packaging materials and treatments on the stability of color for the buffalo meat products was shown in Table 3. The color measurements showed a decrease in the redness value (a*) for all samples during storage period. The rate of reduction was much higher in the control samples than the treated ones. Treatment by spice extracts as a natural antioxidant reduced the change in color and maintained the redness value much more than the control samples.

Addition of spice extracts to the buffalo meat product reduced the changing in the lightness values (L*) during the storage period. Samples packaged in LDPE bags without vacuum maintain a redness value much higher than the samples packaged under vacuum.

Figure 12. Effect of storage time, packaging materials and treatments on the total psychrophilic count (CFU/g) of untreated and treated buffalo meat product

Table 3. Influence of spice extracts and packaging materials and treatments on color (L*, a*, and b*) of buffalo meat product during frozen storage
<table>
<thead>
<tr>
<th>Treatment/Tretman</th>
<th>Zero time/multo vrem</th>
<th>2 months/mesece</th>
<th>4 months/mesece</th>
<th>6 months/mesece</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LDPE</td>
<td>Lam/ vac</td>
<td>LDPE</td>
<td>Lam/ vac</td>
</tr>
<tr>
<td>Control/Kontrol</td>
<td>L*</td>
<td>50.93 a</td>
<td>50.93 a</td>
<td>49.44 a</td>
</tr>
<tr>
<td></td>
<td>a*</td>
<td>19.64 a</td>
<td>19.64 a</td>
<td>17.86 a</td>
</tr>
<tr>
<td>Cardamom ext./Kardamom ek.</td>
<td>L*</td>
<td>48.03 a</td>
<td>48.03 a</td>
<td>50.69 a</td>
</tr>
<tr>
<td></td>
<td>a*</td>
<td>18.50 a</td>
<td>18.50 a</td>
<td>18.17 a</td>
</tr>
<tr>
<td></td>
<td>b*</td>
<td>12.78 b</td>
<td>12.78 b</td>
<td>13.95 b</td>
</tr>
<tr>
<td>Nutmeg ext./Muskatni orah. ek.</td>
<td>L*</td>
<td>49.23 ae</td>
<td>49.23 ae</td>
<td>51.64 a</td>
</tr>
<tr>
<td></td>
<td>a*</td>
<td>17.91 a</td>
<td>17.91 a</td>
<td>17.78 a</td>
</tr>
<tr>
<td></td>
<td>b*</td>
<td>13.50 a</td>
<td>13.50 a</td>
<td>13.85 a</td>
</tr>
<tr>
<td>Black cumin ext./Crni kumin ek</td>
<td>L*</td>
<td>48.60 a</td>
<td>48.60 a</td>
<td>48.45 a</td>
</tr>
<tr>
<td></td>
<td>a*</td>
<td>19.11 a</td>
<td>19.11 a</td>
<td>18.87 a</td>
</tr>
<tr>
<td></td>
<td>b*</td>
<td>9.98 c</td>
<td>9.98 c</td>
<td>14.27 a</td>
</tr>
<tr>
<td>Mixture/Mešavina</td>
<td>L*</td>
<td>49.13 a</td>
<td>49.13 a</td>
<td>50.16 a</td>
</tr>
<tr>
<td></td>
<td>a*</td>
<td>18.89 a</td>
<td>18.89 a</td>
<td>18.17 a</td>
</tr>
<tr>
<td></td>
<td>b*</td>
<td>13.11 b</td>
<td>13.11 b</td>
<td>14.10 a</td>
</tr>
</tbody>
</table>

UTICAJ EKSTRAKATA ZAČINA U KOMBINACIJI SA MATERIJALIMA ZA PAKOVANJE I TRETMANIMA NA STABILNOST PROIZVODA OD MLEVENOG BIVOLJEG MESA SKLADIŠTENIH U ZAMRZNUTOM STANJU

M. A. Kenawi, H. A. Abdel-Aal, S. S. Latif

Rezime

Približna analiza, EP vrednost, sposobnost zadržavanja vode (WHC), pH vrednost, ukupna kiselost, slobodne masne kiseline (FFA), vrednosti tiobarbiturne kiseline (TBA), okean boje i mikrobiološko ispitivanje je urađeno radi ocene uticaja ekstrakata začina u kombinaciji sa materijalima za pakovanje i tretmanima na stabilnost proizvoda od mlevenog bivoljeg mesa skladištenih u zamrznutim uslovima do 6 meseci. Uzorci su tretirani ekstraktima začina i pakovani u dva materijala za pakovanje – kese od polietilena niske gustine (LDPE) bez vakuumu, i laminatne polietilenske/najlon kese vakuumirane. Rezultati ukazuju da su uzorci izgubili vlagu tokom skladištenja, a gubitak je bio veći kod uzoraka pakovanih u (LDPE),
takođe vrednost EP se povećala, dok se sposobnost vezivanja vode WHC smanjivala sa dužim trajanjem skladištenja za sve uzorke.

Uzorci su ukazali na smanjenje pH vrednosti i povećanje kiselosti posebno u toku prvih četiri meseca skladištenja, tako da su ove promene povezane sa povećanjem vrednosti FFA kao posledica skladištenja. Povećanje pH vrednosti je bilo najmanje u kontrolnim uzorcima što je ukazalo na uticaj prirodnih antioksidanata u smislu odlaganja formiranja FFA. TBA vrednosti za kontrolne uzorke su bile veće nego kod uzoraka u vakuumiranom pakovanju ili tretiranih ekstraktima začina. Trajanje skladištenja je imalo negativan uticaj na ukupni broj bakterija i koliformne grupe za sve uzorke. Redukcije je bila veća kod uzoraka u vakuum pakovanju i uzoraka tretiranih ekstraktima začina, pogotovo onih uzoraka koji su tretirani crnim kuminom u odnosu na netretirane uzorke pakovane bez vakuuma. Merenje boje je pokazalo povećanje vrednosti prisustva crvene za sve uzorke tokom perioda skladištenja. Redukcija je bila veća u kontrolnim uzorcima nego kod tretiranih.

**Ključne reči:** pakovanje, ekstrakt začina, bivolje meso, skladištenje u zamrznutom stanju.

**References**


