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Effects of Various Packaging Systems on the Quality Characteristic of Goat Meat

**Morales-delaNuez, A., I. Moreno-Indias, A. Falcón[1], A. Argüello*
D. Sánchez-Macias, J. Capote[2] and N. Castro**
Animal Production Unit, University of Las Palmas de G. C., 35413-Las Palmas, Spain

ABSTRACT : 40 goat kid ribcages were held for 7 days in storage conditions (4°C) and used to determine the effects of three different packaging methods (atmospheric air, vacuum and modified atmosphere package (MAP) 10:70:20 mixture of N_2:O_2:CO_2) on meat quality of the chops. L* was affected by the packaging method being lighter than MAP chops. The coordinate a* significantly increased during storage time. For MAP-packed chops and those kept in atmospheric air, b* increased markedly during storage time whereas it remained unaffected throughout storage when in vacuum packages. Final pH values ranged from 5.6 to 5.8 and no effects were found for either storage time or packaging method. WHC means were lowest for the three packaging methods on day 7 of storage and highest on day 1. Storage time increased water loss in vacuum treatments. Trained panel colour acceptability was lower at 3, 5 and 7 days than on day 1 of storage for atmospheric air treatment and vacuum packaging, while for the MAP treatment average values on days 5 and 7 were lower than those observed on days 1 or 3. Trained panel odour was lower for atmospheric air and vacuum packages at 3, 5, and 7 days storage than at 1 day, while no differences were found in trained panel odour acceptability for MAP packages. With reference to consumers, the MAP proposed in the present study is the chosen method for storing goat meat, rather than vacuum or atmospheric air packaging. (**Key Words :** Goat Kid, Modified Atmosphere Packaging, Meat Quality)

INTRODUCTION

Naudé and Hofmeyr (1981) described the goat population as comprising four types, i.e., fibre goats (e.g. Angora, Cashmere), dairy goats (e.g. Saanen, Toggenburg, and Nubian), meat goats (e.g. Boer) and feral goats. The goat is an important meat animal in Africa, Asia, and the Far East, and is now emerging as an alternative, and attractive, source of meat in other parts of the world (Dhanda et al., 2003). Spain has one of the largest goat populations in the European Community. Most of these goats in Spain are dairy breeds, such as Murciano-Granadina, Malageña and the Majorera. However, goat meat production in Spain is high. Carcass weight in Spain is less than 5 kg, and carcasses are cut into small pieces that are packaged to increase value. In recent years, world production of goat meat has been increasing, which necessitates changes for goat meat shelf-life extension. Nowadays, poultry, fish or pork meat are bought by consumers in packages, because by using this technology storage labour is reduced and food safety is enhanced (Chae et al., 2007). Today, the majority of poultry and pork products in developed countries arrive at retail stores as "case-ready" using Modified Atmosphere Packaging (MAP). The most commonly used gases for packaging meat are carbon dioxide (CO_2), nitrogen (N_2) and oxygen (O_2) (Young et al., 1988). Packaging systems using atmospheric air are not commonly used to package meat, but goat meat is mainly distributed in undeveloped areas, where MAP will not be available.

No research has been done on the MAP (excluding vacuum) effects on goat kid meat quality, but there are some information in adult meat (Rajkumar et al., 2004). Therefore, the objective of this study was to determine the effect of three different MAP (vacuum, atmosphere air and 10:70:20 mixture of N_2:O_2:CO_2) on goat kid meat quality.

MATERIAL AND METHODS

This experiment was conducted at Las Palmas de Gran

* Corresponding Author: A. Argüello. Tel: +34-928451094, Fax: +34-928451142, E-mail: aarguello@dpat.ulpgc.es
[1] Jucarne, S.A. 35012-Las Palmas, Spain.
[2] Institute of Canary Agronomic Science Institute, La Laguna, Tenerife, Spain.
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Canaria University (Canary Isles, Spain). Live animal procedures used in this study were approved by the University Institutional Animal Care and Use Committee. Forty male kids of the Majorera breed were involved in present study. Animals were removed at birth from their dams and fed with lyophilized colostrum for one day (Castro et al., 2005). Afterwards, they received milk replacer (23.6 and 22.7% crude protein and ether extract, respectively) reconstituted at 16% w/w twice a day during the experimental period using buckets with silicon teats. On the 15^{th} day, water and starter mix feed (16.4 and 2.5% crude protein and ether extract respectively) were offered *ad libitum*.

Slaughter was done at the Experimental Slaughterhouse of the Las Palmas de Gran Canaria University (Spain). When kids reached approximately 10 kg of live weight at slaughter (LWS) (approximately 60 days old, daily gain 108 g/d), they were weighed and then fasted. The kids were subsequently slaughtered using captive bolt stunning followed by exsanguination. Kids were dressed as described by Colomer-Rocher et al. (1987), after which the carcasses were chilled at 4°C for 24 h. Subsequently, the ribcage was obtained in accordance with Colomer-Rocher et al. (1987). Each ribcage was divided into 13 meat samples (chops) with similar thickness including a vertebra and rib following vertebrae-sternum direction.

The chemical composition was performed according with Argüello et al. (2005), and was (mean±standard deviation) 19.9±0.7% of protein, 77.1±2.2% of moisture, 1.5±0.03% of fat and 1.1±0.01% of ash. Results were similar to findings of Argüello et al. (2005) for the same breed, LWS and nutrition management.

Three different packaging methods were used during 7 days of storage (atmospheric air, vacuum and modified atmosphere rich in oxygen). As a new alternative for undeveloped countries, atmospheric air packaging was investigated. Atmospheric air packaging consisted of placing chops in barrier bags and sealing them with atmospheric air inside using a sealing machine (Tecnotrip, Terrasa, Spain). Vacuum packaged chops were inserted into vacuum bags (oxygen transmission rate of 35 $cc/m^2/24$ h at 23.9°C/50% relative humidity, and a moisture vapour transmission rate of 10 $g/m^2/h$ at 37.7°C/70% relative humidity) and vacuum-sealed with vacuum-sealing instrument (Tecnotrip, Terrasa, Spain). Additional chops were packed in polystyrene/EVOH/PE (moisture vapour transmission rate of 10 $g/m^2/h$ at 37.7°C/70%RH) trays (gas flushed with a 10:70:20 mixture of N_2:O_2:CO_2) and heat-sealed using a low-oxygen-permeable (3 $cm^3/m^2/24$ h) lid material composed of a laminate of 20 μm oriented polypropylene and a co-extrusion layer (50 μm) of PE/EVOH/PE (moisture vapour transmission rate of 20 $g/m^2/h$ at 37.7°C/70%RH) (Cryovac; W.R. Grace Europe Inc., Lausanne, Switzerland). Inside package gas concentration after the packaging procedure was not measured.

Twelve chops per ribcage were randomly assigned to three different treatments, and introduced in a cooler at 4ºC until analysis. One chop for each ribcage was removed from the cooler at 3, 5 and 7 days post slaughter and subsequently analyzed. One chop was used as starting point prior to packaging (day 1).

All chops were assayed for instrumental colour, pH, water holding capacity (WHC), water loss and trained panel odour and colour according to this sequence. Immediately after the package was opened, each chop was assessed for odour quality by a trained panel (ISO 4121, 2003) according to Vergara and Gallego (2001) using the following categories: 1 = not acceptable (strong off-odour); 2 = acceptable (slight off-odour) or 3 = very acceptable (no off-odour). After that, pH was determined using a Crisson 507 pH meter with a penetrating combination electrode and WHC was measured according to methods proposed by Grau and Hamm (1953). Water loss (mix of liquids expelled from meat during storage, water, sarcoplasmic protein, etc.) was estimated by weighing the empty package and the package with meat at day 1. After storage, the meat was removed from the package and the weight of the package plus the juice was recorded. Water loss was expressed as a percentage of the initial weight of the meat (Insausti et al., 2001).

Instrumental and trained panel colour was assessed 15 min after opening the package. Instrumental colour was measured using a Minolta CR200 Chroma-meter (Minolta, Japan) in the CIE L*a*b* space (Wyszecki and Stiles, 1982) using an illuminant D65 and 10° observer. The trained panel colour (ISO 4121, 2003) was measured by the method proposed by Vergara and Gallego (2001) and scored on a five point hedonic scale where 1 corresponds to bad colour, 2 = poor colour but customer would purchase if less expensive, 3 = good colour, 4 = very good colour, and 5 = excellent colour. Eight people were enrolled in the trained panel, and each panellist make one evaluation on each chop.

The SAS (v 9.0, 2002) program package was used for statistical analyses. A PROC MIXED procedure and Tuckey test options were performed to evaluate the effect of the package method (atmospheric air, vacuum and MAP) and storage time (1, 3, 5 and 7 days) and package method× storage time were used as main effects. Data are presented as Least Square Means±SEM. Differences were reported as significant when the P values was less than or equal to 0.05.

RESULTS AND DISCUSSION

Colour coordinates are given in Table 1. L* coordinate

Table 1. Least square means for the effect of packaging on meat instrumental colour (coordinates L*, a*, b*) of Majorera kids

Measure	Treatment	Storage time 4°C (days)				SEM	Treatment×storage time
		1	3	5	7		
L*							0.001
	Atmospheric air	$55.0^{a,x}$	$56.5^{ab,y}$	$57.5^{b,y}$	$57.8^{b,y}$	0.49	
	Vacuum	$55.0^{a,x}$	$58.4^{b,x}$	$60.4^{c,x}$	$56.3^{a,y}$	0.59	
	MAP[1]	$55.0^{a,x}$	$57.5^{b,x}$	$61.4^{c,x}$	$62.7^{c,x}$	0.69	
a*							0.001
	Atmospheric air	$12.1^{ab,x}$	$12.7^{a,x}$	$11.7^{b,x}$	$12.4^{ab,x}$	0.26	
	Vacuum	$12.1^{a,x}$	$12.8^{ab,x}$	$12.6^{a,x}$	$13.6^{b,y}$	0.28	
	MAP	$12.1^{a,x}$	$12.1^{a,x}$	$11.1^{a,x}$	$13.3^{b,y}$	0.25	
b*							0.001
	Atmospheric air	$4.7^{a,x}$	$9.3^{b,x}$	$8.1^{b,z}$	$9.0^{b,z}$	0.49	
	Vacuum	$4.7^{a,x}$	$5.4^{ab,y}$	$6.3^{b,y}$	$3.8^{a,y}$	0.38	
	MAP	$4.7^{a,x}$	$9.8^{b,x}$	$10.2^{b,x}$	$10.7^{b,x}$	0.52	

Values in the same row with different letters (a, b, c) are different (p<0.05); values in the same column with different letters (x, y, z) are different (p<0.05).
[1] MAP = Modified atmosphere packaging consisted in a 10:70:20 mixture of N_2:O_2:CO_2.

ranged from 55.0 to 62.7 on days 1 and 7, respectively. The gas used in packaging significantly affect the L* values; on days 3 and 5 the vacuum packed and MAP chops were lighter than atmospheric air chops, but on day 7 MAP L* values were significantly highest. Storage time significantly affected the L* coordinate. Chops stored in atmospheric air showed an increase in L* as storage time increased, whereas chops on days 5 and 7 were lighter than on day 1. Chops stored in MAP showed an increase in L* as storage time increased, whereas chops on days 5 and 7 were lighter than on days 1 or 3. On the contrary, the L* value of vacuum chops increased until day 5, but after that lightness decrease to a value similar to that on day 1. Colour coordinate a* ranged from 11.1 to 13.6. The packaging method affected a* coordinate only on day 7; results on days 1, 3 and 5 were similar among methods. On day 7 of storage vacuum chops were significantly redder than atmospheric air chops, while values for MAP chops were intermediate. Storage time had a statistically significant effect on a* with each method tested. Atmospheric air chops had a lower a* value on day 5 than on day 3. Vacuum and MAP chops on day 7 were significantly redder than on previous days. Colour coordinate b* ranged from 3.8 to 10.7. The packaging method significantly affected the b* coordinate on days 3, 5 and 7 of storage. Atmosphere air and MAP chops had higher b* values on day 3 than vacuum chops and similar results were obtained on days 5 and 7 of storage. Atmospheric air and MAP chops had greater changes in b* with increasing length of storage than vacuum chops, with differences between day 1 and 3 greater.

L* increases during storage in vacuum and MAP packages have been reported by Insausti et al. (1999) in beef and Berruga et al. (2005) in lamb. Change in L* values with increasing storage length have been attributed to the changes in meat structure, especially protein destruction, which results in greater light dispersion and, thus, increased lightness (MacDougall, 1982). The differences in L* between atmospheric air and MAP might be explained by the fact that there was a higher oxygen concentration around chops stored under MAP (70%) compared to atmospheric air (Feldhusen et al., 1995), making them lighter. The observed increases in a* with increasing time of storage differ from results with beef and lamb meat (Gatellier et al., 2001; Insausti et al., 2001) where a* declined. Beef and lamb meat are characterized by higher a* values than kid meat (Insausti et al., 1999; Berruga et al., 2005), and the difference in myoglobin concentration might make kid meat less susceptible to alteration in a*. Kannan et al. (2001) reported lower a* values during storage time in 8 month old goat kids. The average a* on day 1 reported by Kannan et al. (2001) was approximately 17. As in beef and lamb, lower a* values on day 1 may be the reason for not detecting the effects of different packaging method in the present study. During the storage period, chops lost the initial pink colour and became brown. This change may be responsible for the increase in b*, doing vacuum packages the best method of preserving the chops.

Trained panel colour acceptability (Table 2) values were significantly lower at 3, 5 and 7 days than on day 1 of storage in atmospheric air and vacuum treatment, while acceptability for MAP on days 5 and 7 were significantly lower than observed on days 1 or 3 (Table 2). At day 3 and 5 of storage, colour acceptability was significantly higher on MAP chops, but for day 7, the lowest acceptability was observed on vacuum chops. On day 7, atmospheric air and MAP chops presented similar values that were higher than those observed for vacuum packages. In contrast to findings of Smith et al. (1983) working with lambs, the results of the present study show that MAP maintained a desirable appearance at day 7 of storage similar to atmospheric air and better than vacuum packaging.

Table 2. Least square means for effect of packaging on meat trained panel colour and odour of Majorera kids

Measure	Treatment	Storage time 4°C (days)				SEM	Treatment×storage time
		1	3	5	7		
Colour							0.001
	Atmospheric air	5.0^{a,x}	4.2^{bc,y}	4.0^{c,xy}	4.4^{b,x}	0.10	
	Vacuum	5.0^{a,x}	4.3^{b,y}	3.8^{c,y}	3.3^{d,y}	0.15	
	MAP[1]	5.0^{a,x}	4.8^{a,x}	4.3^{b,x}	4.2^{b,x}	0.10	
Odour							0.034
	Atmospheric air	3.0^{a,x}	2.83^{a,x}	2.63^{b,x}	2.63^{b,y}	0.05	
	Vacuum	3.0^{a,x}	2.63^{b,y}	2.54^{b,y}	2.33^{c,z}	0.06	
	MAP	3.0^{a,x}	2.88^{a,x}	2.73^{a,x}	2.83^{a,x}	0.04	

Values in the same row with different letters (a, b, c) are different (p<0.05); values in the same column with different letters (x, y, z) are different (p<0.05).
[1] MAP = Modified atmosphere packaging consisted in a 10:70:20 mixture of N_2:O_2:CO_2.

Trained panel odour acceptability was significantly lower in atmospheric air and vacuum packaging at 5 and 7 storage days than on 1 day, while no differences were found for trained panel odour acceptability for MAP packages. On days 3 and 5 of storage, vacuum chops had significantly lower trained panel odour acceptability values than atmospheric air or MAP, while on day 7 MAP chops had the highest trained panel odour acceptability. Odour and colour deteriorated similarly during storage, so it was not clear which was the limiting factor to shelf life of the kid meat. Clark and Lentz (1973) also found that changes in both odour and colour during storage occurred at similar times when meat was packed in oxygen concentrations above 50%, although the former change was related to microbial growth and the latter to metmyoglobin formation. Oman et al. (2000) reported a reduction of overall appearance of 50% after four days of storage of goat kid chops package in oxygen-permeable polyvinyl chloride overwrap film.

Changes with advancing storage time and effects of packaging method on final pH, WHC and water loss are shown in Table 3. Final pH values ranged from 5.6 to 5.8 and no differences were observed among storage time or packaging method. Similar values of final pH have been reported by Marichal et al. (2003) for the same breed and LWS. Clark and Lentz (1973) also found that pH was not significantly affected by the O_2 or CO_2 content of the package atmosphere, although package gas was not measured in the present study. The lack of change in pH reflects that there was not enough protein breakdown during these storage times to elicit increased pH typical of meat storaged for longer periods.

WHC values ranged from 10.0 to 24.3%, and values obtained on day 1 post slaughter were similar to those found by Argüello et al. (2005) with the same breed and LWS. WHC means were significantly lowest for the three package methods on day 7 of storage and highest on day 1. There were more than 50% of differences for the average WHC between days 1 and 7 of storage, which denote an important failure in the three packaging methods tested.

Water loss due to drip ranged from 0.8 to 3.1%. There was significant water loss during storage only for the vacuum treatments, with the loss being highest on day 7 and lowest on day 3. Gill (1996) reported that exudative losses of approximately 5% of the primal cut weight at the packing plant are expected. Working with beef, Insausti et al. (2001)

Table 3. Least square means for effect of packaging on meat pH, WHC and water losses of Majorera kids

Measure	Treatment	Storage time 4°C (days)				SEM	Treatment×storage time
		1	3	5	7		
pH							NS
	Atmospheric air	5.7	5.6	5.7	5.7	0.02	
	Vacuum	5.7	5.7	5.8	5.8	0.04	
	MAP[1]	5.7	5.7	5.7	5.8	0.01	
WHC (%)							0.037
	Atmospheric air	24.3^{a}	17.0^{b}	15.3^{bc}	11.3^{c}	1.25	
	Vacuum	24.3^{a}	19.3^{b}	15.0^{bc}	12.0^{c}	1.54	
	MAP	24.3^{a}	13.0^{b}	12.3^{b}	10.0^{c}	1.38	
Water loss (%)							0.037
	Atmospheric air	-	0.8^{a,x}	0.8^{a,x}	1.2^{a,x}	0.10	
	Vacuum	-	1.4^{b,y}	1.6^{b,y}	3.1^{a,y}	0.21	
	MAP	-	1.9^{a,y}	2.0^{a,y}	1.8^{a,z}	0.14	

Values in the same row with different letters (a, b, c) are different (p<0.05); values in the same column with different letters (x, y, z) are different (p<0.05).
[1] MAP = Modified atmosphere packaging consisted in a 10:70:20 mixture of N_2:O_2:CO_2. NS = No significative.

reported water loss increasing to a maximum of 2.64% on day 10. These results agree with those of the present study. An inverse relationship was observed for water loss and WHC ($r = 0.85$; $p<0.05$). Obviously, meat lost more water during storage, decreasing the ability of meat to expel water on compression.

CONCLUSION

In reference to consumers, the MAP proposed in the present study is the chosen method for storing goat meat, rather than vacuum or atmospheric air packaging. It is important to remark that atmospheric air packaging is a suitable method for undeveloped countries as day 7 of storage presented similar values to MAP chops.

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