SESSION III Consumers Preferences, Perceptions, and Meat Quality

SESSION III.b Pages

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A PROTOCOL TO MEASURE THE FREE WATER IN RAW AND COOKED MEAT

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Abstract – The water holding capacity of meat is one of the most important factors affecting the quality. There is a multitude of procedures to measure the WHC on raw and cooked meat but results in the literature are difficult to compare and correlate. To solve this problem it has been developed a protocol to be used on the same meat sample, to analyze the water loss at different stages of its commercial food life during: thawing, cooking, cooling and consumption. The water on raw meat is measured as: thawing; drip; total area, ring and meat film area at 10' by compression; free water. On cooked meat: cooking and cooling loss; available cooked meat water. Parameters are expressed as the per cent out of the total water content. The traditional parameters are achieved at a lower cost and with coefficients of variation lower or at most similar to that reported in the literature. In addition, two new parameters which measure cooling loss and available cooked meat water allow to better define the available water at the time of consumption. The protocol uses two devices specifically designed by the authors to automate and improve the accuracy of some of the proposed parameters.

I. INTRODUCTION

Meat has a central role in our eating and the world consumer's demand is still increasing. The water holding capacity (WHC) of meat and meat products is one of the most important factors affecting economic value and meat quality. WHC affects the weight change during transport, storage, thawing, weight loss and shrinkage during cooking, and juiciness and tenderness of the meat (1). The WHC is the ability of meat to retain its water during application of external forces, such as cutting, grinding or pressing and processing (1). Changes in WHC in muscle *post mortem* involves lateral shrinkage of myofibrils as the principle mechanism driving water loss but there are many other factors, both genetic and non-genetic, that can influence WHC. There is a multitude of procedures to measure the WHC on raw and cooked meat or meat products (2, 3, 4, 5, 6). Because of the variation in used methods, the results for the water loss in the literature are difficult to compare. All the methods chosen to measure water loss in raw and cooked meat are generally independent of each other. Each method requires its sample and the treatment is specific but this includes an assumption of homogeneity of the muscle under investigation, an assumption that is particularly critical when measuring drip loss (7). So in addition to the method variability there is the variability of the meat samples. The increased variability reduces the correlation among the different methods that measure the loss of water at different times of commercial life and during consumption. To solve this problem it has been developed a protocol to be used on the same fresh or frozen meat sample, to analyze the water loss at different stages of his simulated commercial food life during: thawing, ageing, cooking, cooling and consumption.

II. MATERIALS AND METHODS

The proposed protocol measures water loss on raw meat as: thawing (TH); drip (DL); Water Holding Capacity (whc600), ring (ring), the ratio meat film area on total area (whcrp) at 10'; the free water (frwt). On cooked meat: cooking (clmcs) and cooling (cwmcs) loss by Meat Cooking Shrinkage (MCS) method (8); water loss (srwl) by Stress Resistance and Relaxation (SRR) method (9). It is also reported the total moisture content of the meat (tmc) and the pH at the analysis. The parameters TH, DL, frwt, clmcs cwmcs and srwl are expressed as the per cent out of the total water content to compare the contribution of each parameter. All these analysis are carried out, in a consecutive way, using only a 3cm thick sample (*M. Longissimus thoracis*). The showed results were obtained from the analysis of samples get out from meat aged for 7 to 14 days and fresh or frozen.

Meat sample

M. Longissimus thoracis obtained from veal, beef and pork were used as source of samples from the 12th thoracic rib in the caudal direction. When frozen the samples were vacuum packed

and stored at -20°C until analysis. Two days before analysis day sample were thawed at 4°C.

Thawing loss (TH)

The day of analysis every thawed sample was taken from the bag and weighed. The bag was gently dried using blotting paper and then it was weighed. The difference between frozen packaged sample *minus* the thawed sample and the bag was the thawing loss. It was expressed as the per cent out of the weight of the frozen packaged sample and corrected for the tmc.

Drip Loss (DL)

A first slice (1cm thickness) was taken from the sample. A rectangular meat piece (4x4cm) was obtained from this slice. It was weighed and put in a plastic closed container. This container had a perforated support that permitted the escape of fluid. After a storage period (48h) at chill temperature (4°C) sample was weighed again (4). The difference between initial weight and the weight after storage was DL measurement. It was expressed as the per cent out of the initial weight and corrected for the tmc.

Water Holding Capacity (whc600), meat film area/whc600 (whcrp) and Ring

Raw meat remains (80g), obtained from the previous analysis, were trimmed of external fat and chopped before grinding. Afterwards 250 ± 10mg of minced meat were weighed on a filter paper sheet to measure total and meat film area (whcmt) after 600s of compression at 500N (10). Three replicates of every sample were carried out. The total area in mm^2 on the filter paper was the Water Holding Capacity at 10' (whc600) and the difference to the whcmt, expressed as the per cent out of the whc600, evaluates the ring. The whcrp measures the whcmt as the per cent out of the whc600.

Free water (frwt)

The free water is the ring area expressed as the per cent out of the total moisture content (tmc) according to Wierbicki and Deathrage (11) as reported in the formula [1] where 0.09470518941 mg of water/mm^2 is the regression coefficient.

$$[1] \qquad frwt = \frac{(whc600 - whcmt) * 0.09470518941}{weight\ sample * H_2O}$$

Total cooked loss by MCS (clmcs)

A second slice (1 cm of thickness) was cut from initial sample using a knife and a cutting system, based on two horizontal guides. From this slice a circular steak (5.5cm Ø) was obtained according to MCS protocol (8). Row sample, on temperate glass, was weighed then cooked in an electric forced air convection oven for 600s at 165°C and 69-70°C in the center of the sample. After it was put in a Petri dish, between two dried filter paper sheets. After 20min of cooling at room temperature, the circular steak was gently dry and weighed. The difference among raw and cooked sample was the cooked loss (clmcs), expressed as the per cent out of the raw sample weight and corrected for the tmc.

Cooling loss by MCS (cwmcs)

Petri dish with two dry filter paper sheets was weighed before and after sample cooling. The difference expressed as the per cent out of the raw sample weight, evaluates the cooling water loss (cwmcs) and corrected for the tmc. Data didn't need to be corrected for the expressible fat as it was irrelevant according to our test.

Cooking loss by MCS (clwmcs)

The difference between the total cooked loss (clmcs) and the cooling loss (cwmcs) measures the water lost in the oven when meat is cooking, expressed as the per cent out of the clmcs (8) and corrected for the tmc.

Available cooked meat water by SRR (srwl)

The cooled previous circular cooked steak was used to obtain three cylinders of 1cm of diameter. These cylinders were compressed according to the SRR method (9). Each cylinder was weighed before and after compression and the difference, expressed as the per cent of the cooked cylinder, evaluates the water in the cooked meat available to the consumer (srwl) and corrected for the tmc.

Statistical analysis was carried out with the SAS version 9.4 (12) using the Pearson Correlation analysis among continuous variables. Results are expressed as Means, standard deviations (STD) and coefficients of variation.

III. RESULTS AND DISCUSSION

In Table 1 are reported the means and their coefficients of variation. The N is variable according to the availability of the measured parameters. The coefficients of variation are very large for some parameters also due to effect of species and categories. Muchenje *et al.* (13) reported similar ranges for some parameters related to the WHC: drip loss 0.14-3.89%; WHC 37.0-72.7%; cooking loss 13.1-34.5%. Otto *et al.* (5) reported, for the drip loss using two different methods, a coefficient of variation ranging between 47.4 to 65.1%. Cheng *et al.* (14) reported coefficients of variation for drip loss of

Table 1 Mean, STD and Coefficient of variation of the water loss parameters (%).

Parameters	N	Mean	STD	CV
Thawing loss	226	7.84	3.68	46.9
Drip loss	285	5.30	3.57	67.4
WHC (mm^2)	407	1363.8	86.2	6.3
Ring	407	41.66	6.92	16.6
Meat film area/Total area	407	58.34	6.92	11.9
Free water	325	28.23	5.73	20.3
Total cooked loss	332	30.50	5.94	19.5
Cooling loss	308	5.81	2.18	37.5
Cooking loss	308	24.72	6.40	25.9
Available cooked meat water	116	35.30	7.34	20.8
Total moisture content	334	74.13	2.10	2.8
pH	121	5.47	0.22	4.0

63.5%, cooking loss 31.5% and cooling loss 43.4%.

The measured parameters by the proposed protocol analyze all the different water content in the raw and cooked meat. It is possible to analyze how the meat water is lost during the shelf life until consumption.

The maximum water loss is during cooking meat (24.72% out of tmc) and when cooling the meat still loses 5.81% out of tmc for a total cooked loss of 30.50%. The available cooked meat water (srwl) is more than a third (35.3 out of tmc). The sum of the parameters measured on the cooked meat is equal to 65.83% plus the thawing loss (7.84%) and the drip loss (5.3%) is equal to 79% which is not the expected free water (85-95%) (15). The missing 6-16% of free water could be in the residual sample at the end of the SRR method. This method compresses the 1cm cylinder to 0.75cm, and then there is still water in the sample.

The free water measured by compression on the raw meat was 28.23% out of the tmc and summed to TH and DL is equal to 41.4%, very far from the expected free water (85-95%). It was added also the DL but it should already be considered in the measured free water.

The table 2 shows the correlation among parameters. The TH is negatively correlated to the DL, whc600 and cwmcs; positively to the clmcs and clwmcs. Less water is lost during thawing and greater is the amount lost later on raw meat but not on the cooked meat. DL is positively correlate with frwt, whc600 and ring to indicate that higher is the free water and greater will be the losses. DL also indicates a greater loss on cooked meat. DL is negatively correlated to the whcrp which indicates a larger percentage of the meat film area, then less available free water. DL is negatively correlated to the pH to confirm what is already known (15, 16). The whc600, ring and frwt are positively correlated to the other parameters except TH, cwmcs and pH. The whcrp is negatively correlated to them because it measures the meat film area.

The clmcs is negatively correlated to the srwl to indicate a lower loss when cooking and cooling then more water when the meat is consumed. The tmc is positively correlated to the compression methods on the raw meat (whc600, ring and frwt) and, as expected, negatively with whcrp. It is not clear why it was found a strong negative correlation between pH and srwl (-0.55); it would be expected a positive correlation.

IV. CONCLUSION

The proposed protocol achieves some of the traditional parameters at a lower cost and with coefficients of variation lower or at most similar to that reported in the literature. In addition, two new parameters which measure cooling loss and available cooked meat water allow to better define the water available at the time of consumption. It is responsible, along with the fat content, of the sensation of juiciness detected by the consumer. The protocol uses two devices specifically designed by the authors to automate and improve the accuracy of some of the proposed parameters.

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Table 2. Correlations among water loss parameters

Pearson Correlation Coefficients Prob > |r| under H0: Rho=0 Number of Observations	TH	DL	whc600	ring	frwt	whcrp	clmcs	cwmcs	clwmcs	srwl	tmc	pH
TH Thawing Loss	1.00000 226	-0.40308 <.0001 183	-0.12097 0.0747 218	-0.11268 0.0970 218	-0.10973 0.1062 218	0.11268 0.0970 218	0.15651 0.0188 225	-0.22320 0.0010 213	0.23015 0.0007 213	-0.15650 0.2728 51	-0.10772 0.1063 226	0.16897 0.4093 26
DL Drip Loss	-0.40308 <.0001 183	1.00000 285	0.21920 0.0002 279	0.21550 0.0003 279	0.22819 0.0001 279	-0.21550 0.0003 279	0.31365 <.0001 284	0.19007 0.0020 262	0.23011 0.0002 262	-0.10658 0.2569 115	0.01847 0.7562 285	-0.38215 0.0448 28
whc600 10' WHC Total Area	-0.12097 0.0747 218	0.21920 0.0002 279	1.00000 407	0.61809 <.0001 407	0.79981 <.0001 325	-0.61809 <.0001 407	0.30055 <.0001 324	0.05618 0.3321 300	0.25759 <.0001 300	0.18221 0.0556 111	0.35592 <.0001 325	-0.12174 0.2790 81
ring Ring water	-0.11268 0.0970 218	0.21550 0.0003 279	0.61809 <.0001 407	1.00000 407	0.96001 <.0001 325	-1.00000 <.0001 407	0.29920 <.0001 324	0.01692 0.7703 300	0.26391 <.0001 300	0.08809 0.3579 111	0.31399 <.0001 325	0.00948 0.9330 81
frwt Free water %	-0.10973 0.1062 218	0.22819 0.0001 279	0.79981 <.0001 325	0.96001 <.0001 325	1.00000 325	-0.96001 <.0001 325	0.33822 <.0001 324	0.03300 0.5691 300	0.29834 <.0001 300	0.11239 0.2402 111	0.23198 <.0001 325	-0.11543 0.5912 24
whcrp Meat area/total %	0.11268 0.0970 218	-0.21550 0.0003 279	-0.61809 <.0001 407	-1.00000 <.0001 407	-0.96001 <.0001 325	1.00000 407	-0.29920 <.0001 324	-0.01692 0.7703 300	-0.26391 <.0001 300	-0.08809 0.3579 111	-0.31399 <.0001 325	-0.00948 0.9330 81
clmcs Total Cooked Loss by MCS	0.15651 0.0188 225	0.31365 <.0001 284	0.30055 <.0001 324	0.29920 <.0001 324	0.33822 <.0001 324	-0.29920 <.0001 324	1.00000 332	-0.03624 0.5263 308	0.94050 <.0001 308	-0.26650 0.0038 116	-0.08352 0.1288 332	-0.20919 0.2761 29
cwmcs Cooling Loss by MCS	-0.22320 0.0010 213	0.19007 0.0020 262	0.05618 0.3321 300	0.01692 0.7703 300	0.03300 0.5691 300	-0.01692 0.7703 300	-0.03624 0.5263 308	1.00000 308	-0.37366 <.0001 308	-0.12239 0.1906 116	-0.10458 0.0668 308	-0.08621 0.6566 29
clwmcs Cooking loss by MCS	0.23015 0.0007 213	0.23011 0.0002 262	0.25759 <.0001 300	0.26391 <.0001 300	0.29834 <.0001 300	-0.26391 <.0001 300	0.94050 <.0001 308	-0.37366 <.0001 308	1.00000 308	-0.20041 0.0310 116	-0.07120 0.2127 308	-0.19614 0.3079 29
srwl Available cooked meat water	-0.15650 0.2728 51	-0.10658 0.2569 115	0.18221 0.0556 111	0.08809 0.3579 111	0.11239 0.2402 111	-0.08809 0.3579 111	-0.26650 0.0038 116	-0.12239 0.1906 116	-0.20041 0.0310 116	1.00000 116	0.02336 0.8034 116	-0.55154 0.0035 26
tmc Total Moisture Content	-0.10772 0.1063 226	0.01847 0.7562 285	0.35592 <.0001 325	0.31399 <.0001 325	0.23198 <.0001 325	-0.31399 <.0001 325	-0.08352 0.1288 332	-0.10458 0.0668 308	-0.07120 0.2127 308	0.02336 0.8034 116	1.00000 334	-0.18630 0.3332 29
pH pH at the analysis	0.16897 0.4093 26	-0.38215 0.0448 28	-0.12174 0.2790 81	0.00948 0.9330 81	-0.11543 0.5912 24	-0.00948 0.9330 81	-0.20919 0.2761 29	-0.08621 0.6566 29	-0.19614 0.3079 29	-0.55154 0.0035 26	-0.18630 0.3332 29	1.00000 121

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FEEDING SYSTEM AND GLUTATHIONE PEROXIDASE ACTIVITY, SELENIUM CONTENT AND ANTIOXIDANT STATUS OF ANGUS MEAT

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Abstract - The objective of this study was to determine the glutathione peroxidase (GPx) activity, the selenium (Se) content, and the total antioxidant status in bovine meat produced in three different feeding systems. For this, 10 Aberdeen Angus steers were fed natural and improved pastures, 10 were fed pasture plus grain supplementation and 10 were produced in a feedlot. After slaughter, the *Longissimus dorsi* (LD) muscle was obtained and divided in two pieces, one was frozen at -20ºC and the other was vacuum packaged and aged at 1-2ºC during 14 days. A feeding system effect ($p<0.01$) (pasture<pasture+supplementation<feedlot) and an ageing effect ($p<0.05$) were found (aged<fresh) for the GPx activity. A feeding system effect ($p<0.05$) was also found for Se content (feedlot<pasture), but no ageing effect was observed. No feeding nor ageing effects were found for the antioxidant potential results, but an incubation time effect was observed ($p<0.0001$), where oxidation values increased with incubation time. So we can conclude that the feeding system affects the GPx activity and the selenium content in Angus meat and that GPx activity decreases with meat ageing.

I. INTRODUCTION

In Uruguay, beef cattle production systems are based on pasture feeding, but more recently livestock producers have been investing on improved pastures and supplementation with concentrate, leading to cattle with different carcass and meat quality attributes [1]. Feed-lot strategies are also gaining place among producers. Meat produced on pasture or grain differs in their antioxidants, pro-oxidants and fatty acid composition. Pasture-fed cattle rendered meat with higher n-3 polyunsaturated fatty acids (PUFA) and conjugated linoleic acid (CLA) content than their counterparts fed concentrate diets [2]. Grass, in pasture feeding, is particularly rich in natural antioxidants such as vitamins from group A, C and especially E, or phytochemicals such as carotenoids and flavonoids, and so, offers a great protection against lipid oxidation. Grains are less rich in vitamin antioxidants, but also contain antioxidant compounds such as polyphenols and phytic acid [3]. Oxidation induces modifications of muscle lipids and proteins and, therefore, affects the organoleptic and nutritional properties of meat and meat products [4]. In meat, to decrease oxidation, endogenous protective systems, including small peptides such as glutathione, carnosine and anserine or proteins, essentially antioxidant enzymes, are also implicated. The enzymes superoxide dismutase (SOD), catalase and glutathione peroxidase (GPx) constitute the primary mechanism for protecting cells from oxidative damage in vivo [3]. GPx is a key enzyme in the antioxidant defence system of cells since it reduces a number of peroxides [5]. The GPx family contains at least four selenoproteins, cellular, extracellular, phospholipid hydroperoxide and gastrointestinal GPx [6]. The importance of Se is principally associated with its role as an essential part of GPx [7]. The Se content in animal derived foods reflects that of the feeds consumed by the animals [8]. Contribution of each antioxidant, when measured separately, does not really reflect antioxidant status of meat. An estimation of global antioxidant

status can be useful to describe the capacity of muscle to resist oxidation processes [3]. The aim of this work was to determine the effect of feeding system (pasture, pasture plus grain supplementation and feedlot) on Angus meat antioxidant status, considering its selenium content, GPx activity and total antioxidant potential. Also, search for a relationship between Se content and GPx activity.

II. MATERIALS AND METHODS

Briefly, 30 Aberdeen Angus steers were divided into three different feeding systems: 1) free access to pasture where animals reached a mean weight of 479.8 kg, 2) pasture plus grain supplementation during the last month where animals reached a mean weight of 502.4 kg, and 3) feedlot during the last 110 days reaching a mean weight of 497.4 kg. After slaughter, the *Longissimus dorsi* (LD) muscle was removed from each carcass and divided in two pieces. One of them was vacuum packaged, aged during 14 days at 1-2 ^{o}C and then frozen at -20 °C. The other piece was directly frozen at -20 °C, until further analysis. For the glutathione peroxidase (GPx) activity determination, the De Vore & Greene (1982) method was followed, adapted by Terevinto [9]. Results were expressed as nanomoles of NADPH oxidized/min/mg protein. The protein content of the muscle extracts was determined at 280 nm [9] using bovine serum albumin as a standard. Selenium was analyzed by graphite furnace atomic absorption [10] with Cu and Mg (nitrate salts, Fluka) as chemical modifiers for the determination of selenium in aqueous media. All the determinations were performed in triplicate. To measure the total antioxidant potential, the iron-induced lipid oxidation method described by Mercier et al. [11] was followed. The data of GPx activity, Se content and iron-induced lipid oxidation were reported as mean ± standard error of the media for fresh and aged meat. To evaluate feeding and ageing effects for each variable determined, an analysis of variance using the GLM procedure (NCSS, 2007) was followed. Also, a one way ANOVA was used to compare within feeding systems, fresh and aged muscle.

III. RESULTS AND DISCUSSION

Results of GPx activity and Se content are shown in Table 1. A feeding system effect was found for the GPx activity ($P<0.01$), were meat produced on pasture had lower activity than that from pasture plus supplementation, and this one lower than that from feedlot. This agrees with other works [4] where also found a higher GPx activity in meat from steers fed grains compared to meat from steers fed pasture. Also, an ageing effect was found ($P<0.05$), were aged meat had lower activity than the fresh one. With regards to selenium content results, we found a feeding system effect ($P<0.05$), were meat from the feedlot system had lower Se content than the meat from pasture, and the meat from the pasture plus supplementation was not different from neither of the other two systems. This result is opposite to what we expected because a higher GPx activity was found in meat from the feedlot system, which could be explained by a higher Se content in the LD muscle of animals in feedlot. No ageing effect was found for Se content in LD. As the principal form of GPx is a seleno-dependent protein, it has been proposed that selenium in the diet is the major source of variation of GPx activity [2]. It has been reported that, cereal grains, were richer in selenium than forages [11]. Hintze et al. (12) showed that in muscle of bovines fed grass, the selenium content of muscle was significantly correlated with selenium level in the grass and that the greatest source of variation in selenium content of muscle was the geographic region from which the beef originated. In the study of Gatellier et al. [3] important differences in muscle selenium content were found between the two diet groups. Mixed diet finished animals had higher content of selenium than pasture finished animals. This difference in selenium content in meat from animals finished on pasture or with the mixed diet, could partly explain difference in GPx activities. A significant correlation between GPx activity and Se content in beef muscles were found by Gatellier et al. [3]; and DeVore & Greene (1982) but not by O´Grady et al. [13] as in the present work.

Table 1. Glutathione peroxidase activity (nmoles/min/mg protein) and total selenium concentration (µg/kg), in fresh and aged *Longissimus dorsi* muscle of steers fed pasture, pasture plus grain supplementation (P+S) and feedlot.

		Pasture	P + S	Feedlot
GPx	Fresh	9.6 ± 0.7 a	11.0 ± 1.1	10.7 ± 0.2
	Aged	7.6 ± 0.5 b	9.2 ± 0.3	10.7 ± 0.4
Main effects: Diet: p<0.01 Ageing: p<0.05				
Se	Fresh	555 ± 20	441 ± 45	357 ± 36
	Aged	423 ± 36	398 ± 89	303 ± 52
Main effects: Diet: p<0.05 Ageing: NS				

Data are means ± SEM (n=10). Different lower case within each feeding system means significant difference to *P<0.05*

No feeding nor ageing effects were found for the total antioxidant potential results, but an incubation time effect was observed (*P<0.0001*), where oxidation values increased with incubation time with iron and hydrogen peroxide. When observing Figure 1, we can see that meat from the feedlot system has lower initial levels of lipid oxidation and significantly increases (*P<0.05*) with time of incubation, while in the meat from animals fed pasture lipid oxidation values keep almost constant.

IV. CONCLUSION

From this work we can conclude that the feeding system affects the GPx activity and the selenium content in Angus meat and that GPx activity decreases with meat ageing. When evaluating the global antioxidant status of meat, no differences between production systems can be seen.

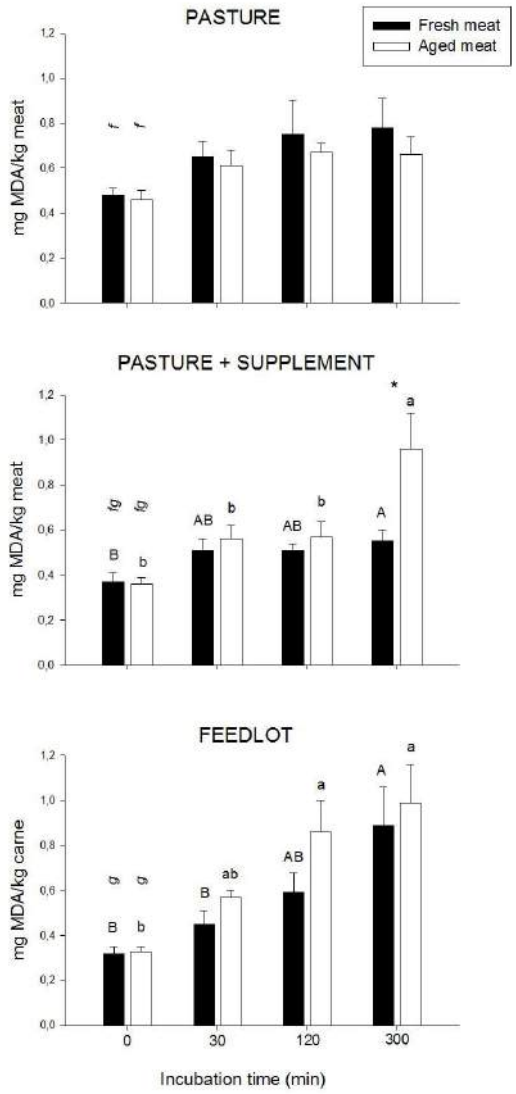

Fig. 1. Iron-induced lipid oxidation (TBARS) in fresh and aged *Longissimus dorsi* muscle of Aberdeen Angus steers fed pasture, pasture plus grain supplementation and feedlot. Bars are means ± SEM (n=10). Different capital letters show significant differences between incubation times for fresh meat (*P<0.05*). Different small letters show significant differences between incubation times for aged meat (*P<0.05*). Different small letters in italics show significant differences between feeding systems for fresh or aged meat in each incubation time (*P<0.05*). * indicates significant differences between fresh and aged meat of the same feeding system in each incubation time (*P<0.05*).

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MEAT AND CARCASS QUALITY OF YOUNG BULLS AND STEERS FROM THE NORTHWEST OF ARGENTINA

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Abstract - The objective of this study was to carry out a meat and carcass quality survey on young bulls and steers, focusing at the relationship between the argentine grading on carcasses and shear force values. Samples of *Longissimus dorsi* muscle (9-13 rib) were collected on castrated (S) or young bulls (B) confined and slaughtered at the same chronological age (DCA) (not permanent teeth (0), 2 (2) and 4 (4) permanent teeth). There were classified according the argentine system and measured the Warner Bratzler shear force. Data were analyzed using the Proc Mixed (Infostat); differences among treatments (category and chronological dental age) were analyzed by Tukey test. It was possible to show that Argentina needs a more sensitive method to ensure reliability classification for carcass quality, do not observe significant differences between quality grades and chronological dental age in WB shear force however differences between categories were significant in hardness.

Key Words: beef, quality grades, chronological age, shear force

I. INTRODUCTION

Argentine beef industry does not have an objective system of carcass quality control. The classification system of Argentine cattle is a subjective method based on certain physical characteristics of the animal, made by a qualified person (Resolution No. J-240/90 Former National Meat Board). The cattle is classified by development of muscle mass and degree of fatness, regardless of the value of tenderness, being one of the qualities most valued by the consumer [1][2] confusing high grades of beef average values with tender meat [1][3]. Animals are rated without regard the chronological dental age. Only few commercials slaughterhouses that export meat add the classification taking in account chronological dental age, being a method that could be added to the existing, especially for Bos Indicus breeds and the crossbreeds, as the meat of these biotypes gets tougher with increasing maturity.

II. MATERIALS AND METHODS

The study was conducted in the northwest region of Argentina on confined productive system. Steers (S) or uncastrated (B) animals ('Criollo', Zebu, Braford/Brangus cattle) slaughtered at the same dental chronological age (DCA) (not permanent teeth, 2 and 4 permanent teeth).

Samples: Animals were slaughtered in a commercial slaughterhouse where were first classified according the argentine grading

system. This determination is based by the observation, on the analysis of the development of the muscular masses, relating of the proportion of meat and bone, being guided by the shapes, profiles and contours of the carcass. Also, the fat coverage is observed, assigning on it an alphanumeric classification.

Then, samples were obtained from *Longissimus dorsi* muscle (9 to 13 ribs) of 27 steers and 24 young bulls. Vacuum packed samples were frozen (-18ºC±1), transported and delivered to the Meat Quality Laboratory of the School of Agriculture (University of Buenos Aires). After that, samples were thawed at a chamber of refrigerated temperature for 24 hours; they were placed in another refrigerated chamber (2.5±0.5ºC) with light control to simulate retail conditions and exhibition. Ageing time of the samples was 4 days.

Measurements: Shear force with a Warner Bratzler shearing attachment (Instron 4442 Universal Testing Machine; Canton, MA, USA) on cooked samples (water bath heated at 70ºC for 50 minutes, monitored by thermocouples) was carried out. Statistical analysis of data was performed using the Proc Mixed of SAS. Differences among treatments were analyzed by Tukey test ($p < 0.05$).

III. RESULTS AND DISCUSION

Data and significance differences on Warner Bratzler values of Category, Quality Grade and Dental chronological age are shown in Table 1. There were no significant differences between quality grades and chronological dental age, but differences between categories were significant, as demonstrated in a previous work [4]. The number of samples could be the cause that no differences were found between the variables analyzed. Furthermore, the *Bos Indicus* crossbreeds, commonly used in the northern region, are less tender than meat from *BosTaurus* cattle used in other regions [4][5][6][7] so it would be of great importance to include the tenderness in carcass classification, like the Australian VIASCAN or the Beef Center Classification in Denmark. In other countries such as Australia, the use of evaluation systems for consumers (Standards Association of Australia (MSA) brings benefits for both, consumers and producers.

Table 1. Probability and Warner Bratzler shear force values (lbs) according to the castrated/uncastrated category, quality grades and dental chronological age.

		MeansWB	SE
Category	S	8,33 a	0,22
	B	9,96 b	0,25
Quality Grade	J	8,28 a	0,41
	U	8,26 a	0,32
	A	8,70 a	0,39
	B	9,45 a	0,32
	U2	9,10 a	0,48
	C	10,05 a	0,48
DCA	0	9,03 a	0,19
	2	8,76 a	0,30
	4	9,85 a	0,75
Probability	Category	0,0379	
	CQG	nsd	
	DCA	nsd	

Category: S: uncastrated and B: young bull. CQG: Carcass Quality Grade: J, U, A, B, U2, C (alphanumeric classification for carcass quality grade). DCA: Dental Chronological Age: 0 (not permanent teeth, 2 (2) and 4 (4) permanent teeth). nsd: no significant difference. Means with common letter are not significantly different ($p \leq 0.05$)

IV. CONCLUSIONS

Tenderness remains one of the most important sensory attribute that determines consumer acceptability and as the official classification system in Argentina does not take in account it as an important parameter, beef quality is affected. It is necessary a more objective system classification that

ensures to the consumers the meat quality, basing on the assessment of tenderness, among others major attributes. A best grading system would improve the rate price/product.

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EFFECT OF COOKING SYSTEM ON WARNER-BRATZLER SHEAR FORCE MEASURE IN POULTRY MEAT

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Abstract - Numerous studies report poultry meat tenderness results but the cooking methods are different (e.g. water bath, grill, oven). Quality assessment results of cooked meat can be significantly affected by sample preparation with different cooking techniques. The aim of this study was to investigate the effect of boiling water bath or grill on Warner-Bratzler shear force determination in poultry meat. Cooking loss, Warner-Bratzler shear force, pH, moisture, lipids and protein content were determined. According to our results, poultry meat tenderness was higher in samples cooked in grill than boiling water bath. Cooking loss, moisture and lipid content did not change.

I. INTRODUCTION

Meat tenderness evaluation is important to consumer appraisal. Numerous studies report tenderness results but cooking methods were different (e.g. water bath, grill, oven). Quality assessment results of cooked meat can be significantly affected by sample preparation with different cooking techniques (1). During heat treatment, meat hardness occurs due to myofibrillar proteins denaturation (40-50ºC), collagen contraction (60-70ºC) and actomyosin contraction and dehydration (70-90ºC) (2).

To obtain accurate and repeatable Warner-Bratzler shear force data it is necessary to be care with regard to various factors such as cooking methodology or core removal (3). There are several cooking systems proposed for Warner-Bratzler shear force determination. The American Meat Science Association (4) recommends two cooking procedures: roasting (oven) and broiling (open air broiler) to an internal temperature of 71ºC. Honikel (5) suggests cooking in a water bath (55, 65, 80 or 95ºC) for tenderness measurement. Moreover, whole poultry carcasses are usually roasted and excised meat is grilled (6).

The aim of this study was to investigate the effect of cooking system (boiling water bath or grill) on Warner-Bratzler shear force determination in *pectoralis major* poultry muscle.

II. MATERIALS AND METHODS

Pectoralis major muscle from poultry was collected at 24 h post-mortem from a commercial abattoir. Each breast was divided in 2 fillets (average weight: 213.7 ± 34.9 g; n: 32) and randomly assigned to each cooking method. Cooking procedures used were boiling water bath (each sample inside a hermetic plastic bag) and grill (Gorge Foreman, two cooking surfaces) at 170 ± 10ºC. The procedure was carried out until an internal temperature of 71°C was reached. When the end-point temperature had been attained, samples were removed and cooled in ice slurry. Time-temperature profile was recorded individually with a thermocouple inserted into the meat geometric centre (Yokogawa DX106-1-2).

Warner-Bratzler shear force (N) was determined using a texture analyzer (Stable Micro Systems TXT, UK) with a Warner-Bratzler cell. Four 1.27 cm round cores were obtained parallel to the muscle fiber (4). Cooking loss was calculated as the difference in samples weight before and after cooking, expressed as a percentage of the initial sample weight. Moisture, fat and protein were analyzed by AOAC (7). pH was measured with a pH-meter with puncture electrode.

A complete randomized block design was carried out. Analysis of variance with a significant level of 0.05 was performed using Statgraphics Centurion XV (StatPoint Tech, Inc., Warrenton, VA, USA).

III. RESULTS AND DISCUSSION

Raw muscle pH was 5.74 ± 0.17, moisture content: 75.26 ± 0.64%, lipid content: 2.87 ± 1.29% and protein content: 92.62 ± 2.26% (both on dry basis). These results are consistent with the data reported by Qiao *et al.* (8) and Pearson *et al.* (9), in poultry breast fillet. Values obtained after cooking are reported in Table 1. Shear force values were lower in grill than water bath treatment. This is consistent with the findings of Lyon & Lyon (10) in breast muscle cooked in water bath or belt grill oven. Likewise, beef (*longissimus dorsi*) cooked on iron grill pan resulted in lower shear force than water bath (11). Time-temperature profile for poultry meat heating is shown in Fig. 1. According to Ghita *et al.* (12) the best cooking conditions for chicken breast meat were found to be short cooking times and lower temperatures that led to a tender meat. In beef, Lawrence *et al.* (13) found that methods that used a shorter processing time resulted in a smaller number of myofibrillar protein and collagen per unit area to be sheared when comparing different cooking systems (oven, electric grill and belt grill). In the present study, the method with lower processing time (grill: 8 min vs water bath: 21 min) showed higher meat tenderness. After the heat treatment, no significant differences in cooking loss between cooking systems were found.

Table 1. Shear values (WB), cooking loss, moisture, lipids and protein content (dry basis) of *pectoralis* poultry meat cooked in water bath or grilled.

	Water bath	Grill
WB (N)	16.1±3.8[a]	13.0±2.6[b]
Cook. loss (%)	14.7±1.7[a]	16.4±2.9[a]
Moisture (%)	71.19±0.52[a]	70.66±0.70[a]
Lipids (%)	5.09±1.43[a]	5.04±1.58[a]
Protein (%)	90.15±2.00[a]	86.54±1.52[b]

a, b means within rows with different letters are significantly different (P<0.05).

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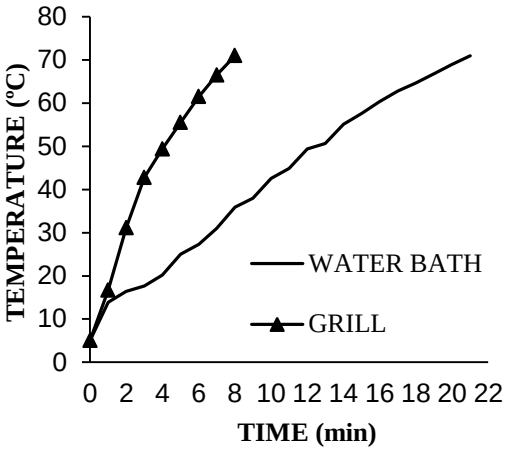

Figure 1. Time-temperature profile in *pectoralis* poultry meat cooked in water bath or grilled.

The raw meat showed higher moisture content than the cooked samples. Cooking produces an increase in palatability, digestibility and food security, and induces moisture reduction in meat (14, 15). No statistical differences were found in moisture and lipid content between treatments. Protein content was lower in grill than water bath, this is probably related with the slightly higher cooking loss (although no significant), observed in this treatment. In fish, comparing different cooking methods (baked, broiled, fried and microwave at 71°C internal temperature) it was found that the treatment with higher cooking loss had the lowest protein content (16).

IV. CONCLUSION

Grill cooked poultry meat showed lower shear force values and processing time than boiling water bath. Cooking loss, moisture and lipid content did not change due to the cooking system.

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DRY CURED SHEEP/LAMB MEAT: NORWEGIAN BIRKEBEINER "FENALÅR" COMPARED WITH SHEEP PASTRMA FROM BOSNIA & HERZEGOVINA AND MONTENEGRO

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Abstract – Traditional dried sheep products from Western Balkan (WB) were compared with a commercial Norwegian (NO) dry cured sheep product (Birkebeiner "fenalår"). The methods used to compare the samples were: volatile compound analysis by Gas Chromatography- Mass Spectroscopy and sensory profiling. Dried products were characterized by 30 different volatile compounds. Most of these volatiles were in higher amounts in the WB product. The components were from smoke, lipid degradation and derived lipid degradation products as well as microbial metabolites. Both types of hams were described as salty, but the NO hams got higher scores for the sensory attribute matureness despite their saltiness and lower amount of volatiles.

The WB products were, in average, more acid. This could suggest that the salting step influenced bacterial growth inducing desirable or undesirable traits.

I. INTRODUCTION

A traditional way of maintaining sheep production sustainable has been the production of dry-cured sheep products. There is presently a general interest in the traditional processing methods both to stimulate documentation of unique quality characteristics and market advantages, but also to identify processing method that will make it easier to sell sheep meat, a less sought after commodity from lamb meat and sheep milk production.

Parts of Norway and parts of Western Balkan are mountain areas and best suited for small ruminants. These two regions have developed their dry cured sheep/ lamb production methodologies completely independent of each other and also use different breeds. Within the Balkan Peninsula the primitive Pramenka breed and its strains, are raised [1]. Pramenka is an indigenous sheep breed that is well adapted to the often unfavorable growing conditions in the mountain region of Balkan. Norway's dominant White Sheep breed is a relatively new breed, made by crossing of several local sheep breeds (Dala, Rygja and Steigar) and Texel breed. It was defined as a separate breed in 2000-2001 [2].

Compared to the many papers dealing with dry cured pork ham there is little information about dry-salted (cured) sheep/lamb meat production. The aim of this study was to compare the sensory properties and occurence of volatile compounds in dry salted ham products produced in Montenegro (MN) and Bosnia & Herzegovina (B&H) with the Norwegian commercial sheep product Birkebeiner "fenalår".

II. MATERIALS AND METHODS

Three different dry salted products were used:
1) Sheep ham from Norway (NO); 2) Pastrma from Bosnia & Herzegovina (B&H) and 3) from Montenegro (MN).

Table 1 Dry salted Birkebeiner "fenalår" (NO) and *Pastrma (*B&H & MN)

Process. step		NO *Birkebeiner*	MN and B&H *Pastrma*
Salting	Days	2	7-21
	T (^{0}C)	4	4
Smoking	Days	1	7-14
	T (^{0}C)	13	12-18
Drying	Days	50-60	7-15
	T (^{0}C)	13	7-15

Table 1 gives characteristics of the production. The products from NO and MN were produced by commercial companies while the products from B&H were produced by a local butcher. The target NaCl concentration of Norwegian Birkebeiner "fenalår" is 8.0 % w/w and for water activity 0.890. WB sheep hams should have water activity below 0.9. There is no present target for NaCl for WB hams.

Analysis of volatile compounds: These were analyzed by: 1) gas chromatograph 6890 (Agilent technologies Santa Clara, CA, USA), equipped with a 30 m x 0.25 mm i. D. DB - water fused silica capillary column; 2) Mass spectrometer with mass range of m/z 30 - 550 3) identification of compounds by NIST US Government library (NIST 05 Mass Spectral Library, Agilent technologies Santa Clara, CA, USA).

Sensory analysis: A trained panel of 8 persons evaluated: yellowness of fat, redness, marbling, fat firmness, hardness, aroma intensity, saltiness, bitterness, acidity, mature flavour and metallic flavour.

III. RESULTS AND DISCUSSION

The focus in this paper was to compare one type of Norwegian dry salted sheep product with similar products from B&H and MN. Table 1 indicates that there are differences in production methods between WB hams (from B&H and MN) and Norway. The processing procedures also vary substantial within WB. The more typical difference is a longer salting and smoking period for B&H and MN products than for the commercial salting/smoking step used in Norway. The smoking in the two Balkan regions are typically done in smoking houses where the product is also dried according to the temperature and relative humidity of the season (late winter). The salting step is also different; in Western Balkan (B&H) the hams are left to form brine for several days and no nitrite (valid in both B&H and MN) is added.

We have not included volatiles that identifies the products produced in B&H and MN as different as that will be described elsewhere [3].

Figure 1 is a web presentation of 30 volatiles that revealed a similar pattern in all Balkan products. It is apparent that the two Balkan products had higher prevalence of most of volatiles although exceptions existed.

Lipid degradation products: There were 4 compounds that stood out in the Norwegian ham production, namely 1,3 pentadiene (E), heptanal benzene and 1,2,4-benzenetricarboxylic acid, 1,2-dimethyl ester.

Benzene was more abundant in the NO ham, but the related compounds benzene, 1-ethynyl-4-methyl- and naphthalene were more abundant in WB hams as was other cyclic hydrocarbons. 2-cyclopentene-1-ones were more abundant in the Western Balkan production process. The formation of these compounds are not always clear but could be formed by the reaction between aldehydes from lipids, and they represent more mature lipid degradation products. Also 1-hydroxy 2-propanone was mostly present in WB products and this product can also originate from a previous reactive aldehyde that may originate from degraded lipids. Butanoic and propanoic acids were higher in WB hams than in NO hams.

Degradation components from beech chips: The WB products were more abundant in smoked components. 2(5H) furanone and 2-methoxy 4 methyl phenol were typical degradation product from wood and was only found in WB products. The NO sheep ham products are smoked mildly in modern cabinets, if smoked at all.

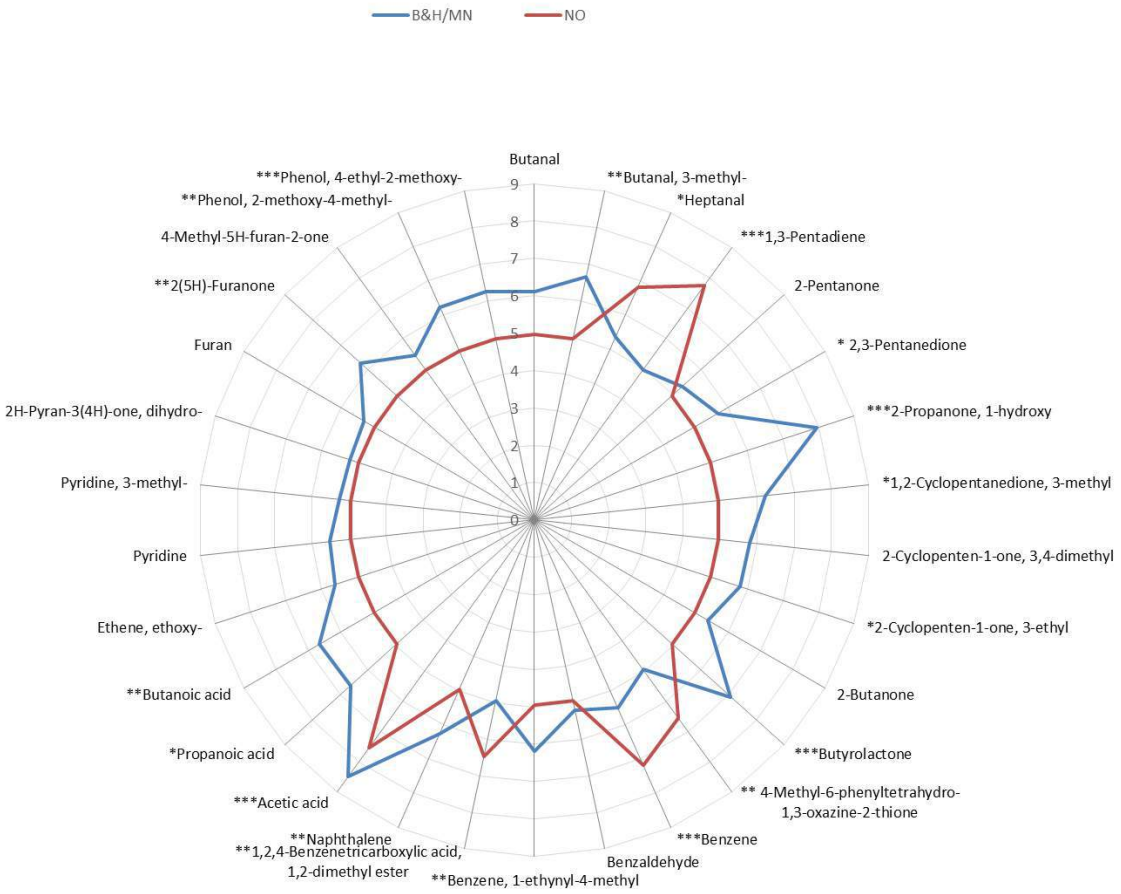

Figure 1. Volatile compounds (log area) of dry-cured sheep hams from Montenegro (MN)/Bosnia & Herzegovina (B&H) and Norway (NO).The stars in front of the names indicate significant differences between the 2 countries' ham productions (***=P<0.001; **=P<0.01; *=P<0.05, t-tests). Some volatiles have no indication of significance; such compounds were only found in either hams from Norway or in hams from Western Balkan with a level closed to detection treshold (*e.g.*set at log area equal to 4.95).

The results of the sensory analysis are shown in Fig. 2. The WB products tended to have more yellow fat, but the yellowness also varied more than in the NO product. The WB ham fat was less firm.

The NO product obtained higher scores for marbling and for redness. The latter may be due to the fact that nitrite was used during salting in NO and this may hide the fact that WB production generally uses elder animals that usually give a more intense colour. The assessors described both products as quite red/dark since the scores were up to 8 (Fig. 2).

The WB product was harder than the NO product (muscle part). This can be due to lack of fat in combination with less control of the relative humidity during the smoking/ drying step as this step relies on the outdoor humidity.

Despite the fact that the WB product had more smoke volatiles and transformed lipid degradation products, the sensory assessor did not use the sensory attribute (total) aroma intensity to differentiate between the products (Fig. 2). No ham was identified as rancid by the sensory panelists despite the fact that lipid degradation volatiles were obviously present in both productions. On the other hand, the sensory panel assessed the NO ham as more mature (Fig. 2). There were only a weak correlation (R^2=0.33) between mature flavour and

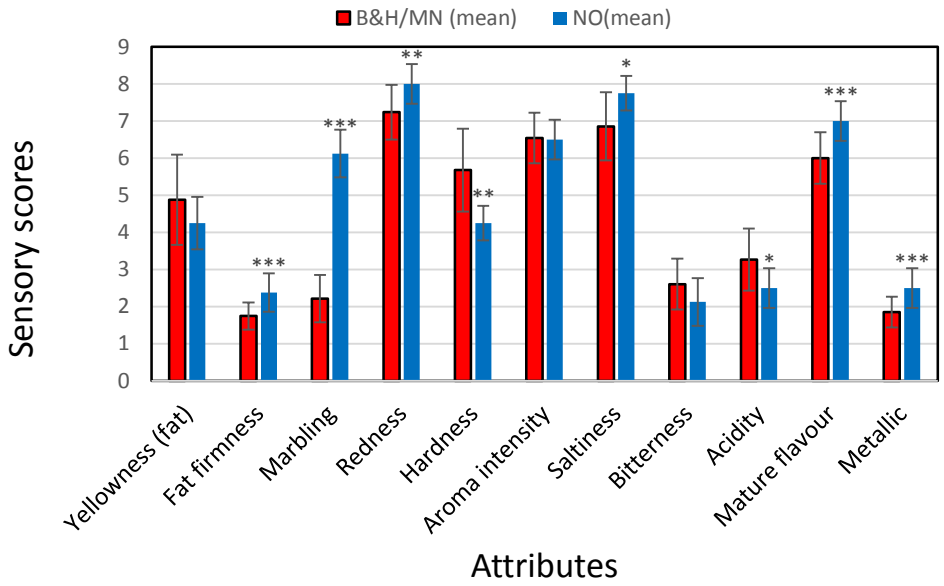

Figure 2. Sensory profile of dry cured sheep ham products from Montenegro (MN)/Bosnia & Herzegovina (B&H) and Norway (NO). The stars indicate significant differences between the two countries' ham productions (***=P<0.001; **=P<0.01; *=P<0.05, t-tests).

aroma intensity. The fact that both total aroma and mature flavour received high scores could indicate that both products had specific flavours, but that these flavours were difficult to differentiate.

The sensory analysis confirmed that the WB hams were more acid (Fig. 2). This seems only interpretable as the microbial metabolism being more intensive in WB hams. This may indicate a different microbial profile during the salting step in WB compared to NO products.

Bitter flavour is sometimes a challenge with sheep and lamb meat, but was here assessed as low, but it tended to be higher (P=0.08) in the WB hams.

Metallic flavour might be related to feeding differences and/or lipid degradation components [4]. The attribute was higher in Norwegian hams suggesting a different lipid degradation/ripening process.

These sheep hams were all regarded as salty. Western Balkan products varied more in salt content than Birkebeiner "fenalår" (Fig. 2) but only a few (out of 30) WB sheep hams scored higher in saltiness than the Norwegian ham.

IV. CONCLUSION

The WB dry cured sheep ham had more volatile compounds, were less salt and scored less for the sensory attribute mature flavour.

ACKNOWLEDGEMENT

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DISASTER AND HOSPITAL DIET PREFERENCES AS EVALUATED BY DIFFERENT CATEGORIES OF CONSUMERS

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Abstract – Individuals evaluated six different parameters of a diet. Two surveys were conducted, the first involved individuals who had not received prior humanitarian aid and the second involved individuals who had received prior humanitarian aid. In the first survey, both nutrition and cost were found to be most important factors. In the second survey, nutrition was found to be the most important factor; however cost was the least important factor.

I. INTRODUCTION

The best way to find out what consumers think is to ask them. Survey information data can make the difference between smart decisions and misguided, inefficient ones. The objective of these surveys was to evaluate the desirability of product nutrition, palatability, texture, tenderness, flavor and cost by individuals from three areas (India, Tibet & outback Australia). Individuals who had not received humanitarian aid were compared to individuals who had experienced a disaster and had received humanitarian aid. The first survey sampled medical personnel, patients and general population. The second survey concentrated on medical personal and a few patients. Two evaluations (ranking and rating) were utilized to compare the two scoring systems and to test the individuals' understanding of the two evaluation procedures.

II. MATERIALS AND METHODS

Experimental design is shown in **Figure 1**. Informed consent and confidentiality was maintained.

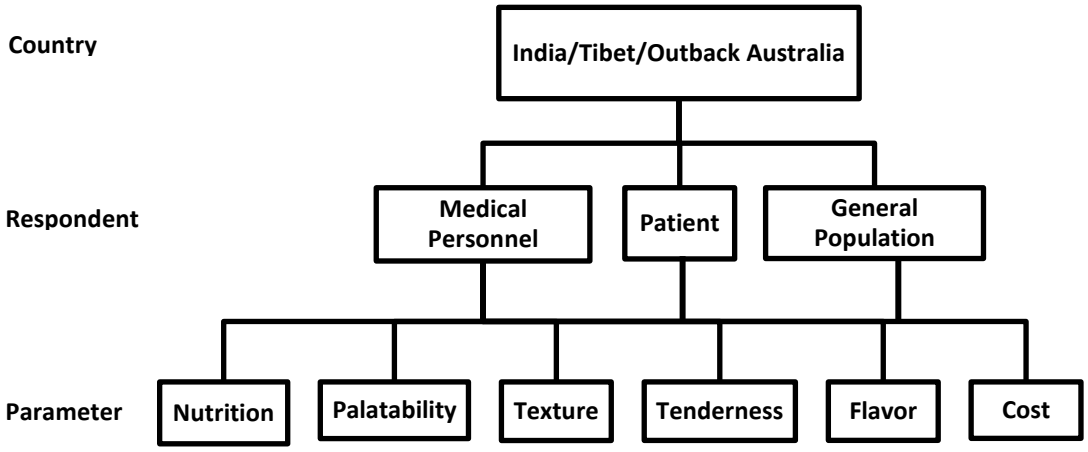

Figure 1. Flow Chart of Survey 1 Information Collected - both Rank and Rating

III. RESULTS AND DISCUSSION

Survey 1

Results from the surveys for 'Rating' are shown in **Figure 2** and for 'Rank' in **Figure 3**.

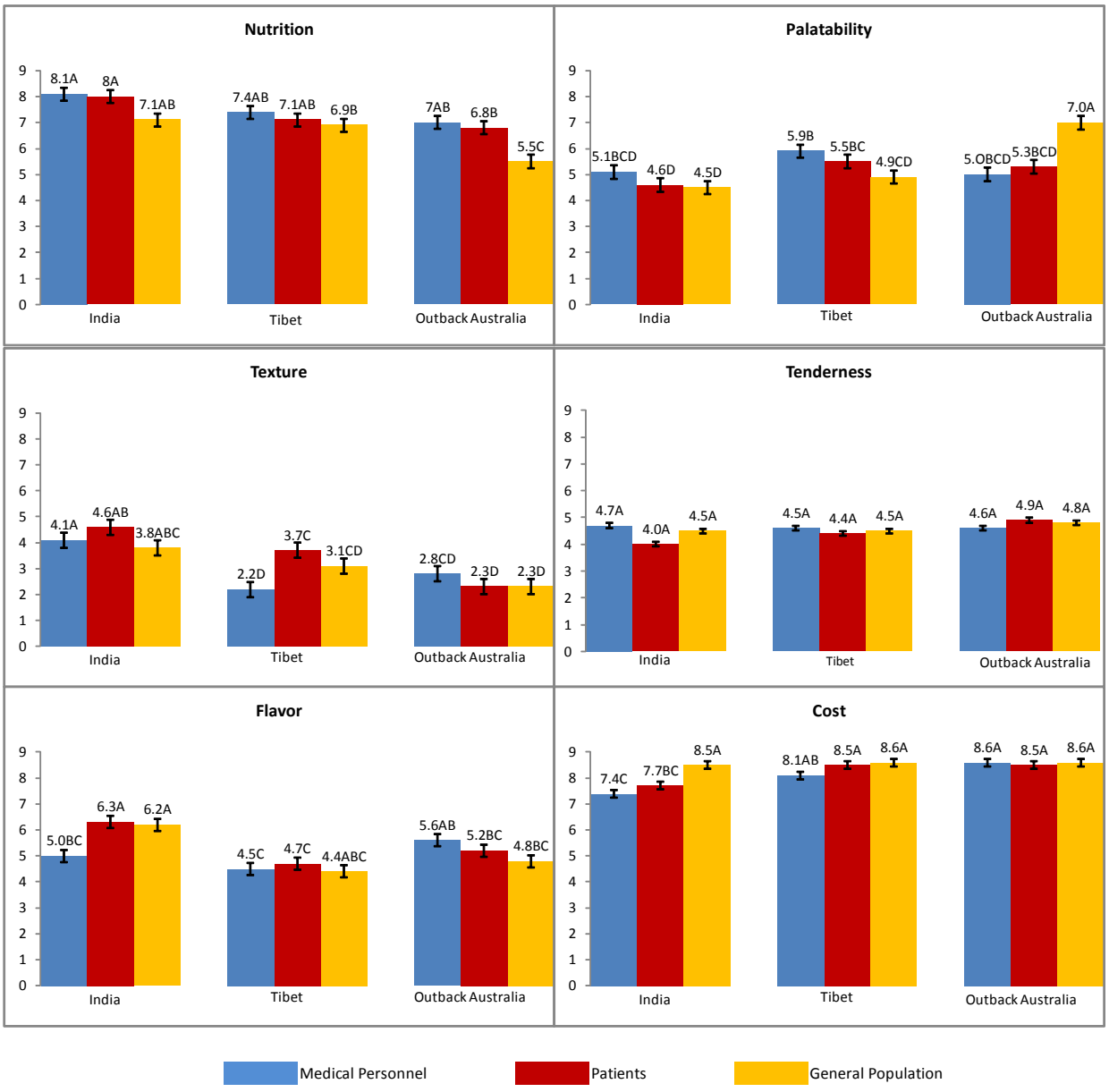

Figure 2. Bar graphs for 'Rating' (Higher values indicate more importance) indicating the main effects of each country (vertical lines indicate standard deviation). Letters indicate significance in each of the six parameters evaluated [1].

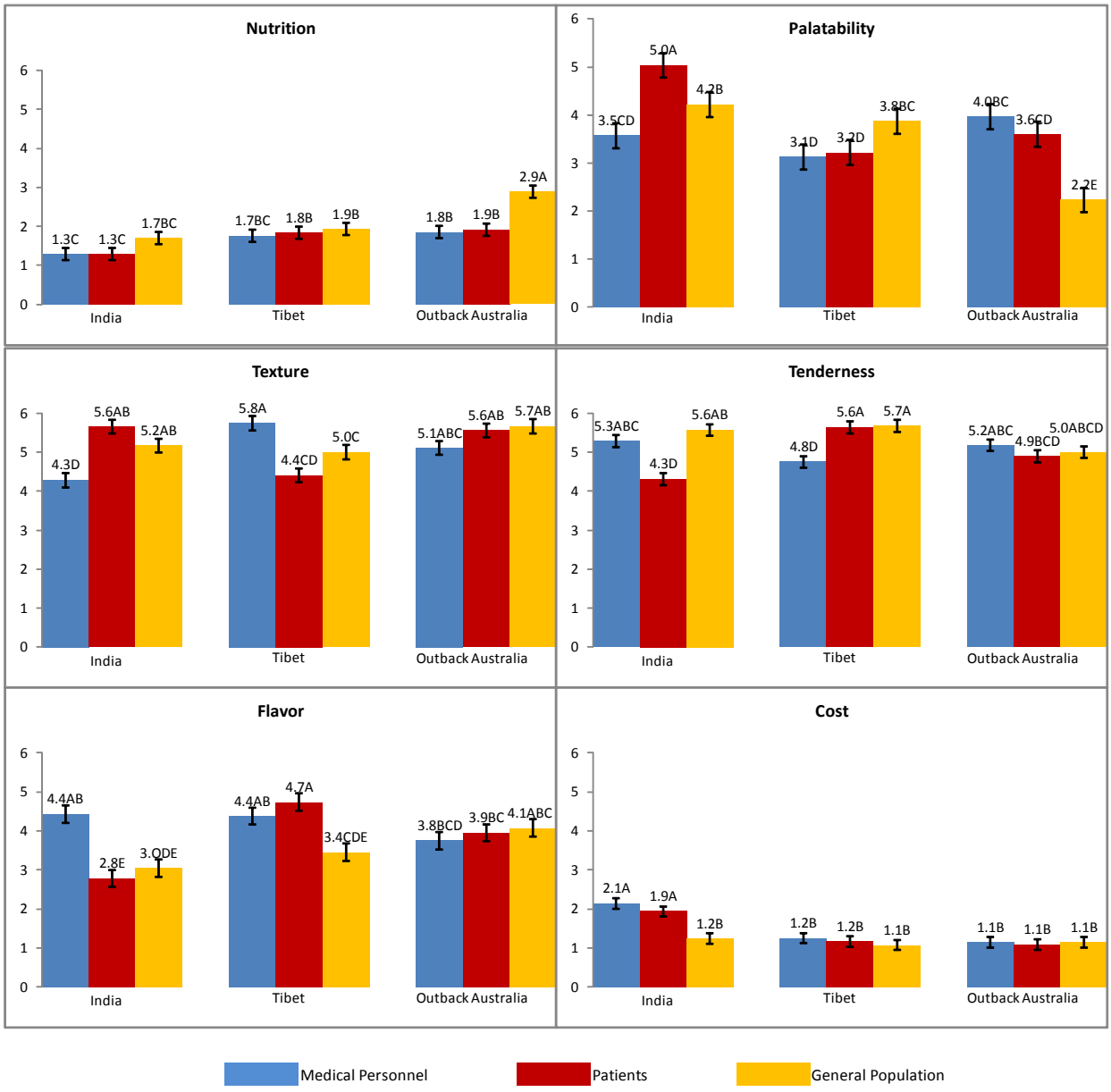

Figure 3. Bar graphs for 'Rank' (lower values more important) indicating the main effects of each country (vertical lines indicate standard deviation). Letters indicate significance in each of the six parameters evaluated [1].

Statistics [1] indicated that two way interactions (Country x Respondent) were significant. This interaction would suggest that the food product needs to be manufactured for each location which is not practical since we do not know where the next disaster will occur.

In spite of the fact that the respondents on the rating questionnaire could repeat the scores, and on the rank survey they could not repeat the scores, the correlation between rating and rank for nutrition, palatability, texture, tenderness, flavor and cost was negative and highly significant in all cases. The negative correlation was a result of the reversal of desirability scales for each factor.

The rank and rating factors showed essentially the same patterns, When overall rank and rating for all data were used (country,

medical personnel, patients, and general population was absorbed), the correlation was negative and highly significant ($P<0.01$) for all factors evaluated. This would suggest that the respondents understood the rating systems.

When the data was evaluated by absorbing medical personnel, patients and general population in each country, the correlation between rank and rating was always negative (due to scale orientation) and usually highly significant.

It is evident that nutrition and cost are the most important factors in all situations. It would appear that as long as these two factors are satisfied for emergency use, a generic product could be utilized at least for a short term solution.

The country evaluation indicates that India had the highest score on nutrition followed by Tibet and Outback Australia in that order. For rank cost data, the interaction graph is again a negative mirror image of the rating interaction graph. The general population scored the cost lower than the medical personnel and patients. The country evaluation of cost was similar as nutrition

Survey 2

Second analysis (with much smaller numbers in medical personal and minute numbers in patient category) surveyed people that had received humanitarian food aid after a natural disaster to see if these recipients had a different opinion on which food factors were the most important using the same procedure as the previous analysis. A summary of results are illustrated in Table 1.

Nutrition remains the most important factor, but cost dropped from the top two factors and was considered to be to less important, as would be expected. In the rate evaluation, the cost standard deviation is extremely large suggesting that not all observers agreed on the importance of this factor and I am sure the suppliers would consider it important and the higher the cost most likely the shorter the supply.

Table 1. Results of the second survey (Rank low numbers are desirable and in Rate high numbers are desirable).

Mean± standard deviation	Medical personal (42 observations)		Patients (4 observations)	
	Rank	Rate	Rank	Rate
Nutrition	1.1±0.5	5.8±0.63	1.0±0.0	6.0± 0.0
Palatability	3.7±0.7	2.8±2.4	3.6±1,1	2.3±2.2
Texture	4,7±1.5	2.5±1.9	4.7±1.5	2.3±1.8
Tenderness	5.2±3.1	2.0±2.0	5.2±3.1	0.5±2.1
Flavor	3.1±1.3	5.7±1.7	3.1±1.3	4.7±0.8
Cost	4.1±1.8	1.0±10	4.1±1.8	0.0±12.2

IV. CONCLUSION

In the first survey (had not received aid), the most important factors were nutrition and cost. In the second survey (had received humanitarian aid), nutrition was still found to be the most important factor however cost was no longer important for the participants surveyed.

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INFLUENCE OF MYOFIBRIL ORIENTATION ON LAMB COLOUR MEASUREMENT AND COLOUR STABILITY

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Abstract – This study aimed to test the effect of surface myofibril orientation upon colorimetric results. Thirty *semimembranosus* (SM) muscles removed from individual lambs were used to measure CIE reflectance values (*L, *a**, *b**) and wavelength ratio of 630nm and 580nm (R630/580) using by 2 Hunter Lab Mini Scanners (25 mm and 5 mm aperture) and 1 Minolta Chroma Meter. Measurements were taken both across and along myofibrils from each sample upon freshly exposed and bloomed surfaces. Mean *L** was lower when measurements were taken across the myofibrils (*P* < 0.001). Both *a** and *b** average values were higher when measured across myofibrils, with the difference significantly (*P* = 0.001) greater for bloomed surfaces. R630/580 was higher when measured across the myofibrils (*P* = 0.04) and no significant interaction between myofibril orientation and instrument was observed. These results show a necessity to account for myofibril orientation during colorimetric analysis of lamb meat.**

Key Words – Lamb meat, Colour stability, Muscle fibre orientation

I. INTRODUCTION

Lamb meat discolouration is unacceptable to many consumers and can attract heavily discounted prices. Consequently, the accurate and objective measurement of lamb meat colour and colour stability is vital to ensure quality and economic returns are maximised [1]. Meat colour is a function of metmyoglobin and oxymyoglobin levels [2] as the former is strongly associated with meat brownness and the latter with increased redness and heightened desirability [3]. Time on commercial display is known to influence these concentrations, with meat metmyoglobin concentration shown to intensify with display time [4] or ageing [2, 5].

The development of colorimetric instrumentation has significantly contributed to the objective analysis of meat colour. These instruments generally apply an Illuminant to the surface of a meat sample and record the wavelength of reflected light, opposed to light either absorbed or scattered by the meat surface. These measurements are reported as CIE colour space coordinates, or reflectance values; *L** (lightness or brightness), *a** (red/greenness), and *b** (yellow/blueness). Reflectance values can also be reported at incremental wavelengths, depending on colorimeter, and used to calculate the wavelength ratio of 630 nm and 580 nm (R630/580). This ratio provides a useful indication of metmyoglobin formation and hence overall consumer acceptability of a meat product [3]. Therefore, R630/580 has been used in the development of consumer quality thresholds aimed at guiding producers and retailers towards delivering quality meat products [6].

Sterrenburg [7] found fibre orientation affected light reflectance properties in fibrous translucent material, such as pork meat and teflon. Lamb meat is a translucent substrate [8] comprised predominantly of unidirectional muscle fibres (myofibrils) which present different fibre orientation dependent upon muscle cut face. Given research investigating meat colour and colour stability relies upon colorimetric instrumentation providing uniform, nonbiased and compatible measurements [9], this study investigated the effect of myofibril orientation on lamb meat colorimetric assessment.

MATERIALS AND METHODS

At 24 h post-mortem, the *semimembranosus* (SM) muscles were removed from 30 randomly selected lamb carcases slaughtered as a single group at a commercial abattoir. These were aged prior to analysis in individual, gas impermeable and vacuum sealed plastic bags at 3-4°C.

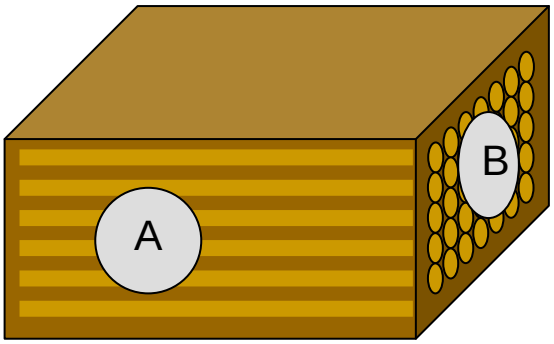

Figure 1. A stylised representation of myofibril orientation at measurement surfaces (A) along and (B) across the myofibrils.

At analysis, each SM had both parallel and perpendicular sections removed to expose the muscle surface (see Figure 1). Colorimetric measurements were taken on each exposed surface immediately and again following a 60 minute blooming period. These were made both across and along myofibrils (see Figure 1) using three colorimeters: 1) Hunter Lab Miniscan Model 45/0-L with an aperture size of 25 mm (Reston, VA, USA) calibrated using black and white tiles and Illuminant D-65 (X = 80.4, Y = 85.3, Z = 91.5), with 10 degree standard observer; 2) Hunter Lab Miniscan Model 45/0-S with an aperture size of 5 mm (Reston, VA, USA) calibrated using black and white tiles and Illuminant D-65 (X = 80.4, Y = 85.3, Z = 91.5), with 10 degree standard observer; and 3) Minolta CR-400 Chroma Meter (Minolta Camera Co., Osaka, Japan) calibrated with a standard white tiles plate (Y = 92.8, X = 0.3160, Y = 0.3323) under D-65 Illuminant. Measurements were made on each sample at each stage (freshly exposed surfaces and after blooming) by each instrument (in duplicate for each Hunter Lab mini scan and in triplicate for the Minolta), first along the fibre and then, immediately following, across the fibre.

To analyse each trait (L^*, a^*, b^* and R630/580) a separate linear mixed model analysis was performed. Model fixed effects included were for time, instrument, orientation, stage (freshly exposed versus 60 minutes blooming), interactions between time and stage and interactions between time, instrument and stage with orientation. Random effects were effects for animal (A) and interaction effects for time x instrument (TI), TI x instrument, TI x stage, A x TI, A x TI x instrument and A x TI x stage. The random error was allowed to differ in variation for Hunter Lab Miniscan and Minolta Colorimeter instruments as the measurements are recorded differently by these colorimeters. Models were fitted using the package *asreml* [10] under R [11].

II. RESULTS AND DISCUSSION

Myofibril orientation was shown to significantly affect average results for L^* ($P < 0.001$), a^*, b^* ($P < 0.001$) and R630/580 ($P = 0.04$). Results are summarised in Figures 2 and 3. Measurements taken across myofibrils had higher average a^*, b^* and R630/580 values and lower L^* values compared with those measured along myofibrils. For a^* ($P < 0.001$) and b^* ($P < 0.001$) values, the differences between across and along measurements are significantly larger for bloomed samples compared with freshly exposed samples ($P = 0.02$ and $P < 0.001$, respectively). Sterrenburg [7] also found these reflectance values to be influenced by fibre direction, finding L^* and a^* measurements were highest when measured on a surface with fibres having a perpendicular orientation. This deviation from the findings of this report is thought to stem from substrate differences, as Sterrenburg [7] analysed Teflon tiles rather than meat samples as per this study. Another source of variation may have been edge-loss effect; being light presumed absorbed when in fact it is projected outside the colorimeter sampling window [12].

Apart from the significant interaction effect associated with orientation and stage on a^* and

*b**, stage also influenced average *L**, with significantly larger results for freshly exposed samples than for samples allowed to bloom for 60 minutes ($P = 0.005$), Average R630/580 values did not differ significantly with stage ($P > 0.05$).

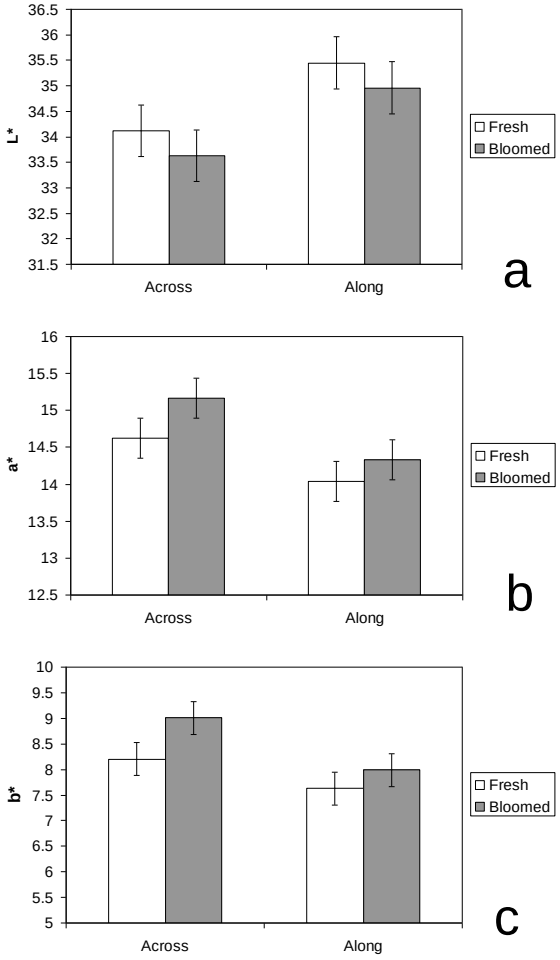

Figure 2. Plots of the mean and standard error for a) *L**, b) *a** and c) *b** reflectance values when colorimetric measurements were taken across or along the m. *semimembranosus* myofibrils on either a fresh cut surface or after it was allowed to bloom.

There was an effect of stage on average *L** ($P < 0.005$) and *b** ($P < 0.001$) values. Blooming permits deoxymyoglobin to be exposed to oxygen which transforms deoxymyoglobin into oxymyoglobin [13]. This shift in concentration is dependent on temperature, time, oxygen penetration into meat surface and competition for available oxygen [14], and ultimately results in a change in meat surface colour. The observed response of L* to bloom in the current study is far from standard, and further research into understanding its underlying biochemistry and trends is required. Nonetheless, in terms of consumer acceptability, L* has been found to have only a minor contribution, with b* and R630/580 the key determinants [3].

Furthermore, the observed interaction between stage and myofibril orientation on *a** and *b** values ($P < 0.001$) suggests oxymyoglobin formation from deoxymyoglobin and the resultant colour change varies dependent on myofibril directionality.

R630/580 was higher when measurements were made across myofibrils rather than along myofibrils ($P < 0.041$; Figure 3). For lamb meat, R630/580 has been used to indicate consumer acceptability of lamb meat in terms of colour [1, 15]. This result is supported by previous research findings showing that perpendicular fibres have greater light reflectance than those of parallel orientation between wavelengths of 400 nm and 700 nm [7], the range R630/580 is calculated within. This suggests colorimetric analysis in the determination of thresholds should include considerations of muscle surface myofibril orientation.

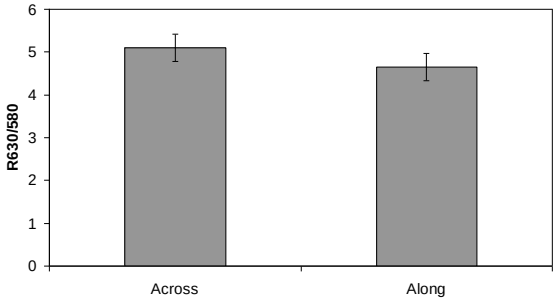

Figure 3. A plot of the mean and standard error for the reflectance ratio of 630 nm and 580 nm (R630/580) wavelengths when colorimetric measurements were taken across or along the m. *semimembranosus* myofibrils.

Significant differences ($P < 0.05$) were identified in this study in the three instruments for measuring *L**, *a** and *b**, but no significant interaction effects were identified between instrument and the other factors in this study, including myofibril orientation. This suggests

observed orientation effects on colorimetric measurement are not restricted to the colour meter or instrument used, within the scope of this study.

CONCLUSION

It appears that the accurate colorimetric analysis of lamb meat depends on myofibril orientation at the site of measurement, as measurements taken across the muscle fibres generally are higher than those taken along these fibres, except for *L** values. Blooming was also confirmed as best practise prior to colorimetric analysis so as to obtain measurements representative of stabilised surface colour. From these observations, it is recommended that myofibril orientation is considered during future research investigating lamb meat colour and colour stability. However, additional research into the effect of myofibril orientation would aid in validating this recommendation.

ACKNOWLEDGEMENTS

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ACCEPTABILITY OF OVINE HAMBURGER PATTIES WITH INCREASING ADDITIONS OF PEANUT AND α-TOCOPHEROL

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Abstract – The effect of the addition of crushed peanuts (0, 10, and 20%) and of α-tocopherol (α-TF, 0 or 1‰) to the acceptability of ovine hamburger patties was investigated. A discontinuous and structured ten-point scale was used to rank acceptability, tenderness, and taste. With the addition of crushed peanuts, the acceptability and tastefulness decreased independently from α-TF additions. It is therefore considered convenient to study the effect of different ingredients and/or processed peanut types in order to improve the lipid profile without affecting product acceptability. On the other hand, the addition of α-TF did not affect the acceptability of the hamburgers, supporting its use as an antioxidant to improve the shelf life of the products. The lipid fractions were subjected to ^{1}H NMR spectroscopy, and the results were consistent with peroxide index (PI) determinations and revealed the modifications to the lipid profile.

I. INTRODUCTION

In Uruguay, the consumption of ovine meat is lower than that of bovine meat, being exports its key role. Regardless, the product added value in either case has been practically absent. The development of alternative meat products using industry low commercial value sub-products (trimmings) has been assessed in our country (1-3). Similarly, Ballesteros made a complete review of the production and innovation of ruminant meat products (4). However, these products have been strongly questioned because their consumption is associated with chronic and degenerative diseases. For this reason, functional meat products are seen as an opportunity to improve the image of meat and satisfy the demand of healthier foods from consumers. Since the ingestion of saturated fatty acids (SFA) is above the recommended levels in most occidental countries, it is considered that an increase in the intake of oleic acid would benefit the health of consumers by improving the dietary balance between SFA and monounsaturated fatty acids (MUFAs). This effect could be reached by changing food habits or by means of applying technical alternatives over traditional products. For instance, peanut oil is rich in MUFAs and polyunsaturated fatty acids (PUFAs), with linoleic acid (C18:2) and oleic acid (C18:1) making up nearly 80% of its lipid composition (5). At the same time, it is possible to lower fatty acid oxidation in these products through the addition of antioxidants that would extend the shelf life of the product.

The object of this study was to evaluate, through a consumer test, the effect of adding increased amounts of crushed peanut and α-TF to the acceptability of hamburgers made of ovine trimmings (80% meat, 20% fat).

II. MATERIALS AND METHODS

Hamburger patties were prepared from ovine trimmings containing 20% fat, provided by Frigorífico San Jacinto (NIREA S.A.). Increasing amounts of ground peanuts and α-TF were incorporated, leading to one set of patties containing 0, 10, and 20% of ground peanut, and one with the same ground peanut content and 1‰ α-TF. This led to 6 treatments that were assessed under 2 factors. The ovine trimmings were processed in a semi industrial meat grinder with a 10 mm plate, followed by the addition of the ground peanut and the other ingredients (salt, garlic, white pepper, oregano and sugar), and further processing of the emulsion with a 6 mm plate. The resulting mixture was then molded into 10 cm diameter hamburger patties, packed in sealed bags, and stored at -10 ºC, away from light, until used in the studies. For the consumer test, the patties were thawed at 4 ºC in a

refrigerator, wrapped in aluminum foil, and cooked in a double plate grill until a thermocouple-measured temperature of 70 ºC was reached in the thermal center. Each patty was then subsampled, and everything was maintained in a container inside a plate warmer at 35 °C until each sample were assigned to each consumer.

For the consumer study, 100 individuals in 10 sessions of 30 minutes were used (70 men and 30 women averaging 31.2 ± 12.2 years of age), in a complete and balanced block designed experiment. A discontinuous and structured ten point scale was used to rank acceptability, tenderness, and taste, being "1" very poorly acceptable, very hard, and very tasteless, and "10" very acceptable, very tender, and very tasteful.

For the estimation of oxidative degradation in all the raw hamburger samples stored at 10 °C, the peroxide index (PI) of the lipidic fraction extracted with an hexane/isopropanol (3:2) mixture was studied (AOCS Cd 8-53). The resulting lipid fractions were also dissolved in $CDCl_3$ and subjected to ^1H NMR spectroscopy to evaluate oxidation levels and unsaturation profiles. These studies were carried out on a Bruker AVANCE III 400 NMR spectrometer working at a ^1H frequency of 400.13 MHz, employing parameters from the literature (6,7). Particular attention was given to the spectral region corresponding to the allylic (R-CH=CH-C**H**$_2$-R, 1.95 to 2.00 ppm) and bisallylic (R-CH=CH-C**H**$_2$-CH=CH-R, 2.75 to 2.80 ppm) protons, as increases in the intensities of these signals are directly related to increases in the PUFA content.

A generalized linear model was used for the statistical analyses of the consumers test, assuming a multinomial distribution that included session, consumer nested to a session, treatment, and interaction between treatments as parameters. The MIXED protocol as implemented in the SAS 9.1 statistical package was employed (8).

III. RESULTS AND DISCUSSION

As expected, the effects of session and consumer were always significant ($p \leq 0,0001$). These are presented in Table 1.

Table 1 Effect of peanuts and tocopherol additions to the patties in the consumers test.

Treatment	Acceptability	Tenderness
	(1-10)	(1-10)
Peanut (%)	0,0001	0,0001
0	7,3a	7,4a
10	6,4b	6,5b
20	5,9c	6,2c
Tocopherol	ns	ns
without	6,5	6,7
with	6,5	6,7
Peanut by tocopherol	ns	0,05
Treatment	Acceptability	Tenderness
	(1-10)	(1-10)
Peanut (%)	0,0001	0,0001
0	7,3a	7,4a
10	6,4b	6,5b
20	5,9c	6,2c
Tocopherol	ns	ns

ns: $p \geq 0,05$. a,b,c: $p \leq 0,05$

The addition of α-TF did not affect acceptability nor the other evaluated parameters of the product regardless of composition. On the other hand, the incorporation of ground peanuts to the hamburger patties was detrimental to the attributes evaluated by the consumers, particularly when the reference patties are compared to those containing 10% ground peanuts. It is likely that the use of ground peanuts as opposed to peanut oil had an impact in the results, as this additive was easily detected by the consumers.

Adding ingredients with a higher MUFA and PUFA content to the formulation of the patties, such as peanuts, improves the lipid profile. However, they also make the product more susceptible to oxidative degradation and would compromise its shelf life. It is therefore noteworthy that the addition α-TF, which would reduce oxidation, did not affect the acceptability of the hamburger patties. On the other hand, and independently from the treatments that were assayed, the acceptability values are considered acceptable, particularly in the ages ranging from 30 to 50 years as opposed to those with ages under 30 years. These results are in agreement with those presented in earlier reports (1-3), and would indicate that the commercial use of ovine trimmings for the elaboration of hamburger patties could generate a product with a higher added value from a low cost raw material. This

would lead to a better value for the carcasses of adult ewes below 22 Kg.

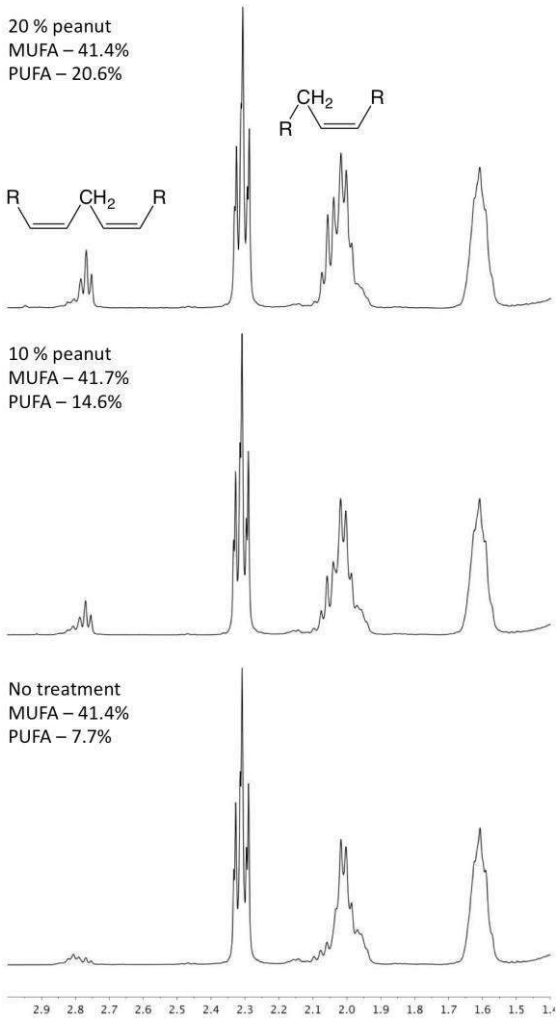

Fig. 1. Selected region of the ^{1}H NMR lipid profile of hamburgers containing increasing amounts of ground peanut. Signals from homoallylic and allylic protons are indicated.

Regarding the PIs, these did not show significant differences between treatments ($p \leq 0.10$), which is to be expected considering the short storage times of the samples prior to use. The ^{1}H NMR spectra obtained, presented in Fig. 1, are consistent with the estimated PIs. The most salient aspect of the latter results is that they show that the method allows to easily distinguish and quantify differences in the lipid profiles for each treatment. Indeed, the rise in the level of PUFAs in the lipid extracts as the amount of ground peanut increases is evident from the spectra (Fig. 1).

IV. CONCLUSION

Hamburgers elaborated from ovine trimmings have a reasonable acceptability among consumers. The use of α-TF in the formulation did not affect this acceptability. Although it improves the lipid profile of the material employed for the preparation of the patties, the use of ground peanuts is sensory detrimental to the final product. Therefore, a different presentation or other ingredients would be necessary to accomplish this.

^{1}H NMR spectroscopy is a promising method which needs further development for application in the meat industry. The technique allows for the quantification of lipid oxidative degradation, and, as shown here, can also be employed to monitor variations in the lipid profile that reflect changes in the content of MUFAs and PUFAs.

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VISUAL EVALUATION OF BEEF TENDERNESS BY USING SURFACE STRUCTURAL OBSERVATIONS AND ITS RELATIONSHIP TO MEAT COLOUR

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Abstract- This paper describes the relationship between visual and instrumental measurements for colour and tenderness between 5 South African beef breeds; *Bos indicus* (Brahman), Sanga type (Nguni), British *Bos taurus* (Angus), European *Bos taurus* (Charolais) and the composite (Bonsmara), 10 animals per genotype, n=50. The carcasses were split and the right sides were electrically stimulated and left sides not stimulated. Steaks were aged till 3 days (d) *post mortem* (pm) on polystyrene plates and till 9, 14 and 20 d pm in vacuum bags. The steaks were evaluated by visual analysis for colour, marbling, fiber separation, surface texture and structure integrity using a 10 member trained panel. Colour was also measured by Minolta meter and tenderness by shear force using Instron. Good correlations were observed between the visual colour and L* (r=-0.809), b* (r=-0.698) and hue (r=0.797). There were also correlations between shear force and structure integrity (r=-0.410) and fiber separation (r=-0.401). Very low correlations were observed between colour and shear force (r=-0.242). Therefore although consumers could judge meat colour by visual analysis, it seems not possible to predict tenderness by colour judgement. There is potential in predicting tenderness by observing visual structural properties such as fibre separation and structural integrity.

Keywords: Visual analysis, colour, tenderness, trained panel.

I. INTRODUCTION

Meat colour is the most important appearance quality trait as it is the first factor by which consumers make a purchase decision and it is used as an indication of freshness and wholesomeness [1]. Color evaluation is an essential part of meat research and when done properly, both visual and instrumental analysis of color are powerful and useful research tools for meat scientists [2].

Meat tenderness is the most important eating quality trait followed by flavour and juiciness [3]. Tenderness is the most difficultly predicted trait, but it is very important to meat quality and consumer acceptance. It is based on ease of chewing that is contributed by many factors. Among them, the fibrous nature of muscle contributes to chewing resistance [4].

The aim of the study is to determine the possibility to predict beef tenderness by judging colour and structural appearance with experienced vision and to determine if an association exists between colour, surface structure (morphology) and tenderness.

II. MATERIALS AND METHODS

The following genotypes were studied – *Bos indicus* (Brahman), Sanga type (Nguni), British *Bos taurus* (Angus), European *Bos taurus* (Charolais) and the composite (Bonsmara). Ten steers per genotype were purchased, n=50. The animals were fed on a feedlot diet for a period of between 90-110 d depending on their readiness for slaughter at the ARC-API feedlot. All animals were slaughtered, processed and sampled at the abattoir of the Animal Production Institute (Agricultural Research Council, Irene, Gauteng, South Africa). After exsanguination the carcasses were halved. The right sides were electrically stimulated for 20 s (400 V peak, 5 ms pulses at 15 pulses per s) and entered the cold rooms (± 4°C) within 60 min after slaughter (ES treatment). The left sides were placed in a room with a controlled temperature of 10 °C for 6 hrs, afterwhich they were placed in the cold rooms at ± 4°C (NS treatment). The carcasses were sampled at the M. *longissimus lumborum* and two retail procedures were simulated for ageing of the steaks. The steaks were aged up to 3 days (d) *post mortem* (pm) on polystyrene plates covered with polypropylene cling wrap (PP) at 6 °C in a display cabinet. The other steaks were aged up to 9, 14 and 20 d pm in vacuum bags at 1-4 °C in a cold room.

Visual analysis - was evaluated by a 10 member trained sensory panel at the ARC-Irene meat science laboratory, according to the ASTM standards [5] developed internally. The steaks were allowed to bloom for 1 hour prior to visual

observations. The steaks were evaluated for colour (with reference to commonly occurring meat colours in SA) marbling (1=practical devoid of marbling; 8=abundant), surface texture (1=very smooth, can hardly distinguish fibre bundles; 6=very course, rough), fiber separation (1=no separation, fibres fit tightly together; 6=fibre structure is falling apart), structure integrity (1=stiff/hard; 4=very soft).

Instrumental measurements- Tenderness was measured by means of Warner Bratzler shear force [6], colour was measured on each steak using CIE measurements, L* (dark to light), and two chromatic components; a* (green to red) and b* (blue to yellow) [7]. Chroma (intensity of the red colour/ saturation index) (S) = $[(a^{*2}+b^{*2})^{1/2}]$ and hue angle (discolouration) =$\tan^{-1}$ (b*/a*) were calculated.

The data was analysed using 5x2 Factorial ANOVA with repeated measurements over time (Angus, Bonsmara, Brahman, Charolais and Nguni) as whole plots and the four ageing periods (3, 9, 14 and 20 d pm) and treatments (ES and NS) as sub-plot factors. Means for the interactions between sub-plot and whole-plot were separated using Fisher's protected t-test least significant difference (LSD) at the 5% level of probability. Correlations were measured using Pearson Correlation Coefficients.

III. RESULTS AND DISCUSSION

The effect of breed (Angus, Bonsmara, Brahman, Charolais and Nguni) on meat colour co-ordinates (L*, a*, b*, chroma, hue), shear force and visual measurements (colour, marbling, fiber separation, surface texture and structure integrity) are shown in Table 1. The type of beef breed had a significant effect on the colour measurements (L*, a*, b*, chroma and hue) ($P<0.0001$), the visually analysed measurements (colour, marbling, fiber separation, surface texture and structure integrity) ($P<0.05$), and shear force ($P<0.0001$). The Brahman produced lighter steaks (L*=43.95) than all the other breeds followed by the Angus, Bonsmara, and Charolais (L*=40.42, 41.35, and 41.06 respectively) while Nguni produced darker (L*= 37.09) steaks. Nguni and Charolais were more red than the other breeds (a*=10.92 and 10.98). Nguni had higher hue angle (indicating greater discolouration) than the other breeds.

Steaks from Nguni and Angus were more tender (shear force=3.86 and 4.06) than Bonsmara but had the same tenderness level as the Brahman and the Charolais. Studies by Wheeler *et al*. [8] have reported that cattle with high *Bos indicus* content tend to have lower marbling scores and produce less tender and more variable striploin steaks than *Bos taurus* breeds while in this study no significant differences in tenderness were observed between the two breeds.

The visual panel observed steaks from Brahman as being lighter/pale pink (score of 4), and steaks from Angus, Bonsmara and Charolais as pink (score of 5) and steaks from Nguni were rated as the darkest with a score of 6 (Light cherry red), these observations showed a similar pattern as the L* values that were measured using the Minolta meter. Charolais and Nguni were evaluated by the panel as the breeds which had more marbling (score of 2=slight marbling) but the amount of marbling was not significantly different from the Angus. The Brahman had less marbling which was similar to the Bonsmara. The fiber separation, visual surface texture and structure integrity were lower in Nguni and higher in Angus; these parameters were expected to have the same effects as the shear force. The panel's observations were similar to shear force for the Angus and different for the Nguni.

Ageing had a significant effect on steaks for both visual and instrumental measurements. Steaks that were aged at 9, 14 and 20 d pm had lower L* and b* values than steaks which were aged at 3 d as shown in Table 2. This could be because of the packaging used; steaks aged at 3 d had access to oxygen while the ones aged at 9, 14 and 20 d were aged in vacuum bags. The a* values (redness) decreased with ageing from 9 d to 20 d pm and there was a significant difference between the packaging types. The 3 d and 20 d had the same redness intensity (chroma) which was lower than the 9 d and 14 d, which also had the same redness intensity. The hue angle was lower at 3 d and higher at 9 d pm. Shear force followed the normal ageing pattern showing that the steaks became tenderer with ageing.

The 3 d steaks were perceived by the panel as lighter (Pale pink) and the 9 d, 14 d and 20 d pm steaks were perceived as pink and these results showed a similar pattern with the L* values. Marbling seemed to increase with ageing, this could be because the structure became looser with ageing, exposing more marbing. Fiber separation and visual surface texture increased with ageing with 3 d significantly different from the 9 d, 14 d and 20 d. The structure seemed to be less intact with ageing and this could be the reason to explain the increase in marbling

visibility and this followed the same pattern as the shear force.

Treatment (ES and NS) did not have any significant effect on tenderness or colour measuments. Similarities were observed for all breeds in colour (L*, a*, b*, chroma and hue), shear force, visual colour, marbling, fiber separation, surface texture and structure integrity when electrical stimulation was applied (results not shown).

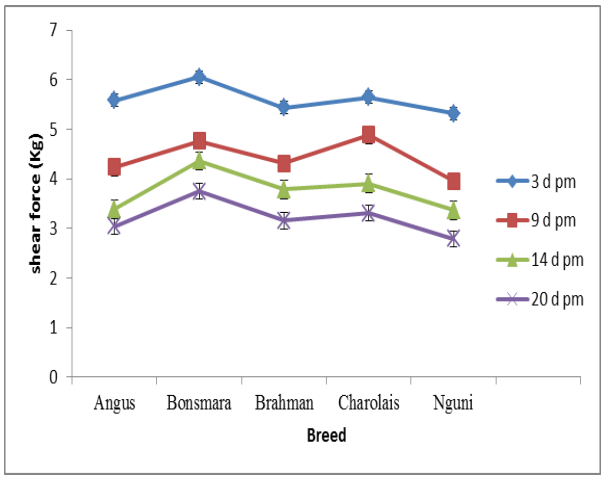

Figure 1: The effect of breed on shear force and ageing/packgaging of M. *longissimus lumborum* (LL).

Figure 1 shows that Bonsmara seemed to produce tougher meat than the other breeds in all the ageing periods. At 3 d pm, the Angus, Brahman and Nguni produced meat with the same tenderness/ shear force measurements. Nguni and Angus produced tender meat at 9 d, 14 d and 20 d pm. But at 20 d pm Brahman and Charolais had shear force values that were not significantly different from Angus. Frylinck *et al*. [9] reported consistently lower shear force values for Bonsmara and Nguni compared to Brahman at 1, 3, 7, 14 and 21 d pm which was also observed in the study, but only for Nguni.

The L* and b* showed very good negative correlations with visual colour (r = -0.809 and r = -0.698 respectively) as shown in Table 3. Hue angle showed a very good positive correlation with visual colour (r = 0.797), while chroma showed negative correlation with visual colour (r = -0.428). Shear force also showed a negative correlation with structure integrity (r = -0.410) and fiber separation (r = -0.401). There were very low correlations between shear force and colour /marbling/texture. And the colour co-ordinates had very low correlations with marbling, fiber separation, surface texture and structure integrity.

IV. CONCLUSION

According to the observed results, electrical stimulation seemed to eliminate the differences in meat colour and tenderness within the breeds. From the study, it is evident that consumers might have the potential to judge meat colour by visual analysis if offered proper training. It could be more difficult for consumers to predict meat tenderness visually by using surface structural observations (fiber separation and structure integrity) but there is potential for an experienced eye. It is clear from the results that there is no relationship between meat colour and tenderness.

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Table 1: The effect of beef breed on colour coordinates (L*, a*, b*), shear force values and visual attributes (colour, marbling, fiber separation, surface texture and structure integrity of M. longissimus lumborum (LL)

	Cattle breed						
	Angus	Bonsmara	Brahman	Charolais	Nguni	SEM[1]	P-Value
L*	40.42[b]	41.35[b]	43.95[a]	41.06[b]	37.09[c]	5.944	<.0001
a*	14.19[a]	12.63[b]	13.22[ab]	10.98[c]	10.92[c]	3.494	<.0001
b*	8.69[b]	8.175[b]	9.89[a]	6.70[c]	6.05[c]	3.537	<.0001
Chroma	16.70[a]	15.12[b]	16.58[a]	12.95[c]	12.57[c]	4.602	<.0001
Hue	1.49[b]	1.41[b]	1.08[c]	1.57[b]	1.81[a]	0.651	<.0001
Shear force	4.06[b]	4.73[a]	4.17[ab]	4.43[ab]	3.86[b]	2.117	<.0001
Colour[2]	5.30[b]	4.92[b]	4.24[c]	5.089[b]	6.33[a]	5.258	<.0001
Marbling[2]	2.06[ab]	1.91[bc]	1.79[c]	2.18[a]	2.25[a]	2.352	<.0001
Fiber separation[2]	2.38[a]	2.21[bc]	2.16[bc]	2.26[ab]	2.05[c]	1.705	0.0026
Surface texture[2]	2.59[a]	2.39[bc]	2.29[c]	2.50[ab]	2.30[c]	1.481	0.0001
Structure integrity[2]	2.57[a]	2.34[b]	2.32[b]	2.45[ab]	2.05[c]	1.893	<.0001

[1] Standard error of means
[2] Average of panel ratings as defined under methods
[a,b,c] Means within a row with different superscripts differ significantly (P<0.05)

Table 2: The effect of ageing/packaging on colour coordinates (L*, a*, b*), shear force values and visual attributes (colour, marbling, fiber separation, surface texture and structure integrity of M. *longissimus lumborum* (LL).

	Ageing					
	3 d pm	9 d pm	14 d pm	20 d pm	SEM[1]	P-Value
L*	41.25[a]	40.57[b]	40.61[b]	40.84[b]	1.292	0.0007
a*	11.12[d]	13.36[a]	12.94[b]	12.26[c]	1.302	<.0001
b*	9.17[a]	7.59[b]	7.64[b]	7.45[b]	0.852	<.0001
chroma	14.49[b]	15.40[a]	15.10[a]	14.44[b]	1.399	<.0001
Hue	0.97[c]	1.66[a]	1.63[ab]	1.58[b]	0.195	<.0001
Shear force	5.60[a]	4.42[b]	3.76[c]	3.21[d]	0.550	<.0001
Colour [2]	4.51[b]	5.40[a]	5.41[a]	5.46[a]	2.135	<.0001
Marbling[2]	1.64c	2.04[b]	2.17[b]	2.33[a]	1.590	<.0001
Fiber separation [2]	1.74[b]	2.40[a]	2.37[a]	2.35[a]	1.183	<.0001
Surface texture[2]	2.24[b]	2.49[a]	2.50[a]	2.44[a]	1.079	<.0001
Structure integrity[2]	1.72[d]	2.18[c]	2.60[b]	2.93[a]	1.311	<.0001

[1] Standard error of means
[2] Average of panel ratings as defined under methods
[a,b,c,d] Means within a row with different superscripts differ significantly (P<0.05)

Table 3: Correlation matrix showing correlation coefficients of colour coordinates (L*, a*, b*), shear force values and visual attributes (texture, fibre separation, marbling and structure integrity rating) of M. longissimus lumborum (LL).

	Colour	Marbling	Fibre separation	Surface Texture	Structure Integrity
L*	-0.809	-0.193	0.067	-0.060	0.080
a*	-0.185	0.005	0.232	0.079	0.157
b*	-0.698	-0.289	-0.095	-0.142	-0.106
Chroma	-0.428	-0.123	0.115	-0.008	0.063
Hue	0.797	0.359	0.250	0.219	0.267
Shear force(Kg)	-0.242	-0.312	-0.401	-0.125	-0.410

EFFECT OF FEEDING BROKEN RICE IN SUBSTITUTION OF CORN ON pH, COLOUR AND LIPID AND PROTEIN OXIDATION OF FRESH AND AGED POULTRY MEAT

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Abstract - The objective of this study was to evaluate the meat quality of poultry meat receiving a diet with increasing levels of broken rice in substitution of corn. For this, 30 Ross birds 35 days aged were fed with a diet containing 0, 30 and 60% of broken rice in substitution of corn. The birds were slaughtered and pH and colour, L*, a*, b*, were measured at 10, 45, 90 and 24 hours *post mortem*. At 24 hours *post mortem,* drip loss was determined in *Pectoralis major* (PM) and *Gastrocnemius* (GM) muscles. After that, both muscles were obtained and divided in two pieces, one was frozen at -20ºC and the other was vacuum packaged and aged at 2-4ºC during 5 days. TBARS and carbonyls were measured in fresh and aged muscles. Increasing broken rice in the diet decreased pH at 45, 90 min *post mortem* in both muscles but no effect on drip loss was observed. Parameters b* and a* and b*, were significantly decreased ($p<0.05$) in GM and PM respectively, by the broken rice. Lipid oxidation was significantly ($p<0.03$) decreased by 60 % broken rice while protein oxidation was not affected. We can conclude that broken rice, a strategic source to substitute corn, modifies pH and colour and improves oxidative stability in poultry meat.

I. INTRODUCTION

In Uruguay, rice production is a valuable and exportable commercial product and its by-products as broken rice is an alternative to corn in poultry diets (1). The broken rice separated out after the polishing stage has the similar chemical composition as polished rice. There is seldom any surplus of broken rice available for feeding. Broken rice is a palatable, energy-rich and easily used feed. It is used for all classes of livestock, but its high energy value and low fiber content make it especially valuable in rations for growing chickens. Broken rice produced in Uruguay has a chemical composition, 9.4 % CP and 17.83 MJ/kg EM that makes it adequate to replace corn in diet for poultry (2; 3). Uriyapongson et al. (4) and Hung et al. (5) showed that the inclusion of broken rice in the diet in substitution of corn increases nutrient digestibility while modifications in pH fall *post mortem* in meat was observed. The aim of this work was to evaluate the modifications in meat quality caused by the level of broken rice in the diet on pH, colour, drip loss and lipid and protein oxidation in *Pectoralis* and *Gastrocnemius* muscles fresh and aged during 5 days in vacuum packaged at 2-4 °C.

II. MATERIALS AND METHODS

The animal care and handling were approved by the Honorary Committee of Experimental Animals of the Universidad de la República, Montevideo, Uruguay (CHEA) before the experimentations started. The trial was conducted at the Facultad de Agronomía of the Universidad de la República (UDELAR, Montevideo, Uruguay), following the human animal care and handling procedures, according to the protocol accepted. One-day old males birds (Ross) obtained from a commercial hatchery were reared until thirty-five days of age on litter floor, in an acclimatized room with a photoperiod of 23 hours of light. They were fed *ab libitum* with a commercial corn-soya diet (21.9 % PC; 13.35 MJ of ME/kg). Fresh water was provided *ad libitum*. At thirty-five days old, twenty- four birds were selected by weight and health appearance and assigned completely randomly into three groups of eight birds each individually located in the pens with floor litter. Each group was fed with one of the experimental diets until sacrifice. All birds received water and food *ad libitum* during the whole period. At fifty-

six days old, all the birds were sacrificed in an experimental abattoir. Pre-harvest handling and transportation (transportation time was 3 minutes) were in accordance with good animal welfare practices. Slaughtering procedures followed the CHEA accepted protocols. A corn-soya based diet was formulated to meet nutrient requirements for finishing male broilers (6; 7) using ground corn as a starch source and considered as a test diet. The additional two diets were formulated by substituting 30% or 60% of corn by broken rice in the iso-nitrogenous and iso-caloric diets. At 56 days all the birds were slaughtered after fasting for 4 hours according to standards established by CHEA, making the sacrifice by cutting the jugular vein until total bleeding (3min) so as to cause the least possible stress to the animal. Immediately after exsanguinations the pH was determined at 10, 45, 90 minutes and 24 hours *post mortem* (kept at 4°C) in the *Pectoralis* and *Gastrocnemius* muscles from both sides, using a penetration pH meter LT Lutron pH-201. Also, meat colour was determined using CIELAB method, L*, a*, b* at 10, 45, 90 minutes and 24 hours *post mortem* (at 4°C), with a Minolta Lab CR-10 colourimeter. Water drip loss was determined by the weight difference in 2.5 g of each muscle samples at 24 hours *post mortem* from both sides (8). For the oxidation of lipids and proteins determinations, samples of both muscles (both sides and at 24 hours *postmortem*) were stored in polyethylene bags at -30°C until analysis (fresh meat) or were vacuum packaged, kept at 4°C for 5 days and then frozen at -30°C until determinations (aged). Lipid oxidation was determined by TBARS method (9) with some modifications (10). The results were given as mg of MDA/kg of fresh meat. Protein oxidation was estimated by the reactions between carbonyls and DNPH (*2,4*-dinitrophenylhydrazine) (10) with the resulting formation of a Schiff base which produces the corresponding hydrazone, quantified spectrophotometrically at 360 to 385 nm. The determination was carried out using the method of (11) with some modifications. The concentration of DNPH was calculated using its molar extinction coefficient of 22.000 M-1 cm-1, and results were expressed as nmol DNPH/mg protein. Protein content was determined at 280 nm in the homogenized using bovine serum albumin (BSA). To evaluate level of broken rice, muscle, time *post mortem* and ageing effects for each variable determined, a repeated measures ANOVA or ANOVA GLM (NCSS, 2007) was followed. Also, a one way ANOVA was used to compare within diet, muscles or fresh and aged muscles.

III. RESULTS AND DISCUSSION

In Table 1, it can be observed that broken rice in substitution of corn modifies the pH causing a higher pH at 10, 45, 90 min and at 24 hours *post mortem* with a marked effect of muscle type. Indeed, this effect is more clear in PM than in GM. It would be doubt to highly digestible starch in broken rice which could be influenced by the glycogen stores (12). Also, the parameters of colour, L* are higher and a* and b* are decreased by the incorporation of broken rice in diet (Table 1). Redness and yellowness of the PM are diminished and it remains at 24 hours *post mortem* while in GM the effect on redness disappears at 24 hours resting only the effect on the b* parameter. Drip loss was not affected by the broken rice (Table 2). When increasing the level of substitution of broken rice to 60% in the diet of poultry, the lipid oxidation expressed as TBARS was decreased in the Pectoralis and *Gastrocnemius* muscles, fresh and aged related to 30 % and 0% (Table 3). No effect on protein oxidation was observed (Table 3).

Table 1. Effect of increasing broken rice in poultry diet on the kinetics of *p*H and color L*, a*, b*, of *Pectoralis* (PM) and *Gastrocnemius* (GM) muscles at 10, 45, 90 min and 24 hours *post mortem (*T*pm).*

	T*pm*	Broken rice (%)					
		0	30	60	0	30	60
		PM			GM		
*p*H	10min	6.27 ±0.06 a	6.13 ±0.06 a	6.46 ±0.07 b	6.24 ±0.04 a	6.24 ±0.09 a	6.60±0.11 b
	45min	5.98±0.04 b	5.52 ±0.05 a	6.08 ±0.06 b	6.07 ±0.04 a	5.78 ±0.01 a	6.20 ±0.06 b
	90min	5.92 ±0.09 b	5.44 ±0.09 b	5.55 ±0.04 a	5.99 0.1 b	5.56 ±0.12 a	6.02 ±0.07 b
	24 h	5.91 ±0.02 a	6.00 ±0.02 b	6.02±0.01 b	5.96±0.06	6.10±0.05	6.09±0.01
L*	10min	45.52 ±0.3	46.74 ±0.4	47.37 ±0.8	55.06 ±0.09	55.16 ±0.79	54.13± 1.0
	45min	46.44 ±0.4	46.57 ±0.5	46.61 ±0.3	54.55 ±0.4	55.63 ±0.6	53.5 ±0.9
	90min	46.84 ±0.3	46.02 ±0.5	46.64 ±0.3	56.65 ±1.08	54.37 ±0.9	55.18 ±0.9
	24 h	51.13 2.9	54.9 ±0.7	56.65 ±0.6	54.2± 0.7	53.3± 1.2	54.0 ±0.9
a*	10min	0.26 ±0.1 b	0.09 ±0.1 b	-0.89 0.1a	4.45 ±0.3 b	3.38 ±0.4 ab	2.73 ±0.4 a
	45min	0.52 ±0.1 c	-0.09 ±0.1 b	-0.68 0.1a	3.7± 0.6	2.97 ±0.4	3.14± 0.4
	90min	0.4 ±0.1 b	0.17±0.11 b	-0.55 0.07a	2.8 ±0.5	2.3 ±0.4	2.27 ±0.5
	24 h	1.43 ±0.2 b	-0.34± 0.1 a	0.19 0.3 a	6.12 ±0.8	5.06± 0.5	5.19 ±0.6
b*	10min	6.8 ±0.2 c	5.6 ±0.2 b	3.5 ±0.2 a	10.9 ±0.8 b	8.63 ±0.5 ab	6.52 ±0.6 a
	45min	9.01± 0.3 b	7.76 ±0.2 b	4.72 ±0.3 a	12.0 ±0.7 b	9.01 ±0.4 a	7.21 ±0.2 a
	90min	8.6 ±0.4 b	7.81 ±0.4 b	6.03 ±0.2 a	10.8 ±0.4 b	9.83 ±0.5 a	8.17 ±0.4 a
	24 h	10.01 ±0.3 c	8.23 ±0.5 b	4.97 ±0.2 a	14.7 ±0.7 b	10.91 ±1.1 a	7.41 ±1.2 a
		Mains effects					
	pH *Diet: p<0.001* *Muscle:p<0.001* *Time: p<0.001*		*L* *Diet: p<0.05* *Muscle:p<0.001* *Time:p<0.01*		*a** *Diet:p<0.001* *Muscle:p<0.001* *Time: p<0.01*		b* Diet: p<0.001 Muscle:p<0.001 Time: p<0.001

Data are mean ±SEM. Main effects for diet, muscle and days of aging were analyzed by repeated measures ANOVA and post hoc Tukey test (P<0.05) (NCSS, 2007).

Table 2. Effect of broken rice in diet on the drip loss (%) of *Pectoralis* and *Gastrocnemius* muscles 24 hours post mortem.

	Muscle	**Broken rice (%)**			
		0	**30**	**60**	***P***
Drip loss (%)	**PM**	**3.43±0.43**	**3.04±0.3**	**3.98±0.41**	**ns**
	GM	**3.46±0.38**	**2.96±0.3**	**3.43±0.26**	**ns**

Data are mean ± SEM of n=8. Main effects for diet and muscle were analyzed by ANOVA GLM and post hoc Tukey test (P<0.05) (NCSS, 2007).

IV. CONCLUSION

From this work we can conclude that the substitution of corn with broken rice is a valuable alternative. The main effects on meat quality are the modification of pH and the loss of redness and yellowness at 24 hours *post mortem*. The positive improvement on the fresh and aged meat stability is an interesting and original effect of rice in diet in the preservation of the oxidative deterioration of poultry meat.

Table 3. Effect of feeding broken rice in substitution of corn on the lipid (TBARS, mg MDA/kg meat) and protein oxidation (carbonyls, nM DNPH/mg protein) of *Pectoralis* and *Gastrocnemius* muscles fresh (F) and aged (A).

			Broken rice (%)		
	Muscle	Aging	0	30	60
TBARS (mg MDA/kg meat)	PM	F	0.29	0.31	0.28
		A	0.30	0.27	0.26
	GM	F	0.30	0.40	0.27
		A	0.38	0.40	0.26
Main effects					
Diet : *p<0.03* ; 60%<30%<0					
Muscle : *p<0.03* ; G>P Aging : ns					
Carbonyls (nM DNPH/mg protein)	PM	F	0.15	0.17	0.15
		A	0.14	0.18	0.15
	GM	F	0.13	0.11	0.15
		A	0.13	0.18	0.14
Main effects					
Diet : ns Muscle : ns Aging : ns					

Data are mean ± SEM of n=8. Main effects for diet, muscle and ageing were analyzed by ANOVA GLM and post hoc Tukey test (P<0.05) (NCSS, 2007).

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THE LABELLING OF RELIGIOUSLY SLAUGHTERED MEAT IN THE UK: AN INDUSTRY AND CONSUMER PERSPECTIVE

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Abstract – The Muslim Council of Britain (MCB) and Shechita UK have been leading campaigns to promote awareness about their methods of killing animals for food, insisting that their religious way of killing result in no compromise to animal welfare when compared to conventionally slaughter. However, further than the welfare debate, it seems peculiar and inappropriate that consumers do not get informed whether the meat they buy from supermarkets is religiously or conventionally slaughtered.

To establish whether the UK should enforce the mandatory labelling of religiously slaughtered meat within its supply chains, a mixture of qualitative data from industry interviews and quantitate data through the distribution of a consumer questionnaire were performed.

Overall the outcome highlighted concerns including the mistrust within the halal industry, alongside fears raised regarding anti-Semitism and Islamophobia if labelling is undertaken in a biased manor. Christians and those of no-religion advocate the labelling of such meat, alongside expressing concern regarding the welfare of animals slaughtered without prior stunning.

For the mutual benefit of the Muslim community, those of Christian faith and of no religion the results of this study indicate a recommendation for the mandatory labelling of religiously slaughtered meat.

I. INTRODUCTION

The religious slaughter of animals for both the Islamic and Jewish faiths is steeped in historical context [1]. With a growing multicultural population in the UK there is an increased production of religiously slaughtered meat. Whilst labelling is currently in place for halal and kosher meat sold to the designated communities, a percentage of religiously slaughtered meat is being shifted into the conventional supply chains and sold un-labelled [3].

The debate regarding religious slaughter of meat and thereafter the labelling has reached parliamentary level at the EU, and has also been debated within UK parliament. With increasing media coverage, the topic of religious slaughter and then after the labelling has been put under the national spotlight in recent months. As such, there was urgent need for research to be carried out as to the industry perspective of religious slaughter alongside consumer opinion from a cross section of the population.

With a growing desire for increased consumer choice this study aims to analyse the industry and consumer perspective of religious slaughter labelling from a variety of religious backgrounds.

II. MATERIALS AND METHODS

Industries opinion and stance on the labelling of religiously slaughtered meat was studied by conducting a number of interviews. As this is a very emotive topic that has differing significant to those of varying religious beliefs, one key objective of the interviews was the contacting of different organisations each representing a different viewpoint of religious slaughter, the Halal Food Authority (HFA) representing the views of the Muslim community whilst Shechita UK of represents the views of the UK Jewish community. With their current research into the possibility of a voluntary halal assurance scheme, the organisation for the English beef and sheep industry (EBLEX) were a priority to contact in terms of labelling possibility and opinion within the industry. As the welfare of the animals slaughtered without stunning is one topic at the heart of this debate contacting Compassion in World Farming (CIWF) was imperative in understanding, from a religiously unbiased stance, the welfare perspective of religious slaughter from this charity [2].

The consumer opinion and perception of labelling was also examined through questionnaire. Responses from consumers of differing religious background allowed for unbiased results. Skew analysis was used in this study to determine any patterns of behaviour.

III. RESULTS AND DISCUSSION

As can be seen in figure 4.1, there is a relatively even collection of data from those of Muslim, Jewish, Christian belief and those of no religion. The lower data collection for those of a Jewish faith could be accredited to the smaller Jewish population in comparison to those of Christian and Muslim communities within the UK.

The consumer opinion of labelling of religiously slaughtered meat was met with a mixed response. The results from the industry interview signify that a possible explanation for the skew results of -1.98 for the Muslim population in terms of advocating labelling of religiously slaughtered meat could be attributed to the high level of miss trust within the halal industry. Theoretically the mandatory labelling of halal meat could prove to be of a twofold benefit, with the Muslim communities able to confidently purchase halal meat whilst those of a Christian faith and those of no-religion having their desire for the labelling of such meat that was apparent through the irrefutable negative skew analysis results for these two demographics. Carcasses rejected from the kosher food chain could evidently not be labelled as kosher. Thus, labelling would theoretically be required to state the slaughter method, and primarily that of the slaughter of animals without prior stunning.

As for the impact on the supply chain if mandatory labelling was to be introduced. The interview with Shechita UK stated that the further labelling of kosher meat could not be authenticated outside of the kosher food chain [4]. This was a concern also highlighted by the HFA in which it was noted that full traceability of the supply chain would, at present, be unattainable. Conclusively the feasibility of accurate labelling of all religiously slaughtered meat irrespective of market destination is met with a number of significant difficulties.

A significant outcome that can be drawn from this study is the realisation that both the socio-political and the socio-religious elements certainly must be treated with the upmost respect, yet so must the desires of those consumers who wish, for either ethical or perceived welfare grounds, not to consume such meat. The debate regarding the labelling and indeed the practice of religious slaughter will foreseeably gather increased coverage in the coming months and years.

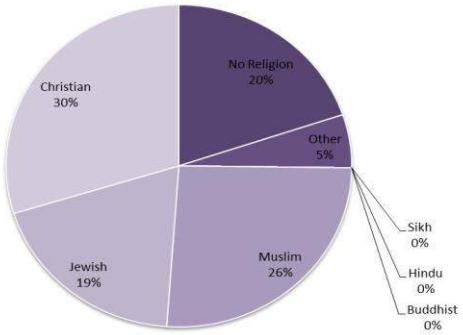

Figure 1. The percentages of the religious breakdown in response to the questionnaire

IV. CONCLUSION

The decision to label religiously slaughtered meat must not be taken lightly and simply placing a sticker on a box of fraudulently processed meat indicating it to be halal or kosher shall not suffice. Would the recognition in law for such meat reduce the fraudulent claims that are both made now and undoubtedly would be made if mandatory labelling was to be introduced? Possibly, yet it shall be through increased transparency, auditing, a heightened number of spot checks and confidence in the certification bodies that shall be needed if mandatory labelling is to be introduced.

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EVALUATION OF GROUND BEEF QUALITY FOLLOWING DIFFERENT ANTIMICROBIAL INTERVENTIONS

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Abstract - Multiple antimicrobial interventions were applied to beef carcasses and trimmings to determine if repetitive applications negatively impacted ground beef patty color and consumer sensory ratings. While some visual darkening of patty color occurred by the completion of the shelf-life period, few significant changes were seen. Consumer scores for overall liking, flavor liking, and beefy flavor liking were impacted ($P < 0.05$) by combined antimicrobial treatment effects. Although there were some significant interactions reflected in consumer panel scores, there was no clear trend describing interaction effects and consumer ratings. Additionally, no clear trends were seen relating trained panel ratings to any single or combined antimicrobial treatment for these scores. Findings supported that the applied food safety interventions did not negatively impact beef patty quality.

I. INTRODUCTION

With the United States Department of Agriculture – Food Safety and Inspection Service (USDA-FSIS) declaration of *Escherichia coli* O157:H7 and Shiga-toxin producing *E. coli* (STEC) as adulterants in non-intact raw beef products and intact raw beef products intended for non-intact use [1], the addition of antimicrobial interventions has become standard procedure during beef harvest and further processing. Using consecutive decontamination processes in beef packing plants as a means of improving the microbiological quality of beef carcasses is beneficial in reducing microbiological contamination of beef carcass surfaces that can occur during the beef harvest process [2]. Bacon, Belk, Sofos, Clayton, Reagan and Smith [2] validated that sequential multiple hurdle interventions reduce bacteria on beef carcasses more effectively than any one intervention alone. There is a need to evaluate the impact of such treatments with respect to meat quality. The goal of this study was to determine if multiple hurdle intervention combinations produced ground beef patties with less desirable quality attributes when compared to control patties.

II. MATERIALS AND METHODS

A. Treatment design

For the control (treatment group 1), lactic acid was applied to the entire hot carcass. Treatment groups 2, 3, 4, and 5 received hot water and lactic acid application to each hot carcass. All carcasses were allowed to chill for 36 h at 2 °C. Immediately before fabrication, sides assigned to treatments 3, 4, or 5 received an application of lactic acid, acidified sodium chlorite or Beefxide (lactic acid and citric acid mixture), respectively. The ten forequarters (across all treatment groups) then were fabricated and made into trimmings. For all control and treatment groups, the trimmings were weighed and divided into four similar subgroups (n = 40). The subgroups within each treatment then were assigned to one of four trimmings treatment groups: control (no trimmings spray), lactic acid, acidified sodium chlorite, or Beefxide.

B. Hot carcass intervention application

On the day of slaughter, lactic acid was mixed and titrated before and after the intervention spray. The lactic acid solution temperature was approximately 55 °C before application and was applied to the entire side for 60 s (approximately 500 ml). The hot water intervention was applied to the forequarter only, at 82.2 °C or higher inside the sprayer, for 90 s (approximately 250 ml). The hot carcass interventions were applied to the carcass after a final wash step. Carcasses then were weighed, tagged, and chilled for 36 h at 2 °C.

C. Cold forequarter intervention application and forequarter fabrication

Antimicrobial solutions — lactic acid, acidified sodium chlorite and Beefxide — were mixed on the day of fabrication; each was titrated to ensure proper concentration. Immediately before fabrication, antimicrobial interventions were applied to the designated forequarters. Duration of application of lactic acid, acidified sodium chlorite, and Beefxide was 30 s (approximately 250 ml). Temperature of each intervention was evaluated before application; lactic acid and Beefxide were applied at approximately 55 °C and acidified sodium chlorite was applied at room temperature (approximately 25 °C). Lean trimmings were separated into four similar subgroups and weighed to achieve similar trim groups. Individual plastic lugs were covered and placed on racks in refrigerated storage (2 °C) until the trimmings interventions were applied. The cold forequarter, fabrication, and trimmings interventions were all performed on the same day.

D. Trimmings antimicrobial application

For the application of the trimmings intervention spray, fresh beef trim was placed on a screen to allow for even distribution. Lactic acid and Beefxide were applied at approximately 55 °C. Acidified sodium chlorite was applied at room temperature (approximately 10 °C). Trimmings were sprayed for either a 10 or 15 sec interval (100-150 ml) based on the amount of trimmings in a subgroup and how many screens were needed to achieve even application. Trimmings were covered and allowed to rest in refrigerated storage (2 °C) for approximately 48 h before grinding.

E. Grinding and production of patties

Trimmings subgroups were ground individually using a coarse-grind plate (1.27 cm diameter) followed by a final grind plate (0.32 cm diameter). Ground product was covered and allowed to rest for approximately 12 h. The following day, twenty-one 150 g patties were made per trim subgroup (n = 840). Patties destined for shelf-life evaluation were assessed for color, pH and temperature before being packaged in a PVC overwrap tray. All other patties were crust frozen, individually packaged, and stored at -10 °C until subsequent evaluations.

F. Shelf-life evaluation

Patties were placed in a "retail-like" refrigerated (approximately 4 °C) setting with fluorescent lights to simulate a retail case. Color measurements were taken using a Hunter MiniScan EZ (HunterLab, Reston, VA) colorimeter on days 1, 2, 3, 4, and 5.

G. Sensory evaluation

Both consumer and trained panels were conducted for sensory evaluation. Patties were cooked to an internal temperature of 70 °C. Internal temperatures were monitored using a copper-constantan thermocouple (Omega Engineering, Stratford, CT) inserted into the geometric center of each patty. Each patty then was cut into 1/6 wedges and served warm in individual booths equipped with red theater gel lights.

Consumer panelists were asked to evaluate patty attributes based on a 9-point scale. Attributes included: overall liking (1 = dislike extremely; 9 = like extremely), flavor liking (1 = dislike extremely; 9 = like extremely), beefy flavor liking (1 = dislike extremely; 9 = like extremely), level of beefy flavor (1 = extremely bland or no flavor; 9 = extremely flavorful or intense), off-flavors (yes or no), intensity of off-flavors (1 = extremely bland or no flavor; 9 = extremely intense), tenderness liking (1 = dislike extremely; 9 = like extremely), juiciness liking (1 = dislike extremely; 9 = like extremely). A total of 80 consumers were used.

A 6-member, trained panel was used to determine flavor, basic taste, mouthfeel, after-taste, and texture attributes The panelists evaluated samples using a 16-point universal scale with 0 = none and 15 = extremely intense for attributes defined during ballot development sessions [3]. A total of eight trained panel sessions were conducted with ten samples evaluated per session.

H. Statistical analysis

All sensory data were analyzed using PROC GLM of SAS (SAS Institute Inc., Cary, NC), where main effects and significant two-way interactions were included in the model. Least squares means were calculated; where ANOVA testing indicated significance, means were separated using the PDIFF procedure and an $\alpha < 0.05$.

III. RESULTS AND DISCUSSION

A. Shelf-life

The *L** values across all treatment combinations and shelf-life days showed some statistical differences (data not shown in tabular form). Trimmings derived from carcass treatment groups 2 (hot water and lactic acid applied to the hot carcass) and 3 (hot water and lactic acid applied to hot carcass, followed by a pre-fabrication cold forequarter lactic acid spray) received lower ($P < 0.05$) *L** values compared to other treatment combinations.

*L** values remained consistent for the beginning of the shelf-life period, but showed a significant decrease ($P < 0.05$) by day 5. There was a decrease ($P < 0.05$) in *a** values over the shelf-life period. The *b** values showed a decrease ($P < 0.05$) from shelf-life days 1 to 3 and a significant increase from day 3 to day 5. Stivarius, Pohlman, McElyea and Waldroup [4] noted that hot water and lactic acid treatments applied to fresh beef trimming before grinding resulted in lower overall color and greater discoloration when compared to a control treatment. Quilo, Pohlman, Dias-Morse, Brown Jr., Crandall and Story [5] also noted decreasing *a** values for antimicrobial treated ground beef versus the control over a 7-day shelf-life period.

B. Sensory evaluation

Overall, few significant relationships were noted between the combined effects of hot carcass, cold forequarter, and trimmings antimicrobial intervention sprays and consumer perception on ground beef quality. Consumer panel scores for overall liking, flavor liking and beefy flavor liking attributes were impacted ($P < 0.05$) by combined antimicrobial treatment effects. Trimmings assigned to either control or lactic acid treatment groups generally performed better in consumer panel responses for overall liking. Further, trimmings derived from carcass treatment group three and subjected to a lactic acid trim spray scored higher ($P < 0.05$) with consumer panelists for overall liking scores when compared to lactic acid treated trimmings from carcass treatment group five. While not significant in all cases, trimmings treated with acidified sodium chlorite tended to return less favorable consumer sensory panel scores for overall liking. In general, consumer panelists again rated control and lactic acid trimmings groups higher for flavor liking than other trimmings treatment groups, regardless of carcass treatment designation. In similar studies, no major differences for beef flavor or off flavor attributes of ground beef patties that received lactic acid antimicrobial treatments were found when compared to a control [6, 7]. Acidified sodium chlorite received lower ($P < 0.05$) beefy flavor liking for treatment group one. In general, consumer panelists again rated control and lactic acid trimmings groups higher for beefy flavor liking than other trimmings treatment groups, regardless of treatment group designation. This did not hold true for treatement group five, as the lactic acid trimmings treatment groups recevied lower scores from consumer panelists. In a similar study, Quilo, Pohlman, Brown, Crandall, Dias-Morse, Baublits and Aparicio [8] found that ground beef patties that received either peroxyacetic acid or acidified sodium chlorite antimicrobial treatments received only slightly lower scores for beef odor when compared to the control.

Of the 32 attributes outlined in the trained panel ballot, panelists detected only 18 attributes over the course of this study. Scores for sour milk/dairy ($P = 0.0132$) and cardboardy ($P = 0.0014$) were impacted by treatment combination effects. Although these patties were frozen immediately after production and thawed for approximately 18 h before each trained panel session, sour milk/dairy and cardboardy attributes are typically considered indicators of spoilage and oxidative rancidity,

respectively. Further, on a 16-point scale (0 = attribute not detected; 15 = strong presence of attribute) panelists did not rate either attribute higher than a three, with mean scores of 0.12 and 0.06 for cardboardy and sour milk/dairy, respectively. Because attributes that showed significance returned low mean scores, there was no reason to believe that the antimicrobial intervention combinations impacted patty quality. Jimenez-Villarreal, Pohlman, Johnson and Brown Jr. [7] found that trained panelists were not able to detect any differences for beef flavor and off flavor when comparing ground beef patties treated with multiple hurdle interventions and a control group, which supports current findings. The lack of differences noted by trained panelists across different studies suggests that multiple hurdle interventions can be used without negatively impacting taste attributes for ground beef.

IV. CONCLUSIONS

Beef safety and quality are continuous challenges for the meat industry. With foodborne pathogens being of upmost concern, antimicrobial interventions are commonly used as a method to reduce the prevalence of pathogenic bacteria throughout the beef production process. Overall ground beef quality was not impacted by the combination of antimicrobial interventions used in this study.

V. ACKNOWLEDGEMENT

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IMPACT OF LOW-DOSE IRRADIATION ON THE QUALITY AND PALATABILITY ATTRIBUTES OF BEEF SUBPRIMALS

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Abstract - This study was conducted to evaluate the impact of low-dose irradiation on beef quality and sensory attributes. Paired subprimals were randomly assigned to treated (irradiated with a surface dose of 1 to 1.5 kGy) and control (non-irradiated) groups. Following treatment, subprimals were fabricated into thirds and randomly assigned to one of three aging days (0, 14, or 21). After the aging period, subprimal pieces were cut into 2.54-cm thick steaks, and the resulting trimmings were ground to produce 0.113 kg patties. Steaks and patties were randomly assigned to one of three shelf-life days (0, 2 or 4). During retail display, L*, a*, and b* measurements were taken for raw and cooked steak and patty color. Steaks and patties from all treatment groups were evaluated by a trained sensory panel and used for thiobarbituric acid reactive substances (TBARS) analysis. Differences in raw steak and patty color were seen. No differences were evident between cooked steak samples; however, cooked patty color differences were observed. Further, numerous palatability attributes were impacted by treatment and differences in TBARS values were seen. These results suggest that if chilled subprimals or carcasses were treated with low-dose e-beam irradiation, quality and palatability characteristics could be negatively impacted.

I. INTRODUCTION

The meat industry is constantly searching for microbial interventions or processing aids to help reduce pathogens, thereby reducing the probability of a foodborne disease outbreak and subsequent economic losses associated with such outbreaks. Although food has been safely irradiated in the United States for more than thirty years, there is limited application of irradiation to fresh beef. Research has been conducted to assure consumers that the use of food irradiation, according to governmental regulations, is safe and does not increase human exposure to radiation. Energy used in this process is not strong enough to cause food to become radioactive [1].

Many beef quality and sensory attributes might be altered when using low-dose irradiation. In the event that the use of low-dose irradiation is used as a processing aid, more information is needed to allow the beef industry to better understand the consequences associated with low-dose irradiation. The objectives of this study were to determine the impact of low-dose carcass irradiation on the quality characteristics of beef subprimals and trimmings and to determine the impact of low-dose irradiation on palatability characteristics of steaks and ground beef produced from treated subprimals and trimmings.

II. MATERIALS AND METHODS

A. Product selection

Beef inside rounds (n = 10), bottom round flats (n = 10), and knuckles (n = 18) were collected, in pairs, from a commercial meat packing facility. Subprimals then were shipped to Texas A&M University (College Station, Texas) and stored for two days under refrigerated conditions (2-4 °C).

B. Treatment design

Paired subprimals were randomly assigned to either the control (non-irradiated) or treatment (irradiated) group. The treatment group was subjected to low-dose irradiation at the National Center for Electron Beam Research at Texas A&M University (College Station, Texas). During the irradiation process, three Kodak BioMax alanine dosimeter strips were placed on the surface of each subprimal.

C. Subprimal fabrication

All subprimals (control and treated) were fabricated into three equal parts and randomly assigned to an aging day (0, 14, or 21). The subprimal pieces assigned to either 14 or 21 days were stored vacuum packaged under refrigerated conditions (2-4 °C). Following the designated aging times, the subprimal pieces were trimmed of all external fat, trimmings were produced by removing approximately 1.27 cm of exposed lean, and 2.54 cm steaks were produced. After the appropriate numbers of steaks were cut, the remaining lean portion was combined with the lean trim. The trimmings were coarse ground through a 2.54 cm plate, hand mixed, fine ground through a 0.3175 cm plate, hand mixed, and formed into 0.113 kg ground beef patties. All steaks and patties were placed in foam trays with PVC overwrap. Following packaging, steaks and patties were randomly assigned to a shelf-life group (0, 2, or 4 d), and placed under continuous fluorescent lighting to simulate retail display.

D. Trained sensory panel

Following storage, steaks and patties were evaluated for sensory and shelf-life characteristics. Descriptive sensory evaluation was conducted at the Texas A&M University sensory testing facility using an expert, trained meat descriptive-attribute panel. For sensory determinations, steaks were cooked to an internal temperature of 70 °C and patties were cooked to an internal temperature of 75 °C on a Hamilton Beach Portafolio Indoor/Outdoor Grill (Hamilton Beach/Proctor-Silex, Inc., Southern Pines, NC). Internal temperatures were monitored by a copper-constantan thermocouple (Omega Engineering, Stanford, CT) inserted into the geometric center of each steak or patty. Once the internal temperature reached 35 °C for steaks and 37 °C for patties, they were flipped and cooked until the final internal temperature was reached. Following cooking, steaks were cut into 1.27 cm cubes and patties were cut into 1/8 patty wedges and served warm (within 5 minutes post-cooking) to each of five trained meat descriptive attribute sensory panelists.

The panel was trained as defined by American Meat Science Association [2] and Meilgaard, Civille and Carr [3]. Flavor, basic taste, mouthfeel, after-taste, and texture attributes were determined during ballot development sessions. After attributes for the ballot were defined, training sessions were conducted. Following training, the study was initiated after panelists could consistently and accurately identify sensory attributes [2]. Each panelist was seated in individual booths equipped with red theater gel lights. Samples were served in a random order and identified using three-digit codes. Unsalted saltine crackers, fat-free ricotta cheese, and double distilled, deionized water were served to the panelists between samples to cleanse their palate. The panelists evaluated each sample using a 16-point universal scale with 0 = none and 15 = extremely intense for attributes defined during the ballot development sessions [3]. Two sessions were conducted with eight samples evaluated per session where samples were represented across treatments.

E. Color analyses

During retail refrigerated storage, color measurements were taken on PVC-packaged steaks and patties on days 0, 2, and 4. After steaks and patties were cooked for sensory analysis, cooked color was assessed. Color was measured using a Minolta Colorimeter (CR-300, Minolta Co., Ramsey, NJ) which was calibrated daily to insure consistency among days. For raw measurements, three different readings were randomly taken from the surface of each patty and steak. For cooked color analysis, three color measurements were taken from the internal portion of each steak and patty by selecting three random cubes and wedges from each steak and patty, respectively.

F. Thiobarbituric acid reactive substances (TBARS)

Lipid oxidation was evaluated using a modified TBA (2-thiobarbituric acid) method defined by Wang, Pace, Dessai, Bovell-Benjamin and Phillips [4]. Standards were produced by combining different concentrations (0, 2, 4, 6, 8, 10, 20, and 30 mg/kg) of tetraethoxypropane (TEP) solution and trichloroacetic

acid (TCA) extraction solution. After the standards were made, samples were prepared for extraction. Samples were minced, weighed, 5 g of each sample was placed in a 50 mL centrifuge tube, and 15 mL TCA extraction solution was added. The samples were homogenized for 20-30 seconds using a Polytron homogenizer (PT 10-35 GT, Kinematica, Bohemia, NY). Following homogenization, tubes were placed in a Jouan cenrtrifuge (C 412, Jouan Inc., Winchester, VA) and centrifuged at 1,500 g for 15 min. The samples were filtered through No. 4 Whatman paper and 125 µL of the resulting extract was loaded in triplicate into a 96-well microplate. After the samples were loaded, 125 µL of TBA solution was dispensed into each well of the microplate using a pipette. The loaded microplate was then incubated for 130 min at 40 °C. After incubation, absorbance was read at 532 nm on a microplate reader (Epoch Microplate Spectrophotometer, BioTek, Winooski, VT).

G. Statistical analysis

Data were analyzed by analysis of variance using SAS PROC GLM (SAS Institute, Cary, NC) with an α of $P < 0.05$. The model included main effects of treatment, subprimal, age day, and shelf-life day. Two-, three-, and four-way interactions were included in the full model. If the interactions were not significant ($P > 0.05$), they were pooled into the error term and the final model was calculated. The p-diff function at $P < 0.05$ was used to separate least squares means when significant differences occurred.

III. RESULTS AND DISCUSSION

A. Raw L, a*, b* color space values*

Raw color differences were seen between treated and control samples on day 0 for all subprimals, but few differences were noted when comparing days 2 and 4. For bottom round steaks, L* values observed on aging days 14 and 21 were higher ($P < 0.05$) than those values recorded on day 0. Conversely, the opposite trend was noted for top round steaks, with day 0 L* values being higher ($P < 0.05$) than those values obtained on days 14 and 21. L* values for knuckle steaks were higher ($P < 0.05$) on day 21 when compared to days 0 and 14. For all subprimals, no clear trend was seen for a* and b* values across aging days.

For patties, raw color trends over aging days differed slightly from trends noted for steaks derived from the same subprimals. Bottom round patties presented higher ($P < 0.05$) L* values when comparing day 0 to days 14 and 21. In general, L* values increased over the aging period for patties from top round subprimals. L* values for knuckle patties significantly increased ($P < 0.05$) with each aging day. No consistent trends were noted for a* and b* values across aging days for all three subprimals.

B. Cooked L, a*, b* color space values*

Cooked steak color differences were not observed for any of the main effects or when considering interactions. The same held true when analyzing L* values for patties derived from top rounds and knuckles. However, bottom round L* values increased significantly ($P < 0.05$) when comparing aging day 0 to 21.

C. TBARS

Differences in TBA values were seen, but were too erratic to attribute to a certain variable. When comparing means between irradiated and non-irradiated cuts, it is apparent that some differences do exist. Overall, the TBA values were lower for steaks in comparison to their corresponding patties. Additionally, as the age day increased, the TBA values elevated. Although not consistent, some irradiated products produced elevated TBA values in comparison to their untreated counterparts.

TBA values generally increased between shelf day two and shelf day four. Additionally, the patty TBA values were higher than their steak counterparts. This would be expected due to the added fat component of the ground beef. Also, the surface area of the lean and fat would increase with the grinding process and would allow for a greater amount of oxygen to interact with the product.

D. Trained sensory panel

The majority of significant differences in trained panel ratings, across study main effects, were seen in bottom round steaks. Overall sweet, sour milk, juiciness, muscle fiber tenderness, bloody, and umami attributes were lower ($P < 0.05$) for treated steaks than control. However, treated steaks also obtained higher ($P < 0.05$) panelist ratings for bitter and cardboard, than control steaks. When comparing aging days for bottom round steaks, panelist ratings for sour milk, sour, bitter, cardboard, liver, and putrid increased ($P < 0.05$) as aging day increased. Similar trends were seen when comparing shelf-life days for bottom round steaks. Top round steaks, when derived from treated subprimals, had lower ($P < 0.05$) ratings for fat and juiciness attributes while receiving a higher ($P = 0.0352$) cardboard rating when compared to control steaks from the same subprimal type. Compared to control, knuckle steaks subjected to treatment received lower ($P < 0.05$) scores from panelists for juiciness, muscle fiber tenderness, overall tenderness, and connective tissue amount.

Ground beef patties originating from treated subprimals received higher ($P < 0.05$) ratings for cardboard, sweet, and hardness, while receiving lower ($P < 0.05$) scores for beefy, brown, bloody, fat, sour milk, sour, and juiciness attributes. Further, significant ($P < 0.05$) score decreases were seen when comparing aging days, with beefy, brown, fat, umami, overall sweet, sweet, attributes decreasing as aging day increased. Metallic, cardboard, sour milk, sour, and bitter attributes were continuously rated higher ($P < 0.05$) as aging day increased. These results are expected as sour and cardboard attributes are indicative of spoilage and oxidative rancidity. Again, similar trends were noted when analyzing panel ratings for ground beef patties across shelf-life days.

IV. CONCLUSIONS

If the application of low-dose irradiation were to be both approved and implemented in the U.S. beef industry, these data can be used to develop educational outreach materials to aid in minimizing the impact of low-dose irradiation on beef quality and palatability. This will help ensure the beef industry benefits from the safety aspects of the low-dose irradiation without creating quality problems that could result in economic losses to the industry. Although the impact on food safety has been demonstrated, it is crucial to the industry that we fully understand the quality implications of this technology.

V. ACKNOWLEDGEMENT

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SELENIUM IN POULTRY DIETS: EFFECT ON pH, COLOR, GLYCOGEN AND LACTATE KINETIC IN FRESH AND AGED *Pectoralis* AND *Gastrocnemius* MUSCLES

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Abstract – The aim of this study was to evaluate the effect of the supplementation on finishing broiler diets with selenium on parameters of meat quality. For this, a corn soya based diet was supplemented with 0,3 ppm of Se from an organic (Selenomethionine) and inorganic source (sodium selenite) and offered to thirty five day old male chickens Ross. At 56 days, the animals were slaughtered. At 10, 45, 90 min and 24 hours post mortem, pH, color, glycogen and lactate content of the *Pectoralis* and *Gastrocnemius* muscles were determined. According to the results, selenium supplementation caused greater pH than the basal diet, darker and redder in *Pectoralis*. Glycogen initial at 10 min was lower with Selenomethionine in *Pectoralis,* but glycogen degradation and final glycogen were not different with Se supplementation. No differences in initial glycogen in *Gastrocnemius* were observed. An effect of diet was obtained on the lactate level with Se supplementation without effect of source. Selenium supplementation is a valuable tool to modulate pH, colour and glycogen store and could be used to improve the quality of poultry meat.

I. INTRODUCTION

The consumption of poultry meat has increased in recent years in the region and the world due to the high nutritional value, health - effect and functional attributes (1). However, the production of poultry meat is facing new challenges that make the concept of nutritional, sensory and technological quality. The major problems of poultry meat that occur in the post mortem may be originated in the ante mortem period, when diet is one of the factors that may influence them. In the post mortem avian muscle suffers important metabolic changes that result in a decrease in the pH of the meat up to 24 hours. Speed of fall and the final value reached; inherit sensory, organoleptic, nutritional and technological quality of poultry meat. The extent and rate of pH fall hits the most indicative of the sensory quality parameters (texture, juiciness, tenderness, flavor, and odor) that affect the acceptability for consumption and promotes a series of biochemical processes modifying the suitability of meat for processing and preservation (2). Oxidative processes such as lipid peroxidation and carbonyl formation (3) is the most prevalent factor in conservation and would strongly affect the water holding and colour. Glycogen stores in the *pre mortem*, is key on the pH falling. A strategic dietary modification to modulate the glycogen utilization could be improve the meat quality and the properties of this for processing. Dietary selenium whose antioxidant effect has been well showed (4), has also a insulin-like (5) effect and it has been observed that it could modify the glycogen stores and the glycolysis (6). According this role in muscle, a hypothesis that the Se supplementation could modulate the glycogen metabolism in poultry could be raised. However, the assimilative capacity of the Se dietary and the possible effect in muscle is largely dependent on the source used, either organic as selenomethionine or inorganic like sodium selenite (7, 8). In relation to the above exposed, the aim of this work was to study the effect of the incorporation of dietary organic and inorganic sources of selenium on pH, colour, and glycogen and lactate kinetic *post mortem* in the avian muscles.

II. MATERIALS AND METHODS

One-day old Ross birds were grown until thirty -five days on litter floor, in climate room with a 23 hours photoperiod. They were fed with a commercial corn-soya diet (21.2% CP, 3191 kcal/kg ME) and fresh water was given *ad libitum*. At thirty-five days twenty-seven birds were divided into three groups of nine birds each one and fed, *ad libitum*, with one of the experimental diets until sacrifice. At fifty-six days old, all the birds were sacrificed according to the CHEA rules. A corn-soya base diet was formulated and considered as a basal diet (9). The other two diets were supplemented with Se from an organic source (0.3 ppm Se, as seleniometionina, SeMet) and an inorganic

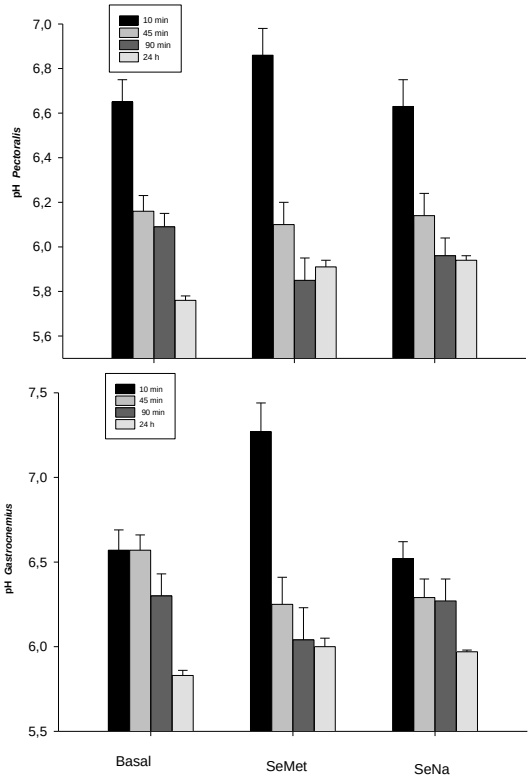
source (0.3 ppm Se, as sodium selenite, SeNa). All diets were iso- protein and iso- energetic (20% CP, 3100 Kcal/kg ME). Immediately after slaughter, pH, color and determinations of glycogen and lactate were carried up at 10, 45, 90 minutes and 24 hours *post mortem* (maintained at 4°C) in the *Pectoralis* and *Gastrocnemius* muscle. To measure pH, a penetration pH meter LT Lutron pH-201 was used. Meat color was determined using CIELAB method L*, a* b* at 10, 45 minutes and 24 hours with a Minolta Lab CR-10 colorimeter. Glycogen was determined as free glucose with an enzymatic colorimetric diagnostic kit trinder GOD-POD and expressed as mg glucose/kg fresh meat. Lactate was determined from the same hydrolyzed using an enzymatic colorimetric kit LO-POD Spinreact 10001330 and expressed as mg lactate/kg fresh meat. Data were analyzed by repeated measures ANOVA (NCSS, 2007) with mains effects of diet, muscle and time *post mortem* or ANOVA one way (for the same muscle and among diets at each time) and *post hoc* Tukey test when significance was obtained ($p<0.05$).

III. RESULTS AND DISCUSSION

In this work pH was measured at 10, 45 and 90 min and 24 hours *post mortem* in response to the organic and inorganic selenium sources, which results are shown in Figure 1. The supplementation with Se did not affect the pH values ($p>0.45$) when both muscles are considered. There was a clear effect of muscle ($P=0.004$) and a clear effect of time ($P=0.004$), which is in accordance with the changes in the muscle metabolism that occur after sacrifice. When each time is considered, in *Pectoralis* and in *Gastrocnemius*, at 24 hours *post mortem*, SeNa and SeMet provoked pH higher than basal diet ($p<0.001$ and $p<0.05$ respectively). The animals feed with SeMet showed a darker and redder meat at 24 hours *post mortem*, but in accordance with the values found by (2) in *Pectoralis* muscle of commercial chickens. No other differences were found in b* parameters.

Mains effects of diet on glycogen were not obtained, while significant differences due to muscle and time were observed (Table 1). Glycogen initial at 10 min was lower with SeMet in *Pectoralis*, but glycogen degradation and final glycogen were not different with Se supplementation ($p>0.47$). No differences in initial glycogen in *Gastrocnemius* were observed.

An effect of diet was obtained on the lactate level with Se supplementation (Table 2). More lactate was produced in meat from animals receiving Se ($p<0.05$), without effect of source.



Main effects					P
Diet	Basal	SeMet	SeNa		
	6.26	6.28	6.26		0.45
Time	10min	45min	90min	24hs	
	6.75a	6.25b	6.11c	5.90d	0.01
Muscle	*Gastrocnemius*		*Pectoralis*		
	6.39a		6.18b		0.01

Figure1. Effect of organic (SeMet) and inorganic (SeNa) Se supplementation in a diet received two weeks prior sacrifice on pH evolution at 10, 45, 90 min and 24 hours *post mortem* in the *Pectoralis* and *Gastrocnemius* muscles. Data are mean ± SEM. Mains effects are analyzed by repeated measures ANOVA for diet, muscle and time *post mortem* .

Table 1. Effect of supplementation and source of Selenium (SeMet, selenium methionene; SeNa, Senite de sodium) in poultry diet on the kinetics of glycogen (g/100 g meat) at 10, 45, 90 min and 24 hours *post mortem* in *Pectoralis* (PM) and *Gastrocnemius* (GM) muscles.

Data are mean ± SEM. Mains effects are analyzed by repeated measures ANOVA for diet, muscle and time *post mortem.*

		Selenium source		
Muscles	Time *post mortem*	Basal	SeMet	SeNa
PM	10min	11.3	6.35	14.4
	45min	8.16	6.04	7.58
	90 min	7.60	7.74	5.91
	24 hours	4.67	6.56	5.92
GM	10 min	4.03	3.98	5.47
	45 min	4.84	3.74	4.31
	90 min	4.43	5.62	4.56
	24 hours	4.76	4.56	4.76
Main effects:				
	Diet: p<0.47			
	Muscle: p<0.001 PM>GM			
	Time: p<0.01 10 min>45 min>90 min>24 hours			

Table 2. Effect of supplementation and source of Selenium (SeMet, selenium methionine; SeNa, Selenite de sodium) in poultry diet on the kinetics of lactate (g/100 g meat) at 10, 45, 90 min and 24 hours *post mortem* in *Pectoralis* (PM) and *Gastrocnemius* (GM) muscles.

Data are mean ± SEM. Mains effects are analyzed by repeated measures ANOVA for diet, muscle and time *post mortem* .

		Selenium source		
Muscles	Time *post mortem*	Basal	SeMet	SeNa
PM	10 min	0.85	1.43	1.62
	45 min	1.34	1.59	1.64
	90 min	1.54	1.61	1.69
	24 hours	1.74	1.16	1.16
GM	10 min	1.03	0.70	0.88
	45 min	1.35	1.14	0.91
	90 min	1.16	1.25	0.89
	24 hours	1.24	0.94	0.96
Main effects				
	Diet: p<0.05 Basal>SeMet,SeNa			
	Muscle: p<0.001 PM>GM			
	Time: p<0.001 24 hours>90 min>45 min>10 min			

IV. CONCLUSION

Selenium supplementation has modified pH, colour, initial glycogen and level of lactate in poultry meat. The source of Se has influenced initial glycogen but not on the initial lactate level. Strategic dietary selenium could be a tool to improve the meat quality.

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ORGANIC AND INORGANIC SELENIUM IN POULTRY DIETS: EFFECT ON LIPID AND PROTEIN OXIDATION, DRIP LOSS AND GPx ACTIVITY IN FRESH AND AGED MEAT

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Abstract – The aim of this work was to evaluate the effect of the selenium supplementation in a finishing diet for broilers on the lipid and protein oxidation, GPx activity and drip loss in *Pectoralis* and *Gastrocnemius* muscles. A corn-soya base diet was supplemented with selenium from an organic source (seleniomethionine) and an inorganic source (sodium selenite) at 0.30 ppm from thirty-five until fifty-six days. In *Pectoralis* and in *Gastrocnemius* fresh or aged during 5 days, Se supplemented in diet did not affect lipid or protein oxidation. However, GPx activity was enhanced in both muscles and the drip loss was reduced significantly at 24 hours *post mortem*. No effect of source was observed. Muscle type has a effect on the response of TBARS and process, as aging in vacuum package reduced the GPx activity. Selenium supplementation could be a strategy to reduce the drip loss in poultry meat and the effect could be mediated by the GPx activity in muscle.

I. INTRODUCTION

The poultry meat has increasing acceptance in recent years in the region and the world due to the high nutritional value, functional attributes and lower cost than red meat (1; 2). However, the production of poultry meat is facing new challenges that make the concept of nutritional, sensory and technological quality. The major problems of poultry meat that occur in the *post mortem* may be originated in the *ante mortem* period, and diet is one of the factors that may influence them. In the *post mortem*, avian muscle suffers important metabolic changes that result in oxidative processes that negatively affect sensorial acceptance, processing and preservation. Oxidative processes such as lipid peroxidation and carbonyls formation (3) are the most prevalent factors in conservation and would strongly affect the water holding capacity of the muscle fiber and nutritional attributes, loss of fatty acids, heme iron loss and formation of secondary compounds (3). Consumers prefer fresh meat with a minimum loss of water during handling and cooking. Therefore, the water-holding capacity of the meat is considered among the most important meat quality characteristics (4). Dietary selenium has been shown to act on the drip loss in poultry meat (5). It has been shown that dietary selenium is a catalyst and has a key role in reducing the lipid peroxides hydrogenated (6) through the participation in the system of antioxidant defenses that comprise the GPx (glutathione peroxidase), SOD (superoxide dismutase) and CT (catalase). The muscle GPx enzyme has a high dependence on dietary Se and its activity increases with the level of dietary Se (7; 8). One approach to enhancing the oxidative stability of meat is to add antioxidants into the animal's diet and that incorporation of Se in the diet of pre slaughter meat birds would act on the oxidation of lipids and proteins, improving the technological characteristics of the meat, particularly the drip loss. However, the assimilative capacity of the dietary Se is largely dependent on the source used, either organic as selenomethionine or inorganic like sodium selenite (9; 10; 11).

Based on this argues, the aim of this work was to evaluate the effect of the incorporation of dietary selenium, in a organic and inorganic form, on oxidative deterioration of lipids and proteins, the activity of GPx and the drip loss in two highly commercial value avian muscles, *Pectoralis* and *Gastrocnemius* associated with technological processes.

II. MATERIALS AND METHODS

One-day old Ross birds were raised until thirty -five days on litter floor, in climate room with a photoperiod of 23 hours. They were fed with a commercial corn-soya diet (21.20 % CP; 3191 kcal/kg ME) and fresh water was given *ad libitum*. At thirty-five days, twenty-seven birds were divided into three groups of nine birds each and fed, *ad libitum*, with one of the experimental diets until sacrifice. At fifty-six days old, all the birds were sacrificed according to the CHEA rules. A corn-soya base diet was

formulated and considered as a basal diet. The other two diets were supplemented with 0.3 ppm of Se coming from an organic source (seleniometionina, SeMet) or an inorganic (sodium selenite, SeNa). All diets were iso-protein and iso- energetic (20% CP and 3100 Kcal /kg ME). Muscles *Pectoralis* and *Gastrocnemius* were obtained at 24 hours *post mortem* and divided in two portions, one was stored at -30 ºC (fresh) and another one was vacuum packaged and stored during 5 days (aged). In fresh and aged samples, lipid and protein oxidation and GPx activity were determined as follows. Lipid oxidation was determined by TBARS method (12) with some modifications (13). Protein oxidation was estimated by the reactions between carbonyls and DNPH (2,4-dinitrophenylhydrazine) (14;13). GPx activity was measured recording the oxidation of NADPH (15; 13). Drip loss was determined by the weight difference in 2,5 g of *Pectoralis* or *Gastrocnemius* samples at 24 hours *post mortem* (16). Data was analyzed for the main effects with ANOVA GLM (NCSS, 2007) with *post hoc* Tukey Test ($p<0.05$).

III. RESULTS AND DISCUSSION

The effect of the supplementation with Se and the process on the lipid and protein oxidation was measured and results are shown in Table 1 and 2. Lipid and protein oxidation was not affected by the selenium supplementation. The type of muscle had an influence on the TBARS but not the process. The *Gastrocnemius* lipid oxidation expressed as TBARS was higher than in *Pectoralis*. Carbonyls were not different among the muscles or process. Data of the GPx activity are shown in Table 3. Selenium supplementation increased the GPx activity in both muscles, but muscle type did not affect it significantly. The GPx activity was higher in fresh than aged muscles. These results are in accordance with previous works (17; 18; 7). In Table 4, it is shown that the Se supplementation decreased significantly ($p<0.01$) drip loss in both muscles, without an effect of source or muscle type on the response. It seems like that a stabilising effect of Se is also associated with maintaining muscle membrane integrity. In this sense, Edens (5) showed that drip loss was decreased when organic Se was fed to broilers. Using a model system based on red blood cell membrane stability, Edens (19) confirmed a membrane-stabilising effect of organic Se.

Table 1. Effect of organic (SeMet) and inorganic (SeNa) Se supplementation in a diet received two weeks prior sacrifice on the lipid oxidation, measured as TBARS (mg MDA/kg meat) in fresh and aged *Pectoralis* (PM) and *Gastrocnemius* (GM) muscle.

		Selenium source		
		Basal	SeMet	SeNa
Process	Muscle			
Fresh	PM	0.28 ±0.02	0.22 ±0.02	0.28 ±0.03
	GM	0.28 ±0.02	0.33 ±0.02	0.31 ±0.03
Aged	PM	0.27 ±0.02	0.29 ±0.02	0.28 ±0.01
	GM	0.28 ±0.02	0.33 ±0.03	0.32 ±0.03
Main effects				P
Diets	Basal	SeMet	SeNa	
	0.278	0.296	0.300	0.49
Muscle	*Pectoralis*		*Gastrocnemius*	
	0.271b		0.312a	0.01
Ageing	Fresh		Aged	
	0.285		0.298	0.41

Table 2. Effect of organic (SeMet) and inorganic (SeNa) Se source in a diet received two weeks prior sacrifice on the protein oxidation, measured as nmoles DNPH/mg protein, in fresh and aged *Pectoralis* (PM) and *Gastrocnemius* (GM) muscles.

		Basal	SeMet	SeNa
Process	Muscle			
Fresh	PM	0.20 ±0.03	0.16 ±0.06	0.17 ±0.01
	GM	0.19 ±0.01	0.16 ±0.02	0.15 ±0.01
Aged	PM	0.22 ±0.02	0.17 ±0.03	0.18 ±0.01
	GM	0.19 ±0.01	0.18 ±0.01	0.20 ±0.02
Main effects				P
Diets	Basal	SeMet	SeNa	
	0.20	0.17	0.17	0.16
Muscle	*Gastrocnemius*		*Pectoralis*	
	0.18		0.18	0.49
Process	Fresh		Aged	
	0.17		0.20	0.41

Table 3. Effect of organic (SeMet) and inorganic (SeNa) source of Se in a diet received two weeks prior sacrifice on the glutathione peroxidase activity (GPx), measured as nmoles/min/mg protein, in fresh and aged *Pectoralis* (PM) and *Gastrocnemius* (GM) muscle.

		Selenium Source		
		Basal	SeMet	SeNa
Process	Muscle			
Fresh	PM	6.71	7.38	8.11
		±0.84	±1.33	±0.63
	GM	6.55	7.35	5.24
		±0.32	±0.65	±0.75
Aged	PM	3.96	6.43	7.25
		±0.57	±2.00	±1.17
	GM	5.95	5.13	5.10
		±1.14	±1.03	±0.14
Main effects				P
Diets	Basal	SeMet	SeNa	
	5.80b	6.58a	6.437a	0.05
Muscle	*Gastrocnemius*		*Pectoralis*	
	5.90		6.65	0.07
Process	Fresh		Aged	
	6.90a		5.64b	0.01

Table 4. Effect of organic (SeMet) and inorganic (SeNa) Se supplementation in a diet received two weeks prior sacrifice on drip loss at 24 hours *post mortem* in the *Pectoralis* and *Gastrocnemius* muscles.

	Selenium Source			
Muscle	Basal	SeMet	SeNa	
GM	2.09	1.31	1.21	
	±0.25	±0.12	±0.22	
PM	1.73	1.31	1.22	
	±0.25	±0.18	±0.10	
Main effects				P
Diet	Basal	SeMet	SeNa	
	1.91a	1.38b	1.22b	0.01
Muscle	GM	PM		
	1.46	1.54		0.63

IV. CONCLUSION

Selenium supplementation as organic or inorganic forms decreased the drip loss in both muscles studied, *Gastrocnemius* and *Pectoralis* and increased GPx activity. However, no effect was observed for lipid and protein oxidation. The muscle type affected the response only in TBARS. Ageing process in vacuum package decreased the GPx activity. No effects of source were observed in anyone of the parameters measured.

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EFFECT OF MILD IRRADIATION DOSES ON QUALITY ATTRIBUTES OF MEAT TRIMMINGS FOR PRODUCTION OF PATTIES

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The objectives of the present work were to assess the use of moderate doses of irradiation (2 and 5 kGy) as a tool to reduce the microbial load without altering the commercial quality of bovine trimmings and of patties made of irradiated trimmings. Independent series of experiments covered microbiological indicators during 30 days of storage (coliforms, *Pseudomonas* spp. and mesophilic aerobics counts), physicochemical indicators (pH, color and tiobarbituric acid assay) and sensory changes during a 180 day storage period at freezing temperatures. Physicochemical changes observed were mainly the development of slightly higher off flavors in patties due to irradiation at the highest dose assayed (5 kGy). Using moderate gamma irradiation doses of 2 kGy, reductions of at least 1.5log CFU/g of mesophilic aerobic counts were achieved as well as counts of *Pseudomonas* spp. and coliform below detection level during the whole storage period. It seems reasonable to suppose that irradiation can be successfully employed to reduce altering microflora of trimmings while producing minimal sensory changes in patties made from irradiated trimmings.

I. INTRODUCTION

The physicochemical composition of meat provides the conditions for microorganism growth and the precursor compounds for the development of aromas and flavors, desirable or undesirable. Physicochemical parameters such as pH, color and lipid oxidation are gross indicators of meat quality, as well as sensory attributes (Lorenz et al. [1], Shahidi [2], Brewer [3]). Bovine trimmings are the main ingredient of patties produced worldwide. Since this meat results from mechanical disruption of several muscles, assessing microbiological markers becomes mandatory and it is used as a trade standard. In particular, for mechanically recovered meat, ground meat and meat mixes with spices, all shall comply with specifications of microbiological markers such as: total mesophilic counts, *Escherichia coli* counts and absence of pathogenic strains. Irradiation may be applied to packaged products extending their shelf-life and improving their microbiological safety with minimal effects on their chemical composition, nutritional and sensory properties. The effects of ionizing radiation on living organisms depends on the total dose absorbed, the rate of absorption, and the environmental conditions (mainly temperature and gas atmosphere) during irradiation (Brewer [3]). Food spoilage microorganisms are generally very susceptible to irradiation; a 90% reduction of most vegetative cells can be accomplished with 1.0 – 1.5 kGy (ICGFI, 1996; Olson, 1998a; Olson, 1998b; Thayer et al. 1995). Irradiation followed to refrigeration was found to be a very effective way to reduce initial microbial loads in ground beef, improve safety and extend shelf life without affecting sensory quality.

When biological materials are exposed to irradiation energy, the atoms or molecules eject electrons producing ions and free radicals. The electron-deficient carbon-carbon double bonds of unsaturated fatty acids and carbonyl groups (fatty acids and amino acids) are particularly susceptible to free radical attack. This is why, even at low dose, irradiation can initiate or promote lipid oxidation resulting in undesirable off-odors and flavors (Lescano et al. [4], Thakur et al. [5]).

Irradiation produces a variety of color changes which are related to the myoglobin concentration, the state of myoglobin prior to irradiation, pH, water activity, presence of reducing equivalents, temperature and gas atmosphere during irradiation. It should be mentioned that, a maximum of 4.5 kGy is permitted for uncooked, chilled red meat and 7 kGy is permitted for uncooked, frozen meat (FDA, 2012). The objectives of the present work were to assess the use of moderate doses of irradiation as a tool to reduce microbial load without altering the commercial quality of bovine trimmings and of patties made of irradiated trimmings, covering: microbiological indicators during 30 days of storage (coliforms, pseudomonas and mesophilic aerobics counts), and physicochemical indicators (pH, color and oxidation) and sensory changes during a 180 day storage period at freezing temperatures.

II. MATERIALS AND METHODS

Commercial quality was evaluated on irradiated trimmings (at frozen or chilled temperatures of (-18±2) and (2±2)ºC, respectively) and on patties made of irradiated trimmings, all stored at (-18±2)ºC after irradiation.

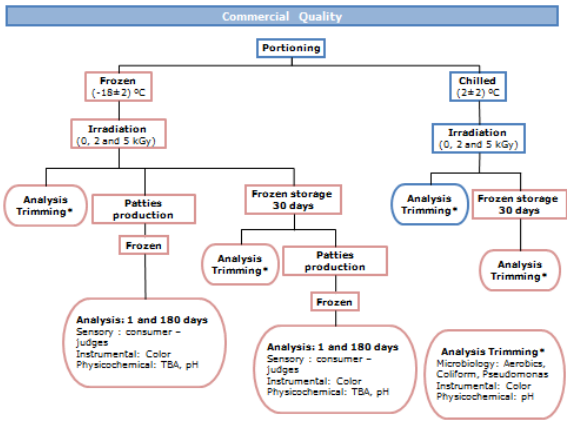

Figure 1. Schematic procedure of sample treatments for commercial quality study.

Beef trimmings (20% fat) were obtained from a local slaughter house. Fresh trimmings (0 days age) from grass-fed animals were divided at deboning room in 2.5 kg and 200g portions for patty production and experiments with trimmings alone, respectively. Trimmings were irradiated at target dose of 2 kGy (D1) and 5 kGy (D2). By used dose-meters real range doses were [2.2 to 3.1] and [4.6 to 5.5] kGy for 2.5kg bags and [2.2 to 2.4] and [4.6 to 5.1] kGy for 200g bags. Non-irradiated (NI, 0 kGy) samples were used as control. Samples were irradiated after 24h of storage, under frozen or chilled conditions in LATU irradiation unit. Irradiated and non-irradiated trimmings bags were stored at (2±2) °C for 24 h before being analyzed. Samples destined to evaluation after 30 days were stored at (-18±2) °C. Irradiation was carried out at room temperature under a Cobalt-60 radiation source. **Production of patties.** For each irradiation dose (NI, D1 and D2) 10kg batches of frozen beef trimmings were fine ground through a 3 mm hole plate. Then ground beef was mixed for 2 minutes with salt (0.75 %), citric acid (0.2 %) and ascorbic acid (0.7 %). Packaging was carried out 24 hours after preparation using. They were immediately placed in cardboard boxes and stored at (-18±2) °C. The same process was repeated with trimmings aged an extra 30 days and stored at (-18±2) ºC during this period.

Analysis. Microbiological (*Total Aerobic* counts, *Coliform* enumerations, *Pseudomonas* spp), pH, and instrumental color analyses were carried out on frozen and chilled trimmings irradiated at NI, D1 or D2 on samples stored 1 and 30 days. Instrumental color, TBA and sensory analysis (trained panel and consumer evaluation) were carried out on patties manufactured from trimmings irradiated at NI, D1 or D2 immediately after elaboration and after 180d of frozen storage.

Statistical analysis. Analyses of Variance (ANOVA) were performed using the statistical software Infostat/L version 2013 and XLSTAT Version 2011. A post-hoc Tukey test was used to obtain paired comparisons among sample means. Level of significance was set to $P < 0.05$.

III. RESULTS AND DISCUSSION

Table 1 shows that for D1 irradiation dose, total aerobic counts of 3log (cfu/g) in trimmings were reduced by at least 1.5log orders. This result agree with previous findings of Chouliara *et al*. [6] who reported that frozen trimmings irradiated at 2 kGy under Co-60 source reduced total aerobic counts of 6.1 log (cfu/g) in 1.6log orders. Karadag *et al.* [7] found that for *Pseudomonas* spp, the same dose (2.2 kGy) caused a reduction of at least 1log order for an initial load of nearly 2log (cfu/g). In this study *Pseudomonas* spp. and coliforms counts were reduced up to the detection level.

Table 1. Mean values of microbiological counts on beef trimmings.

			Total Aerobic log(cfu/g)	Pseudomonas log(cfu/g)	Coliforms (NMP/g)
NI	Chilled	0d	2,68[a]	1,82[a]	<3
		30d	2,54[a]	1,18[b]	<3
	Frozen	0d	2,68[a]	2,03[a]	<3
		30d	2,72[a]	1,11[b]	<3
D1	Chilled	0d	0.45[b]	<1	<3
		30d	<1	<1	<3
	Frozen	0d	<1	<1	<3
		30d	<1	<1	<3
D2	Chilled	0d	<1	<1	<3
		30d	<1	<1	<3
	Frozen	0d	<1	<1	<3
		30d	<1	<1	<3

Counts were obtained from beef trimmings irradiated at Ni (0kGy), D1 (2kGy) and D2 (5kGy) under chilling (2±2ºC) or freezing (-18±2ºC) temperatures (n = 6). Non irradiated samples were used as controls. Within rows, means values with common letters (a, b) do not significantly differ (P>0.05).

The temperature of the different irradiation treatments (chilling vs freezing) did not significantly affect the results. Overall, irradiation at D1 dose had a significant improvement on hygienic quality which was practically similar to that caused by an irradiation dose of 5 kGy. For both irradiation doses, reductions obtained on day 0 after treatment were preserved during a 30 day storage period at freezing temperatures. Most spoilage microorganisms in meat are gram negative with *Pseudomonas* spp. predominant for aerobic storage at chilling temperatures.

The pH results of all samples tested varied between 5.56 and 5.68. pH values did not show significant differences (P>0.05) within the different treatments performed: irradiation dose, temperature and storage time. These results agree with those reported by Fu et al. [8] and Brewer [3].

TBA values of patties made of trimmings irradiated at both D1 and D2, and stored 0 and 30 days did not significantly differ (P >0.05; data not shown). Absence of differences could be due to the fact that, trimmings used was from grass-fed animals. Brito et al. [9] reported that trimmings from grass-fed animals, usually contains high levels of vitamin E that might help to prevent increases in fat oxidation due to irradiation processing. Furthermore, the ascorbic acid used in patties formulation at 0.7%, could be responsible of preventing oxidation increases. Ahn et. al [10] did not report significant differences on TBA values of ground beef with ascorbic acid at 0.1% irradiated at 2.5 kGy along 7 days, while control samples (without ascorbic acid) did show an increase.

Regarding instrumental color measures on beef trimmings, samples showed great variability considering that they consisted of a mix of pieces from different muscles. NI samples presented higher a* and b* values than irradiated ones, but there was no significant difference between D1 and D2 samples. Visual evaluation also suggested that irradiated samples were less red. Nanke et. al [11] reported, as well, lower a* and b* values in beef irradiated with doses ranging from 1.5 to 10.5 kGy compared to control samples non-irradiated. According to Lycometros [12], changing from oxymyoglobin to metmyoglobin at the surface could explain the lower a* values on the exterior surface of irradiated beef. a* and b* values were significantly lower in chilled samples than in frozen ones. For non-irradiated samples, this difference was not significant. In agreement with Brewer [3], this suggests that chilled irradiated samples experimented more changes related to non-irradiated ones, than frozen irradiated samples. Reducing the temperature during irradiation process reduces the effects on odor, flavor and color. Temperature may determine which radiolytic products are generated and in what ratios, affecting also food matrix viscosity and water mobility. Ion and free radical dispersion are lower when free water is in the frozen state. Also, free radicals tend to recombine when water in foods is frozen because they are less likely to diffuse and react with other food components (Taub et al. [13]) Storage time did not affect a* and b* values. Lightness (L*) was not affected by irradiation dose or temperature, but it did decrease with storage time, being lower on samples stored for 30 days after irradiation. The same behavior was observed for the saturation index, decreasing with storage.

Instrumental color on beef trimmings and patties are not comparable in this study, since color measures on beef trimmings were made exclusively in the muscle (excluding the fat) and patties were made by grinding and mixing these two components; thus, differences explained by the contribution of fat to final color of patties were expected.

Irradiation dose did not significantly affect L*, a* and b* values on beef patties (p>0.05). These results agree with those reported by Murano et al. [14], who found that the only differences between non irradiated and irradiated (2 kGy) beef patties were due to packaging atmosphere. All color scores were significantly higher in patties made of trimmings aged for 30 days related to patties made with fresh trimmings. Values of L*, a* and saturation indexes decreased significantly during the 180 days of storage while b* values remained unchanged.

Off-flavor intensity of patties was the only parameter where judges detected differences caused when increasing irradiation dose. Table 3 shows that off flavor intensity scores of patties made of aged irradiated trimmings did not differ (p>0.05) from patties made of fresh irradiated trimmings. Patties made of trimmings irradiated at D2 significantly differed from patties made of non-irradiated trimmings for both fresh and aged ones. Nevertheless, values obtained for off flavor were all below 2 in a 0 to 10 scale and they experienced no changes during the 180d storage period at freezing temperature. Giroux et al. [15] with the use of a trained panel, concluded that there was no significant difference in odor and taste between irradiated (4 kGy) and non-irradiated ground beef patties (23% fat) during 7 days of storage at 4°C. Fan, *et al*. (2004) performed a study evaluating

frozen ground beef patties (15% fat) irradiated and non-irradiated at doses of 1.35 and 3 kGy. Irradiation had no significant impact on the ratings of any of the sensory attributes either at 0 day or after 6 months of storage.

Table 2 Odd flavor intensity means rates for patties

	Off flavor intensity (0 to 10)			
	Patties made of Fresh trimmings(0d)		Patties made of Aged trimmings(30d)	
Dose	1d	180d	1d	180d
Ni	0.3 ^{a,x}	1.5 ^{a,y}	0.1 ^{a,x}	0.2 ^{a,x}
D1	0.7 ^{a,b,x}	1.3 ^{a,x}	0.7 ^{a,b,x}	0.7 ^{a,b,x}
D2	1.4 ^{a,b,x}	1.8 ^{a,x}	1.4^{b,x}	1.7 ^{a,b,x}

Patties made of fresh and aged trimmings. Within columns, treatment means with common letters (a-b) are not significantly different (P>0.05). Within row treatment means with common letters (x-y) are not significantly different (P>0.05).

The other attributes assayed showed no significant changes due to irradiation treatment or storage time of trimmings and patties. Their values, in a 0 to 10 continuous scale ranged as follows: odor intensity [5 to 6]; off odor intensity [0.3 to 1.4]; initial tenderness [4.2 to 5.9]; final tenderness [4.7 to 5.8]; initial juiciness [4.2 to 5.7]; final juiciness [3.9 to 5.7] and flavor intensity [5.0 to 6.2].

Consumer acceptability is one of the tools used to predict market product success and the likelihood of rejection of consumers if this is the case. Table 3 shows that irradiated patties did not differ from non-irradiated ones (P>0.05) for both 0 and 180 d storage times. Irradiated patties 180d old showed less acceptability (P<0.05) than 1d old patties though these values were barely minor than the original ones.

Table 3 Acceptability means values for patties

	Acceptability			
	Fresh trimming (0d		30 days aged trimming	
Dos	1 d	180 d	1d	180d
Ni	6.6 ^{a,x,y}	6.0 ^{a,y}	7.0 ^{a,x}	6.7 ^{a,x,}
D1	6.6 ^{a,x}	5.8 ^{a,y}	6.1 ^{b,x,}	6.2 ^{a,x,}
D2	6.2 ^{a,x,y}	5.5 ^{a,y}	6.0 ^{b,x,}	6.5 ^{a,x}

Patties made of fresh and aged trimmings. Within columns, treatment means with common letters (a,b) are not significantly different (P>0.05).ns, Within row, treatment means with common letters (x,y) are not significantly different (P>0.05).ns

Results from judges and consumers indicate that there are no sensory differences between patties produced from fresh or 30d stored irradiated trimmings at 2 or 5 kGy, suggesting that it is possible to commercialize irradiated trimmings as such to markets that require 30 days for transport and beef patties for up to a 180 d period (p>0.05) taking into account only sensory results.

IV. CONCLUSION

The results of the indicators studied for commercial quality (pH, color, TBA, sensory analysis, *Pseudomonas* spp., coliforms and mesophilic counts) implies that irradiation may provide an alternative capable of decreasing the microbial load of meat products while slightly altering its physicochemical and sensory properties of trimmings and patties.

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