THE EFFECT OF MODIFIED ATMOSPHERE PACKAGING ON THE QUALITY AND SHELF LIFE OF FRANKFURTER TYPE-SAUSAGES

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ABSTRACT

The effects of modified atmosphere packaging on the quality and shelf life of frankfurter-type sausages, prepared exclusively from beef meat, were investigated. Sausages were packed under varying modified atmosphere conditions (30% CO_2/70% N_2; 70% CO_2/30% N_2; 100% CO_2; 80% CO_2/20% O_2) and vacuum, and stored at 4C for 28 days. Lower pH values were observed in the samples packed under modified atmospheres compared to vacuum. Inhibition effect of carbon dioxide concentration on the oxidation was seen. Carbon dioxide caused microbial inhibition. The lowest total viable count was found in the samples packed under 100% CO_2. It was concluded that modified atmosphere packaging had significant effect on the quality and shelf life of frankfurter-type sausages compared to vacuum packaging. The most suitable atmosphere among the tested atmospheres was that with 70% CO_2, 30% N_2 atmosphere. The shelf life of sausages under this atmosphere was 28 days.

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PRACTICAL APPLICATIONS

Meat and meat products are susceptible to spoilage. Several preservation techniques are used to extend their shelf life. Packaging of fresh meat is a common application to protect its quality. Modified atmosphere packaging (MAP) means to replace the air in a package of food with some different mixture of gases. The success in MAP is to choose the suitable gas combination, packaging system, package application and the package material. Proper gas combination to keep meat quality should be provided. Several studies have been performed to extent shelf life of pork sausages and local-type sausages using modified atmosphere packaging technique. However there is no data on beef sausages. The results of this research will form the basis for further studies and also will be beneficial for industry.

INTRODUCTION

Modified atmosphere packaging (MAP) means replacing the air in a package of food with a different mixture of gases, typically a combination of nitrogen and oxygen (Cann 1984).

Sausages, by definition, are prepared from the flesh of meat animals. Sausages can be produced using beef, veal, pork, chicken, turkey or lamb. Frankfurters are nonfermented, emulsion-type sausages. They are usually made from beef, lamb meat and pork, and are flavored with spices and the application of smoke. All frankfurters may contain up to 30% fat. They are cooked before service. Meat products such as frankfurters are sensitive to spoilage and are stored under vacuum or modified atmosphere. Different results have been found in the studies performed on the shelf life of cooked meat products packed under vacuum and modified atmosphere, depending on the type of the product. Some researchers reported that modified atmosphere packaging extended the shelf life of cooked meat products, whereas other researchers found no effect of packaging method on the shelf life (Boerema *et al.* 1993; Borch *et al.* 1996; Samelis and Georgiadou 2000; Metaxopoulos *et al.* 2002; Pexara *et al.* 2002). However, there are very few reports on frankfurters packed under modified atmosphere, and these reports are generally on pork sausages (Liserre *et al.* 2002; Metaxopoulos *et al.* 2002; Martinez *et al.* 2005, 2006) or local-type sausages (Wang *et al.* 1995; Santos *et al.* 2003, 2005; Samelis and Georgiadou 2000). There is no study with beef frankfurters.

Beef frankfurters are widely produced and consumed in Turkey. They are generally marketed in vacuum packs. Some manufacturers use modified atmosphere packaging with different gas mixtures. In this study, we aimed to determine quality changes and shelf life of frankfurter-type sausages packed under varying modified atmospheres and to find most suitable atmosphere to extend the shelf life of frankfurters.

MATERIALS AND METHODS

Processing of Sausages

Frankfurters were manufactured in a private meat processing plant in Antalya, Turkey. Sausages were produced by fresh boneless beef cuts from shoulder. Beef meat was trimmed of visible fat, minced through a 3 mm plate using a Mado mincer MEW 5102 (Domhan, Germany) and then placed in a cutter (Mado, MTK 661) along with the other ingredients. For 1 kg of batter, the following ingredients were used: 600 g beef, 322 g emulsion (containing 50% fat), 60 g water, 3.8 g sodium lactate, 4.8 g monosodium glutamate, 3 g nitrite salt, 4.9 g sodium tripolyphosphate and 2.92 g spice mix. Total mixing time was 10–15 min and the final temperature of the batter was 10.0–12.3C. Prepared frankfurter mixture was stuffed using a vacuum stuffer (Handtmann, VF100/240, Biberach, Germany) into 14 mm diameter cellulose casings. The frankfurters were hanged, smoked and cooked for 25 min in an oven at 76C. The cooked frankfurters were showered with cold water until their internal temperature was reduced to 16–18C, and after showering, they were kept overnight at 4C.

Packaging

Sausages were peeled using machine, placed on plastic foam trays and put into plastic pouches (size: $17.5 \times 13.5 \times 2.5$ cm). The plastic pouches were composed of polyamide (80 μm) and polyethylene (250 μm). The polyamide film had an oxygen transmission rate 68 mL/m^2 day-atmosphere at 10C, 23.08 mL/m^2 day-atmosphere at 25C and water vapor permeability of 1.37 mL/m^2 at 37.8C. Frankfurters were packed under vacuum and (V) under modified atmospheres with the following gas mixtures: (A) 30% CO_2/70% N_2; (B) 70% CO_2/30% N_2; (C) 100% CO_2; (D) 80% CO_2/20% O_2. The packages were gas flushed and sealed using a MULTIVAC packaging machine (R230/719, Multivac, Wolfertschwenden, Germany). The meat to gas volume ratio was 1/1 (Moller *et al*. 2003; Rubio *et al*. 2007). Packed sausages were stored at 4C and assessed for pH, thiobarbituric acid (TBA), color, microbiological counts and sensory attributes on the 7th, 14th, 21st and 28th day of storage. The experiment was repeated with samples produced and packaged at two separate times. For chemical and microbiological analysis, sausages were homogenized using a kitchen blender, the homogenates were pooled for each treatment. All assays were conducted on duplicate samples from the homogenate pool for each replication. Results were expressed as means of four duplicates.

Analysis

pH Measurement. The pH was measured using a pH-meter (WTW Inolab, Weilhem, Germany). The pH electrode was dipped into a mixture of homogenized sample and distilled water (1/1).

TBA Analysis. The TBA distillation method was performed as described by Tarladgis *et al.* (1960). A homogenized 10 g sample was distilled after the addition of 2.5 mL HCl + distilled water solution (1/2). A 5 mL of distilled solution was transferred into the stoppered test tube and 5 mL TBA solution (0.288 g TBA/100 mL distilled water) was added, the test tube was shaken and left in the water bath at 110C for 35 min. The absorbance was determined by a spectrophotometer at 538 nm against a blank containing distilled water and TBA solution. The results were expressed as mg malonaldehyde/kg.

Color Measurement. A CR-400 Minolta chroma meter (Minolta, Osaka, Japan) instrument was used to measure the color of frankfurters after manufacture. Three readings on the surface of frankfurters were taken using the CIE Laboratory L^*(lightness), a^* (redness), b^* (yellowness) system in day light conditions.

Microbiological Analysis. For microbiological analysis, a 25 g sample was added to 225 mL of sterile 0.1% (w/v) saline peptone water (0.1% peptone and 0.85% NaCl) and homogenized in a stomacher (Stomacher 80, Seward Medical, London, UK) for 2 min at low speed at room temperature. Serial decimal dilutions were made and plated onto appropriate culture media. Aerobic mesophilic counts (APC) were determined using Agar (PCA – Oxoid CM0463B) (35C for 48 h under aerobic conditions). Lactic acid bacteria (LAB) were determined on All Purpose Agar with Tween 80-Acumedia 7302 (25C for 72 h in an anaerobic jar). The colonies from selected dilutions were enumerated as colony forming units.

Sensory Analysis. Five experienced panelists, staff members of the Department of Food Engineering, who had experience on meat products were chosen to evaluate the quality of sausages. Before presentation to the panel, the samples were coded using letters and randomly presented to the panelists. Panelists were asked to evaluate the appearance, color and odor of samples. Appearance and color were evaluated in unopened packages; odor was evaluated just after opening the packages. Appearance, color and odor were scored on a 5-point hedonic scale as follows: 5 = excellent, 4 = good, 3 = acceptable, 2 = fair and 1 = unacceptable (Kotzekidou and Bloukas 1996). An overall quality score was calculated as the mean score of appearance, color and odor.

Statistical Analysis

Data were analyzed by a split plot design in a completely randomized system, with treatments as a whole plot and storage time and treatments by storage time as a sub-plot (Gomez and Gomez 1985). Means were compared using Duncan's multiple range test. Data analyses were performed using SAS.

RESULTS AND DISCUSSION

There were differences in pH between vacuum packaging and MAP (Table 1). Lower pH values were observed in samples packed under modified atmospheres when compared with vacuum. The mean initial pH of sausages before packaging was 6.41 and significantly decreased at day 14 in samples packed under 30% CO_2/70% N_2, 70% CO_2/30% N_2 and 100% CO_2 atmospheres (Fig. 1). It is assumed that increase in LAB count of these samples after 14th day cause decrease in pH. The decrease in pH was rapid in samples packed under 70% CO_2/30% N_2 and 100% CO_2 atmospheres. There were no significant differences in pH of samples packed under 80% CO_2/20% O_2 atmosphere between storage days. There were significant differences ($P < 0.01$) in pH among the atmospheres during the storage. The decrease was related to the concentration of carbon dioxide. Lower pH values were found with higher carbon dioxide concentrations for pork sausages (Martinez *et al.* 2005) and pork meat (Juncher *et al.* 2001; Jakobsen and Bertelsen 2004). The reason of this effect for carbon dioxide on the pH can be explained by absorption of carbon dioxide by meat and formation of carbonic acid.

The TBA values of samples packed under 30% CO_2/70% N_2, 70% CO_2/30% N_2 and 100% CO_2 atmospheres increased in 7 days and then decreased ($P < 0.01$) until the end of storage. Whereas TBA values of samples packed under 80% CO_2/20% O_2 atmosphere increased up to 21 days and decreased at the end of storage (Fig. 2). There were no significant differences in the TBA values of samples packed under vacuum during the storage. At the end of storage, the TBA values of the samples were higher than the initial values. This result indicated rancidity development during the storage. It is stated that sausages are susceptible to oxidation compared to whole muscle, because reduction in particle size, by grinding, disrupted membranes cause to incorporation of air and oxygen into the tissues (Martinez *et al.* 2006). According to

TABLE 1.
EFFECT OF PACKAGING METHODS AND STORAGE TIME ON PHYSICOCHEMICAL, MICROBIOLOGICAL AND SENSORY PARAMETERS OF FRANKFURTER TYPE SAUSAGES*

Factors	Parameters							
	pH	TBA†	*L**	*a**	*b**	TVC‡	LAB³	Sensory
Packaging methods§								
A	6.38^{x}	0.56^{x}	49.97^{x}	26.17^{x}	13.08^{x}	5.46^{x}	5.33^{x}	4.12^{x}
B	6.36^{y}	0.34^{xy}	49.71^{x}	26.30^{x}	13.11^{x}	4.49^{x}	4.09^{x}	4.5^{x}
C	6.36^{y}	0.30^{y}	48.69^{x}	25.77^{xy}	13.11^{x}	4.26^{x}	4.29^{x}	4.10^{x}
D	6.38^{y}	0.30^{y}	51.23^{x}	24.78^{y}	13.70^{x}	4.46^{x}	3.52^{x}	3.84^{x}
V	6.47^{x}	0.23^{y}	51.31^{x}	25.21^{xy}	13.97^{x}	4.97^{x}	4.48^{x}	3.54^{x}
Standard error	0.012	0.04	0.49	0.19	0.026	0.2	0.27	0.16
Storage time (d)¶								
0	6.41^{x}	0.13^{x}	48.85^{x}	26.19^{x}	13.38^{x}	3.89^{x}	3.58^{x}	5.0^{x}
7	6.38^{x}	0.44^{y}	49.23^{x}	24.98^{x}	12.83^{x}	4.07^{x}	3.92^{x}	4.46^{xy}
14	6.34^{x}	0.40^{y}	49.23^{x}	25.23^{x}	12.83^{x}	4.61^{xy}	4.18^{x}	4.02^{yz}
21	6.40^{x}	0.42^{y}	50.33^{x}	25.83^{x}	12.83^{x}	5.36^{y}	4.72^{x}	3.72^{z}
28	6.41^{x}	0.33^{xy}	53.28^{y}	25.99^{x}	15.11^{y}	5.71^{y}	5.31^{x}	2.90^{q}
Standard error	0.012	0.04	0.49	0.19	0.026	0.2	0.27	0.16

* Means within the same factor and the same column with different superscript letters (x,y,z,q) are different ($P < 0.05$).

† mg malonaldehyde/kg.

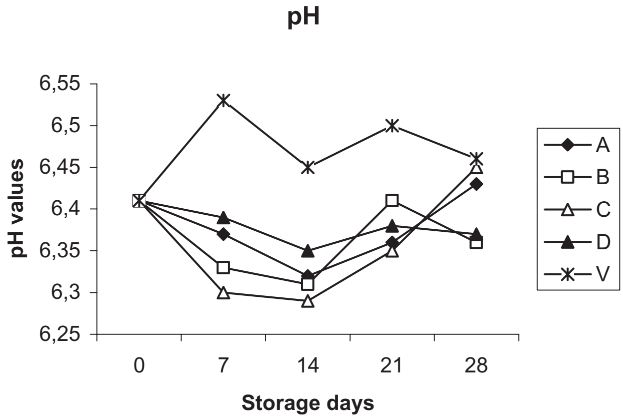
‡ Log_{10} cfu/g.

§ Each number represents the average value of each parameter for all samples of the same treatment. A = 30% CO_2/70% N_2; B = 70% CO_2/30% N_2; C = 100% CO_2; D = 80% CO_2/20% O_2; V = vacuum.

¶ Each number represents the average value of each parameter for all samples with the same storage time.

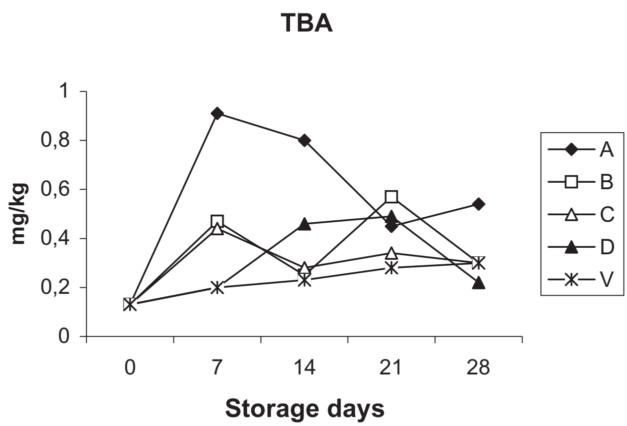
results of TBA analysis, inhibition effect of carbon dioxide concentration on the oxidation was seen at concentrations of $CO_2 > 70\%$. The increase in concentration of carbon dioxide caused inhibition. Our samples packed under modified atmosphere had higher TBA values than those packed under vacuum. While similar findings were reported by some researchers (Kerry *et al.* 2000; Berruga *et al.* 2005; Martinez *et al.* 2006), others found less oxidation in modified-atmosphere packed samples than those in vacuum packed (Wang *et al.* 1995).

Color of meat is an important quality attribute that influences consumer acceptance of meat and meat products (Glitsch 2000). High oxygen concentrations enhance bright-red color to fresh meat, but low concentration accelerates the oxidation of myoglobin to metmyoglobin which turns the color to brown. However, in meat products which are produced with nitrites the red cured color is rapidly turns to brown when oxygen and light are present. There were no significant differences in *L** values of samples in all packages in 14



A = 30% CO_2 / 70% N_2; B = 70% CO_2 / 30% N_2; C = 100% CO_2; D = 80% CO_2 / 20% O_2 ; V = vacuum

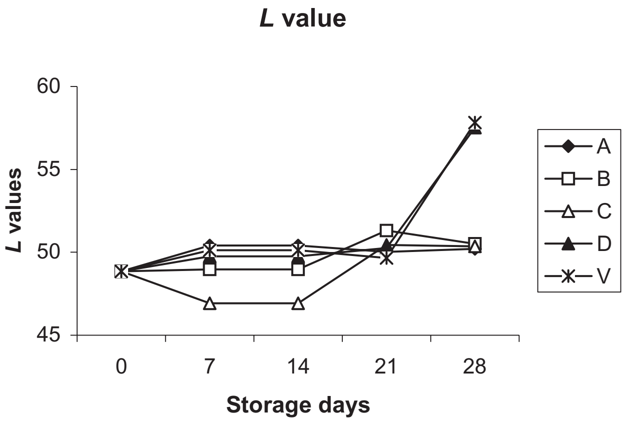
FIG. 1. pH VALUES OF SAUSAGES PACKED UNDER MODIFIED ATMOSPHERE AND VACUUM DURING THE STORAGE AT 4C



A = 30% CO_2 / 70% N_2; B = 70% CO_2 / 30% N_2; C = 100% CO_2; D = 80% CO_2 / 20% O_2 ; V = vacuum

FIG. 2. THIOBARBUTIRIC ACID (TBA) VALUES OF SAUSAGES PACKED UNDER MODIFIED ATMOSPHERE AND VACUUM DURING THE STORAGE AT 4C

days. *L** values increased after 14 days (Fig. 3). The highest value was detected in samples packed under 80% CO_2/20% O_2 atmosphere and vacuum at the end of storage. Lower values were found in samples packed under 30% CO_2/70% N_2 and 100% CO_2 atmospheres during the storage compared to the

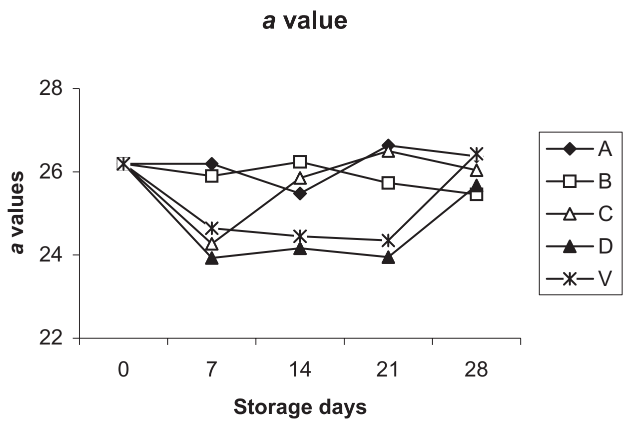


A = 30% CO_2 / 70% N_2; B = 70% CO_2 / 30% N_2; C = 100% CO_2; D = 80% CO_2 / 20% O_2 ; V = vacuum

FIG. 3. LIGHTNESS (*L**) VALUES OF SAUSAGES PACKED UNDER MODIFIED ATMOSPHERE AND VACUUM DURING THE STORAGE AT 4C

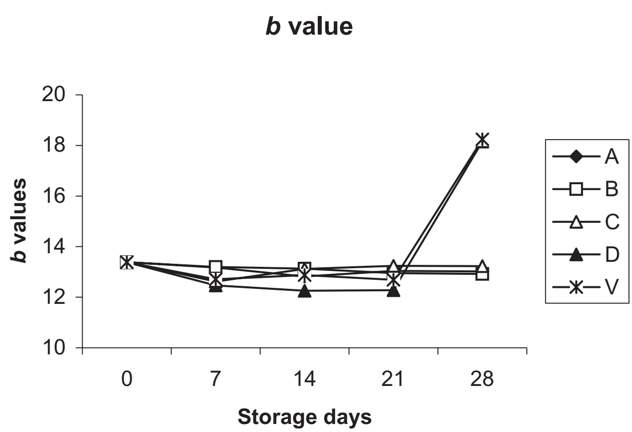
other groups. There were no differences in *a** values of samples packed under 30% CO_2/70% N_2, 70% CO_2/30% N_2 and 100% CO_2 atmospheres throughout storage. Values of samples packed under 80% CO_2/20% O_2 atmosphere and vacuum decreased up to 21 days, then increased and reached initial values (Fig. 4). Lower values were found in samples packed under 80% CO_2/20% O_2 atmosphere than other groups. It has been demonstrated that low concentrations of oxygen in the package are responsible for color fading (Jakobsen and Bertelsen 2000). During storage, the *b** values of samples packed under modified atmosphere and vacuum decreased (Fig. 5).

Total viable count of all the samples increased during storage (Fig. 6). The highest count was found in samples packed under the 30% CO_2/70% N_2 atmosphere. Final total viable count of the samples packed under 30% CO_2/ 70% N_2 atmosphere reached 7.58 log cfu/g. It is stated that spoilage occurs when total aerobic count reach 10^7 cfu/g (ICMSF 1984). Other samples did not reach this level throughout storage. Vacuum packed samples had higher TVC than those packed under modified atmospheres except A atmosphere (30% CO_2/70% N_2). The lowest count was found in samples packed under 100% CO_2. This result showed that carbon dioxide caused microbial inhibition, but it has been stated that a concentration of 20–30% was sufficient to prevent growth of aerobic spoilage bacteria (Sorheim *et al.* 2004) and high concentration of carbon dioxide was pro-oxidant causing loss of color (Jakobsen and Bertelsen 2002).



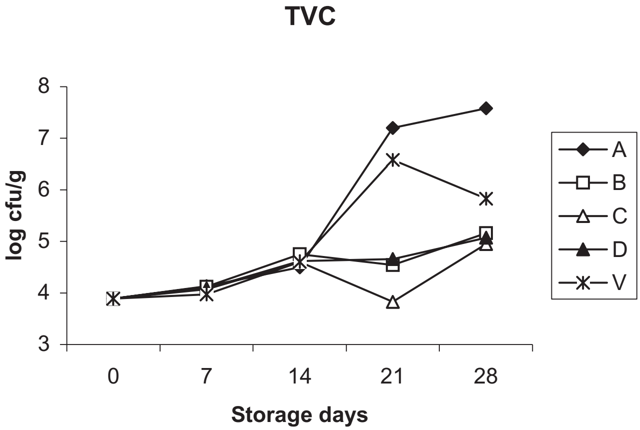
A = 30% CO_2 / 70% N_2; B = 70% CO_2 / 30% N_2; C = 100% CO_2; D = 80% CO_2 / 20% O_2 ; V = vacuum

FIG. 4. REDNESS (*a**) VALUES OF SAUSAGES PACKED UNDER MODIFIED ATMOSPHERE AND VACUUM DURING THE STORAGE AT 4C



A = 30% CO_2 / 70% N_2; B = 70% CO_2 / 30% N_2; C = 100% CO_2; D = 80% CO_2 / 20% O_2 ; V = vacuum

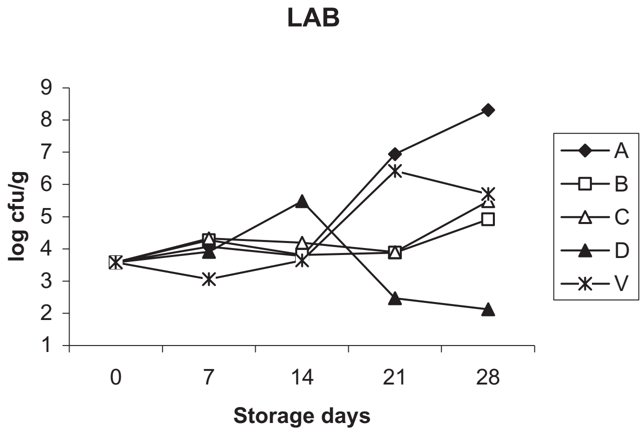
FIG. 5. YELLOWNESS (*b**) VALUES OF SAUSAGES PACKED UNDER MODIFIED ATMOSPHERE AND VACUUM DURING THE STORAGE AT 4C



A = 30% CO_2 / 70% N_2; B = 70% CO_2 / 30% N_2; C = 100% CO_2; D = 80% CO_2 / 20% O_2; V = vacuum

FIG. 6. TOTAL VIABLE COUNT (TVC) OF SAUSAGES PACKED UNDER MODIFIED ATMOSPHERE AND VACUUM DURING THE STORAGE AT 4C

When bacterial flora of such meats is examined it is commonly found that lactic acid bacteria are a major component (Kitchell and Shaw 1975). Vacuum packed cooked meats such as emulsion type sausages are more susceptible to spoilage, due to their pH and water activity values and require refrigeration for an adequate shelf life. Heterofermentative lactic acid bacteria cause spoilage of these products. Spoilage of cured meats by lactic acid bacteria is characterized by sour off-flavor (Egan 1983), discoloration, gas formation, slime production and low pH (Borch *et al.* 1996; Pexara *et al.* 2002). The count of lactic acid bacteria of samples packed under 30% CO_2/70% N_2, 70% CO_2/30% N_2 and 100% CO_2 atmospheres and vacuum increased during the storage (Fig. 7). The removal of oxygen from their packaging creates an environment which is favorable for these bacteria. The count in samples packed under 80% CO_2/20% O_2 atmosphere increased in 14 days and decreased after 14 days. The lowest count was found for samples packed under 80% CO_2/20% O_2 atmosphere at the end of storage. This result was in agreement with Santos *et al.* (2005). At the end of storage lactic acid bacteria count of the samples packed under 30% CO_2/70% N_2 atmosphere reached 8.31 log cfu/g. This is over the limit values given by ICMSF (1984). The rate of carbon dioxide in the gas mixture affected the growth of lactic acid bacteria. Higher inhibition effect was observed when the gas mixture contained over 30% CO_2. Similar results have been given in the previous studies (Blickstad and Molin 1984; Borch *et al.* 1996; Metaxopoulos *et al.* 2002). On the contrary, some researchers have



A = 30% CO_2 / 70% N_2; B = 70% CO_2 / 30% N_2; C = 100% CO_2; D = 80% CO_2 / 20% O_2; V = vacuum

FIG. 7. LACTIC ACID BACTERIA (LAB) COUNT OF SAUSAGES PACKED UNDER MODIFIED ATMOSPHERE AND VACUUM DURING THE STORAGE AT 4C

reported that modified atmosphere packaging did not indicate retarding effect on the growth rate of lactic acid bacteria compared to vacuum packaging (Korkeala *et al.* 1991; Samelis and Georgiadou 2000; Pexara *et al.* 2002; Kant-Muermans *et al.* 1997).

Sensory scores of sausages packed under modified atmospheres and vacuum decreased during the storage (Fig. 5). Lower scores were observed in samples packed under vacuum than those packed under modified atmospheres. Comparing packaging under modified atmosphere and under vacuum, it was found that modified atmosphere packaging had significant effect on sensory quality of the samples. Atmosphere 80% CO_2/20% O_2 had the lowest sensory scores compared to the other packs with modified atmosphere. The best sensory quality among all the tested packaging methods were obtained for 70% CO_2/30% N_2 atmosphere, throughout the storage period. The shelf life of frankfurters in this treatment was more than 28 days at 4C.

CONCLUSION

Sausages are susceptible to spoilage and, so far, vacuum packaging was the most widely used packaging technique for sausages. In this research, it was found that MAP was more effective in improving the quality and shelf life of frankfurter-type sausages than vacuum packaging. Four different gas mixtures were studied and found that concentration of carbon dioxide in the pack was effective to inhibit microbial growth and fat oxidation. High concentration of carbon dioxide also caused decrease in the pH value of sausages. The presence of oxygen in the pack resulted in pale color and lower sensory scores. For this reason, oxygen should not be used in the package of frankfurter sausages. Atmosphere containing 70% CO_2, 30% N_2 was the most appropriate atmosphere to keep quality and extend the shelf life of sausages.

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