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Physical, chemical and sensory factors of Mexican and New Zealand sheep meat commercialized in Central of Mexico

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The object of this study was to determine the physicochemical and sensory quality of national and imported from New Zealand mutton sold in the highest mutton-selling region in Mexico (Capulhuac, Estado de Mexico). Samples were obtained from 6 wholesale points. In each outlet a piece of *longissimus dorsi* muscle was bought. The factors evaluated were moisture, protein, fat, objective color (L*, a* y b*) subjective color and shear force. There were differences (P < 0.05) in variables L*, a*, b*, moisture and protein between national and imported meat. There were also differences in the percentage of protein (national 21.27%; imported 20.27%) of fat (national 2.07%; imported 3.37%), and in shear force (national 3.73 kg; imported 2.09 kg). The sensory evaluation was done by 49 consumer judges. Results showed that consumers prefer imported meat over national meat.

Key words: Quality, ovine, lamb, mutton, meat quality, meat imported, sensory evaluation.

INTRODUCTION

Sheep meat is affected by certain *ante-mortem* factors such as genetics, age, gender, diet and stress among others, and by *post-mortem* factors such as freezing, refrigeration, maturation and electrical stimulation among others. These factors affect the quality of the meat and its physical and chemical composition (Torrescano et al., 2009).

In the center of Mexico, in the states of Hidalgo, Chihuahua, Jalisco, Estado de México and San Luis Potosí, ovine herds are a cross of Suffolk or Hampshire breeds. Of the total number of sheep bred in this area, 20% are finished with balanced concentrates, 40% are finished with a combination of grassland use and energy and protein supplements (Barrios, 2005) and finally 40% are finished with grazing. The latter often using inadequate reproductive and/or sanitary handling, premises in bad conditions and unsuitable ingestion systems, which generally cause malnutrition and parasitism (Martínez et al., 2010; Hinojosa-Cuéllar et al., 2009).

The imported sheep meat comes from New Zealand, where the breeds are mainly Borderdale, B-Leicester,

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Coopworth, Corridale, Dorset Down, Drysdale, E-Friesian, Hampshire, Lincoln, Merino, Texel, Suffolk (New Zealand Sheep-breeders Association, 2011; Scerra et al., 2007). Farmers use *brassica, raigrás perenne, italian raigrás*, turnips, red clover, two types of cabbage and bananas to improve ovine production, seeing as these influence the color, tenderness and pH (New Zealand Sheep-breeders Association, 2011; Scerra et al., 2007). In Mexico there is a growing demand of over 85,000 tons of sheep meat, 40,000 tons of those amount are imported. In 2010 they were sold on the national market for $33 /kg carcass and the frozen imported meat for $42 /kg (Martínez et al., 2011). At present there are no studies comparing the national meat quality vs. imported is therefore vitally important to provide such information to assist domestic producers to market their product best

Usually sheep meat in Mexico is consumed in traditional recipes such as *barbacoa* and *pastor* (Arteaga, 2006). *Barbacoa* is a traditional Mexican lamb dish which involves cooking meat in a pit in the ground along with a container of water, causing the heat that is roasting the meat to be very damp and making the meat moist. *Pastor* is lamb marinaded in chillies and spices and then roasted).

In 2008 there was a deficit of almost 35,000 tons, which had to be imported principally from New Zealand but also from Australia and Chile. That year national production made up 48.9% of total consumption and imported sheep meat made up the remaining 51.1% (Martínez et al., 2010). *Barbacoa* producers prefer Mexican sheep meat due to its taste, however they choose imported meat because it implies less cutting of the carcasses (Martínez et al., 2009). The demand of ovine products is determined by the requirements of human populations of meat, wool and leather. These requirements have been steadily growing by 1.07% for the past 10 years, according to the estimations of the Comisión *Nacional* de *Población* or National Population Commission.

Furthermore it has not been clearly stated if the sheep meat from different sources has varying levels of quality depending on their chemical composition and consumer acceptance. Not being aware of the differences between national and imported meat and their impact on the national market leads to economic loss (5.00/kg) along the production-consumption chain, particularly in the area this study is focusing on, the municipality of Capulhuac, Estado de Mexico. The aforementioned location is the main national collection point for sheep meat and the principal *barbacoa* trader. Imported sheep meat comes in its majority from New Zealand but also from Australia and Chile, which could suggest it is of better quality than the meat from the states of Zacatecas, Jalisco, San Luis Potosí, Chihuahua, Michoacán, Durango and Aguascalientes, even though this has not been proven to date. Therefore the objective of this study was to determine the physicochemical and sensory quality of national and imported sheep meat sold in Capulhuac, Estado de Mexico.

MATERIALS AND METHODS

The testing was carried out in the months of September to November, 2010 in the municipality of Capulhuac, Estado de México The location was chosen for being the greatest ovine livestock center, where circa 400,00 heads are sacrificed per year and approximately 190 sheep meat retailers operate, there are 350 producers and suppliers from 7 states in the Mexican Republic (Zacatecas, Jalisco, San Luis Potosí, Chihuahua, Michoacán, Durango and Aguascalientes, among others), 700 *barbacoa* producing clients and distributors of froze, imported sheep meat from New Zealand, Australia and Chile (Center for livestock introduction and production of Capulhuac, Estado de México, S.P.R. de R.L. de C.V., 2011). These animals are slaughtered and frozen at -18°C, then are shipped and shipped via sea to Mexico (40 days), arriving at the Port of Vera Cruz, immediately are transported in trailers with Termoking to Capulhuac at 6 retailers wholesalers, maintaining the same storage conditions, where samples were taken for the present and taken to the laboratory experiment, while maintaining the same conditions. The animals are slaughtered in Mexico weighing approximately 45 Kg, hybrid line (wool / meat) fed with concentrates mostly slaughtered in backyard, sold unripe or freeze

Sampling

Shop owners were interviewed to find the wholesale points which sold national and imported sheep meat. Six principal wholesale points were identified and a directed sampling method was proposed (Scheaffer et al., 2007). At each point of sale a piece of meat (15 cm) from the longissimus *dorsi* muscle was bought. It was stored in a hermetic plastic bag (Ziploc®) and kept in ice at approximately 3°C while being transported to the laboratory where it was frozen at -2°C, awaiting analysis.

Instrumental analysis

The samples were defrosted for 19 h in refrigeration until they reached approximately 16°C. The surrounding fat and adjacent muscles were removed. The chop from the 5th rib was used to measure subjective color according to the scale (1 = pale pink, 2 = cherry red, 3 = dark red and 4 = deep purple) proposed by Sierra (1974). Objective color was measured with a Minolta Chroma meter CR-400, with observer (2 degrees, standard color matching CIE 1931: (x2λ, y2λ, z2λ) and lighting (C, D65) as well as with a 20° angle of vision made in Tokyo, Japan). The measurements were taken 15 min after cutting the piece of meat transversally (Honikel, 1998). The chops were ground using a Moulinex (France) food processor and tested for moisture using the dry oven method (AOAC, 1990). To determine protein content the Kjeldahl (AOAC,) method was used, and fat was measured using a chloroform-methanol mix 2:1 and the Soxtec Foss Tecator 2055 gravimeter, adapted with the official method AOAC #991 (Mariezcurrena et al., 2010). To test shear force, the chops were cooked on a grill to a final temperature of 70°C measured with a thermocouple (Omega Inc., Stamford, E.U.) and a portable recording thermometer (Omega Inc., Stamford, E.U.) (American Meat Science Association, 1995).

Sensory evaluation

A simple paired-comparison and then a degree of satisfaction test were carried out with 49 non-trained judges (consumers) in semi pilot test ranging in ages from 20 to 50 years old. In preparation for the tasting, the samples were defrosted for 19 h in refrigeration and then allowed to reach room temperature, and then they were grilled

Table 1. Physical and chemical composition of national and imported meat.

Variables	National meat	Imported meat	SEM
Protein (%)	21.27[a]	20.27[b]	0.27
Fat (%)	2.07[b]	3.37[a]	0.05
Moisture (%)	77.33[a]	64.53[b]	0.85
L*	33.63[b]	35.95[a]	0.74
a*	14.37[b]	16.06[a]	0.40
b*	6.13[b]	7.41[a]	0.28
Subjective color (1-4)	3.45[a]	3.55[a]	0.12
Shear force (kg_f)	3.73[a]	2.09[a]	0.39

Means with different superscripts [(a y b)] in the same row are significantly different ($p<0.05$). L* varies from 0 (black) to 100 (white), a* positive (a*>0, red) or negative (a*<0, green), b* positive (b*>0, yellow) or negative (b*<0, blue), EEM: Standard error in means.

Table 2. Simple paired-comparison test for flavor intensity.

Intensity of flavor	National meat	Imported meat	P-Value	SEM
Lamb	6.0[a]	7.0 [a]	0.248	0.416
Mutton	6.0[a]	6.0[a]	0.600	0.456
Fat	3.0[b]	5.0[a]	0.008	0.421
Metallic	4.0[a]	2.0[a]	0.987	0.405

Means with different superscripts [(a y b)] in the same row are significantly different ($p < 0.05$), SEM: Standard error in means, Hedonic scale from 0 to 9; with 0 = absent; 9 = extremely intense.

until the geometric center reached 70°C. Then the borders were removed and the meat was cut into uniform cubes (of approximately 2 $cm^{3)}$, put in plastic bags and placed on bain-marie (23°C; AMSA, 1995). Each judge received two samples on plates labeled with random 3-digit numbers and accompanied by neutral wholemeal crackers, water and the questionnaire. These questionnaires were designed to evaluate a simple paired-comparison which consisted of grading the intensity of taste of the following: lamb (Newborn) mutton, fat and metallic. These variables were measured using this hedonic scale: 0 (absent) to 9 (extremely intense). The meat was also tested for general satisfaction, juiciness, tenderness and taste using the following hedonic scale: 1 (dislike extremely), 2 (dislike very much), 3 (dislike moderately), 4 (dislike slightly), 5 (neither like nor dislike), 6 (like slightly), 7 (like moderately), 8 (like very much), 9 (like extremely). The aforementioned qualities of juiciness, tenderness and taste were also graded from 1 (extremely dry/tough/insipid) to 9 (extremely juicy/tender/tasty). Judges were also asked to state buying preference from 1 (I would definitely not buy it) to 5 (I would definitely buy it).

Statistical analysis

Samples from both imported and national meat were tested, using 5 samples of each. 8 variables were analyzed: objective color (L*, a* y b*), subjective color, fat, protein, moisture and shear force, a variance test was carried out on both types to determine physicochemical characteristics. Significant variation to $P < 0.05$ was observed and the averages were measured with the Tukey test (SAS, 2004). The results of the sensory evaluation were analyzed statistically using the U of Mann-Whitney ($P < 0.05$) test which was carried out on both national and imported meat. 49 repetitions for each type (national and imported) and 12 answer variables (intensity of lamb, mutton, fat and metallic taste; like/dislike, juiciness, tenderness and taste; level of juiciness, tenderness, taste and purchase preference). With this analysis the effects of the two types of sheep meat and the sensory characteristics were discovered. Furthermore an analysis of main components for sensory evaluation was done to reduce the dimensionality of the data and thus discover the causes of variability within it and order them by importance.

RESULTS

Physical and chemical characteristics results

The averages and the standard deviation of the variables of the physicochemical composition of the two types of sheep meat evaluated are shown in Table 1. National meat showed lower scores in the variables L, a*, b*, which shows it is darker meat. It also displayed higher protein and moisture content and less fat content. There were no significant differences in subjective color and shear force.

Sensory evaluation

The consumer judges did not detect significant differences between national and imported meat in terms of intensity of lamb flavor, of mutton flavor or of metallic taste, however they did notice that imported meat tasted more intensely of fat than did national meat (Table 2).

Table 3. Simple paired-comparison test for juiciness, tenderness and flavor.

Characteristics	National meat	Imported meat	P-Value	SEM
Juiciness	5.0[b]	7.0[a]	0.00001	0.252
Tenderness	5.0[a]	7.0[b]	0.00080	0.252
Flavor	7.0[a]	7.0[a]	0.07500	0.324

Means with different superscripts [(a y b)] in the same row are significantly different (p<0.05), SEM: Standard error in means, Hedonic scale from 1 to 9; with 1=extremely dry/tough/ insipid; 5= not dry or juicy/ not tough nor tender/ not insipid nor strong-tasting; 9=extremely juicy/tender/strong tasting.

Table 4. Simple paired-comparison test for satisfaction.

Degree of satisfaction	National meat	Imported meat	P-Value	SEM
Juiciness	5.0[a]	7.0[b]	0.0003	0.254
Tenderness	6.0[a]	7.0[b]	0.040	0.290
Flavor	5.0[a]	6.0[b]	0.009	0.254
General satisfaction	5.0[a]	7.0[b]	0.002	0.297

Means with different superscripts [(a y b)] in the same row are significantly different (p<0.05), SEM: Standard error in means, Hedonic scale from 1 to 9; with 1=dislike extremely; 5=neither like nor dislike 9=like extremely.

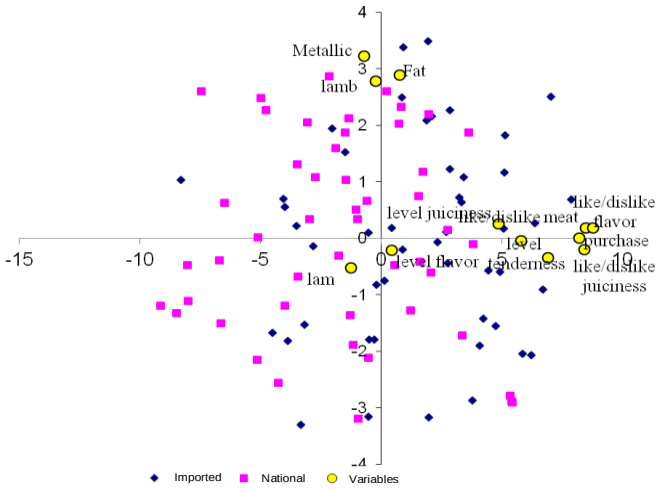

Figure 1. Main components of the sensory evaluation.

The consumer judges did not detect differences in intensity of flavor between national and imported meat, however they did rate imported meat higher on juiciness and tenderness (Table 3). The consumer judges preferred the imported meat over the national meat for juiciness, tenderness, flavor and general satisfaction. The consumer judges showed a preference (P<0.001) for buying imported meat over national meat (Table 4).

Main component analysis in sensory evaluation variables

The analysis of the main components (Table 1) showed main component 1 accounts for 38.37% of the variance of the data obtained and main component 2 accounts for 19.48%, both adding up to 57.86% of variance. Main component 1 is largely determined by the degree of satisfaction test (juiciness, tenderness and general satisfaction regarding sheep meat) and the preference test. Main component 2 is determined by the taste test (lamb, mutton, fat and metallic). Figure 1 shows the decision to buy imported meat is influenced by the general degree of satisfaction in tenderness and taste variables. This allows us to see that the consumers involved in the testing would prefer to buy imported meat over national meat for its juiciness, tenderness, taste and general satisfaction characteristics. Consumers stated that national meat had a more intense taste of lamb, mutton and fat, and this would lead them to not buy it, a trend that is clearly shown in Figure 1.

DISCUSSION

This study showed that imported sheep meat has a larger percentage of intramuscular fat than national meat; this implies the moisture percentage of national meat is greater, as has been previously reported (Forrest et al., 1979). One of the factors affecting the quality of the meat is diet fed to sheep. Gutiérrez et al. (2005), Nuncio et al. (2001) and Hernández and Vidal (2001) reported that there are two production systems in Mexico: extensive (grazing and concentrates) and intensive when sheep fed on concentrates principally based on maize and sorghum. Costa et al. (2009) reported that sheep fed on concentrates, mainly maize and sorghum, show higher percentages of protein and moisture in the meat. There is

virtually a constant between myofibrillar protein and water in meat (Sánchez, 1999) seeing as the majority of water lies trapped between the myofibrillar proteins (70%; Carballo et al., 2001). Farmers in New Zealand feed the sheep with leguminous forage plants (clover) which cause an increase in intramuscular fat, compared to sheep fed on concentrates of high amount of maize, (Research into Lamb Meat Quality, 2010; Schreurs et al., 2008; Scerra et al., 2007; Díaz et al., 2005).

These are the reasons imported sheep meat turned out to be tenderer than national meat. Realini et al. (2004) reported that sheep fed on grass yielded tenderer meat. Another influencing factor is that Mexican *barbacoa* producers prefer warm carcasses, thus there is no maturation of the meat. On the other hand, Costa (2002) reported that intramuscular fat is due to lipids deposited between and inside cells, and this is associated with increased flavor, tenderness and juiciness. This study shows that consumers found imported sheep meat to taste more of fat than national meat, this could be due to diet, seeing as Whittington et al. (2006) and Fisher et al. (2000) found that panelists detected more fat flavor in concentrate-fed sheep. This study found that consumers prefer imported sheep meat, as it is juicier and tenderer than national meat. According to Sañudo (2008), intramuscular fat content is directly related to juiciness and tenderness in sheep meat, this explains why the bromatological analysis showed more intramuscular fat in imported meat, thus preferred by consumers. Furthermore the content of intramuscular fat has bearing on tenderness, acting as a lubricant between teeth and mouth during chewing by diminishing friction.

Conclusions

This study showed that imported sheep meat, sold in the municipality of Capulhuac, Estado de Mexico contained more intramuscular fat than national sheep meat. This made it tenderer and thus preferred by consumers.

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