EFFECT OF FROZEN STORAGE DURATION ON LAMB QUALITY THROUGHOUT DISPLAY

Monge, P., Muela, E*, Sañudo, C. and Beltrán, J.A.

Department of Animal Production and Food Science, University of Zaragoza, Miguel Servet 177, 50013, Zaragoza, Spain

Abstract – The effect of frozen storage (0, 1, 9, 15 or 21 months) and display (0, 3 or 6 days) duration on lamb quality was evaluated. Thirty two lamb carcasses of Rasa Aragonesa breed were randomly distributed in four batches (corresponding to 1 to 21 months of frozen storage) of eight carcasses each. pH, lipid oxidation, colour, instrumental texture and water losses were assessed in the muscle *Longissimus dorsi.* Analyses were performed in fresh and thereafter frozen-thawed meat, both being displayed 0, 3 and 6 days. pH decreased and lipid oxidation increased as storage (freezing or display) duration increased. In general, redness decreased and yellowness increased throughout frozen storage and/or display duration. Thawed meat was more tender than fresh meat when it was aged enough after thawing. Frozen storage and display duration increased the amount of exudate. In conclusion, meat quality was affected by storage, and the longest frozen storage would be considered as acceptable only if meat is not displayed.

Key Words – Lipid oxidation, pH, Texture.

- INTRODUCTION

The most important limitation for the lamb market is that ovine species has a period of sexual inactivity (anoestrus). In Spanish latitude, it goes from late winter to early spring. This fact is responsible of punctual increases in the price of lamb because of its lower availability in the market in certain periods. Frozen meat could help to stabilize markets [1], providing to the retailers a greater flexibility, and allowing to the consumer to choose when to buy and consume lamb [2]. In addition, freezing is a widely accepted method for the preservation of meat for relatively long periods of time, and it has been applied for several years to maintain its quality during storage, distribution and marketing, while retaining properties similar to that of the fresh meat [3]. Although freezing fresh meat provides advantages, frozen meat has a stigma because is perceived to reduce meat quality [4], even though this perception is not clearly supported by scientific evidences [2].

Several authors have suggested that one of the factors that could affect the quality of the meat after thawing is the duration of frozen storage, being its quality gradually deteriorated over time. The effect of freezing on lamb characteristics has not been extensively studied and, therefore, it would be an important tool from the commercial standpoint.

The aim of this study was to evaluate the effects of frozen storage duration on the instrumental measurements of quality of commercial light lamb while assessing the quality of thawed and fresh meat throughout display in chilled conditions.

- MATERIALS AND METHODS

The study used 32 lamb carcasses of Rasa Aragonesa, a rustic medium size breed that is reared for meat purpose in Aragón, Spain. Animals were reared intensively and fed concentrate and cereal straw *ad libitum*, until they reached a live slaughter weight of 23-25 kg and an age no older than 90 days. Animals were slaughtered at an EU-licensed abattoir following standard protocols. All the carcasses were randomly selected among all the commercial lambs

slaughtered on the corresponding slaughter date according to storage duration. Afterwards, carcasses were carried in refrigeration (≥ 15min. from slaughter) to the facilities of Pastores Group. The lamb carcasses were divided in 4 batches, and each batch was composed of eight carcasses randomly selected (cold carcass weight: 11-13 kg). Carcasses were stored in refrigeration (0-2 ºC, 85-90% relative humidity (RH), 0-0.2 m/s air speed) during 24 h. Then, carcasses were quartered and muscle *Longissimus dorsi* (LD) was obtained from the left side of the carcass and sliced according to the analyses requirements. Samples that had to be frozen were vacuum-packaged individually and frozen in a freezing tunnel (-40 ºC, 96% RH, 1-2 m/s, 15 min.). Afterwards, samples were stored into cardboard boxes at -18 ºC in meat quality laboratory of the Veterinary Faculty of Zaragoza. Samples were thawed at refrigeration after 1, 9, 15 and/or 21 months, correspondently. Then, samples were packed on trays with a modified atmosphere (MAP) of 70:30 O_2:CO_2 (one tray for each display duration and for each animal) and stored during 0, 3 and 6 days in darkness at 0-4 ºC until analysis. Fresh samples followed the same process but were immediately MAP and displayed.

Thus, each analysis was assessed in the same fresh and thawed meat at 0, 3 and 6 days of display. A portable CRISSON 5053T pH-meter equipped with a penetrating electrode was used to measure the pH. The colour was assessed after 15 min of blooming in the cranial portion of the LD. Final values were the average of three measurements. A portable Minolta CR-200B reflectance spectrophotometer with a standard illuminate D65 and a 10º standard observer was used. Following the CIE-L*a*b* methodology. Lipid oxidation was performed using the thiobarbituric acid-reactive substances (TBARS) method [5] and results were expressed as mg malonaldehyde (MDA)/kg meat. Texture was determined with a Texturometer Instron series 4301 with a Warner-Braztler (WB) device in cooked meat and the reference variable was shear force (WBSF), expressed in kg. Samples were heated in vacuum-sealed plastic bags in a pre-heated water bath (80 ºC) until the meat internal temperature reached 70 ºC. Instrumental texture assay requires muscle to be cut in parallelepipeds (1cm^2-cross section) parallel to the direction of the muscle fiber longitudinal axis. There were calculated the total water losses (TL) as the addition of thawing, displaying and cooking losses on texture samples. TL were calculated as follows: % TL= [(weight before freezing - weight after cooking)/weight before freezing] x 100).

The effects of frozen storage and display duration (or their possible interactions) on meat quality were analyzed using SPSS 19.0 for Windows XP. Descriptive statistical analysis (mean and standard deviation) were computed for each parameter. To assess the statistical significance of the effects and any interactions, a general linear model (GLM) was used. When the main effect was significant, Duncan's Multiple Range Test was used, with the level for statistical significance set at $p \leq 0.05$.

Fresh treatment was computed as the average of the entire fresh samples of the frozen stored treatments.

- RESULTS AND DISCUSSION

There were significant interactions between frozen storage and display duration (FSD and D, respectively) for the analyzed variables (data not shown). Then, data were analyzed considering FSD for each D and the contrary.

Table 1 shows the results of pH analysis for the five frozen storage and the three display duration studied.

Table 1 Frozen storage and display duration effects on pH. Mean and standard deviation

	0 days	3 days	6 days	*Sig.*
F	5.71 ± 0.05^{aB}	5.63 ± 0.07^{bA}	5.64 ± 0.05^{bA}	***

1m	5.60 ± 0.04^{aC}	5.54 ± 0.02^{bB}	5.55 ± 0.02^{bB}	***
9m	5.77 ± 0.06^{aA}	5.53 ± 0.03^{bBC}	5.55 ± 0.04^{bB}	***
15m	5.47 ± 0.05^{aE}	5.37 ± 0.04^{bD}	5.34 ± 0.04^{bD}	***
21m	5.53 ± 0.04^{aD}	5.48 ± 0.04^{bC}	5.53 ± 0.043^{aC}	*
Sig.	***	***	***	

^{a,b,c} Different superscripts in a same row indicate significant differences among display durations; ^{A,B,C,D,E} Different superscripts in a same column indicate significant differences among frozen storage durations; F: fresh meat; m: month. *: $p\leq0.05$; ***: $p\leq0.001$.

In general, pH was greater for fresh than for the frozen/thawed meat at any display. pH decreased significantly as storage duration increased. The slight decrease in pH due to freezing and thawing could be due to the loss of minerals and small proteins compounds as exudates, which change the ionic balance in meat, and this resulted in a lower pH [6]. Nevertheless, all values were under 5.8, considered as a normal value in lamb [7].

TBARS value increased significantly throughout frozen and/or display duration (Table 2). TBARS values were greater in thawed than in fresh meat, although without statistical differences between fresh and 1 month FSD, in agreement with [8] and [9]. Long frozen storage is prone to produce greater TBARS values, but the current results did not confirm this hypothesis. A possible explanation could be that MDA could make complexes, in case of advanced lipid oxidation, with amino groups or with other carbonyls forming a bound form, and this fact could cause problems related to the quantitative recovery of MDA with TBARS tests [10]. Besides, other authors have suggested that MDA is not stable for a long period of time. The reason is that oxidation of MDA yields organic alcohols and acids, which are not determinate by the test. Both facts could explain the observed results.

Table 2 Frozen storage and display duration effects on lipid oxidation. Mean and standard deviation

	0 days	3 days	6 days	Sig.
F	0.064 ± 0.01^{cC}	0.182 ± 0.14^{abD}	0.368 ± 0.02^{aC}	***
1m	0.065 ± 0.01^{bC}	0.408 ± 0.22^{bD}	0.875 ± 0.34^{aC}	*
9m	0.154 ± 0.03^{cB}	1.792 ± 0.76^{bB}	3.653 ± 0.73^{aA}	***
15m	0.250 ± 0.04^{cA}	2.221 ± 0.94^{bA}	3.696 ± 0.81^{aA}	***
21m	0.167 ± 0.02^{cB}	0.921 ± 0.18^{bC}	1.381 ± 0.50^{aB}	***
Sig.	***	***	***	

^{a,b,c} Different superscripts in a same row indicate significant differences among display durations; ^{A,B,C,D} Different superscripts in a same column indicate significant differences among frozen storage durations; *: $p\leq0.05$; ***: $p\leq 0.001$.

Table 3 shows the results of colour for frozen storage and display duration effects. Luminosity was the colour parameter less variable during storage, since it was only affected by display in fresh meat (increased after 0 days of display) and it showed significant differences among frozen storage duration at 3 and 6 days of display, without a clear tendency. However, both redness (a*) and yellowness (b*) were highly significant affected by storage (FSD and D). Fresh meat showed the higher a* and the lower b* at any D. It was showed an a* increase and a b* decrease throughout display. These results are in agreement with [1], [8], and [11]. The a* decrease and the b* increase have frequently been associated with the gradual discoloration of meat, from bright red colour to brownish, resulted from the accumulation of metmyoglobin in meat surface during storage [11], [12]. Also, b* increase could be related to lipid oxidation.

Table 3 Frozen storage and display duration effects on colour variables. Mean and standard deviation

	0 days	3 days	6 days	*Sig.*
Luminosity				
F	45.20±2.46^{b}	49.04±1.43^{aA}	48.32±1.99^{aAB}	***
1m	45.77±1.38	47.74±1.46^{AB}	46.38±2.17^{BC}	ns
9m	45.77±2.18	48.00±2.90^{AB}	48.88±3.66^{A}	ns
15m	45.36±2.80	46.70±2.87^{B}	45.57±2.56^{C}	ns
21m	44.27±1.08	45.87±2.08^{B}	46.27±2.86^{BC}	ns
Sig.	ns	***	***	
Redness				
F	21.66±1.20^{aA}	19.88±1.18^{bA}	18.82±1.40^{cA}	***
1m	20.83±0.98^{aA}	17.75±1.11^{bB}	16.17±1.11^{cB}	***
9m	19.04±1.27^{aB}	12.97±2.64^{bD}	11.40±1.06^{bD}	***
15m	19.29±1.50^{aB}	13.89±1.64^{bD}	11.98±0.66^{cD}	***
21m	18.42±1.15^{aB}	15.96±1.29^{bC}	13.50±2.50^{cC}	***
Sig.	***	***	***	
Yellowness				
F	4.53±0.74^{bD}	8.44±0.77^{aC}	8.08±0.64^{aC}	***
1m	6.22±0.57^{bC}	12.52±0.73^{aA}	12.17±0.96^{aB}	***
9m	7.04±0.57^{bB}	10.73±2.12^{aB}	12.13±0.93^{aB}	***
15m	7.99±1.43^{bA}	13.00±1.13^{aA}	13.55±1.23^{aA}	***
21m	7.14±0.56^{cB}	12.39±0.72^{bA}	13.18±0.89^{aA}	***
Sig.	***	***	***	

^{a,b,c} Different superscripts in a same row indicate significant differences among display durations; ^{A,B,C,D} Different superscripts in a same column indicate significant differences among frozen storage durations; F: fresh meat; m: month; ns: no signifficant; ***: p≤0.001.

Table 4 shows the results of shear force and total losses for the studied effects. Frozen storage and display duration had a significant effect on WBSF. In the literature, it is mostly reported that tenderness of meat increases with freezing and thawing, showing lower values of peak force. As water is released from meat while thawing, the muscle fibers become less hydrated, the meat increases its toughness due to fiber shrinkage. Besides, it is increased the density of fibers per surface area, thus it increases the force necessary to shear through the fibers [6]. However, this increase in toughness after thawing is quickly offset throughout display, becoming thawed meat even more tender than fresh meat. Some authors have found that if meat was aged after thawing, the shear force would be lower than meat aged prior to freezing [13], in agreement with the current results.

Total losses were significantly affected by frozen and display duration (Table 4). The amount of exudate was lower in fresh (which would be related with the absence of thawing losses) and in not displayed meat. The current results are in agreement with the general belief of a progressive decrease in water holding capacity during frozen storage [6] [9] due to fiber shrinkage.

Table 4 Frozen storage and display duration effects on shear force and total losses. Mean and standard deviation

	0 days	3 days	6 days	*Sig.*
Warner-Bratzler Shear Force				
F	7.33±1.23^{B}	6.99±1.57^{AB}	6.62±1.51^{A}	ns
1m	7.84±1.16^{aB}	5.78±1.36^{bB}	3.37±0.89^{cC}	***
9m	8.34±2.13^{aAB}	6.38±2.00^{abB}	4.55±1.70^{bBC}	***
15m	7.77±1.35^{aB}	5.80±1.45^{bB}	5.21±2.07^{bB}	*
21m	9.27±1.35^{aA}	8.02±0.94^{bA}	4.13±1.00^{cBC}	***
Sig.	*	*	***	
Total losses				
F	9.21±1.80^{cC}	13.12±2.93^{bC}	16.56±3.80^{aC}	***
1m	17.96±2.05^{bB}	19.48±1.97^{abB}	20.90±3.27^{aB}	t
9m	20.96±2.22^{bA}	24.66±3.93^{abA}	27.41±5.94^{aA}	*
15m	18.03±2.39^{bB}	24.56±3.75^{aA}	20.01±2.38^{bBC}	***
21m	18.30±2.30^{cB}	22.72±3.19^{bA}	26.57±2.58^{aA}	***
Sig.	***	***	***	

[a,b,c] Values with different superscripts in a column indicate significant differences between display; [A,,B,C,D] Values with different superscripts in a column indicate significant differences between frozen storage duration; Total losses: thawing, displaying and cooking losses.

- CONCLUSIONS

In the current study, frozen storage up to 21 months extensively modified meat characteristics when instrumental measurements of quality were analyzed. The longest frozen storage duration reduced quality, especially when the meat was displayed. The quality of thawed meat would be unacceptable after 3 days of display.

ACKNOWLEDGEMENTS

This work has been made possible by financial help of a CDTI 2009/0583 project. Authors want to thank to Pastores Group for the animal material and for the use of their facilities. We also thank the Animal Production personal at the Faculty of Veterinary for their technical assistance.

REFERENCES

- Hansen, E., Juncher, D., Henckel, P., Karlsson, A., Bertelsen, G. & Skibsted, L. H. (2004). Oxidative stability of chilled pork chops following long term freeze storage. Meat Science, 68: 479-484.
- Pietrasik, Z. & Janz, J. A. M. (2009). Influence of freezing and thawing on the hydration characteristics, quality, and consumer acceptance of whole muscle beef injected with solutions of salt and phosphate. Meat Science 81: 523-532.
- Smith, G. C., Spaeth, C. W., Carpenter, Z. L., King, G. T. & Hoke, K. E. (1968). The effects of freezing, frozen storage conditions, and degree of doneness on lamb palatability characteristics. Journal of Food Science 33: 19-24.
- Lagerstedt, A., Enfält, L., Johansson, L. & Lundström, K. (2008). Effect of freezing on sensory quality, shear force and water loss in beef M. Longissimus dorsi. Meat Science 80: 457-461.
- Pfalzgraf, A., Frigg, M. & Steinhart, H. (1995). Alpha-tocopherol contents and lipid oxidation in pork muscle and adipose tissue during storage. Journal of Agriculture and Food Chemistry 43: 1339-1342.
- Leygonie, C., Britz, T. J. & Hoffman, L. C. (2012). Meat quality comparison between fresh and frozen/thawed ostrich M. iliofibularis. Meat Science 91: 364-368.
- Devine, C. E., Graafhuis, P. H., Muir, P. D. & Chrystall, B. B. (1993). The effect of growth rate and ultimate pH on meat quality of lambs. Meat Science 35: 63-77.
- Stika, J. F., Xiong, Y. L., Suman, S. P., Blanchard, S. P. & Mood, W. G. (2007). Frozen storage stability of beef steaks made from mature cows. Meat Science 77: 562-569.
- Muela, E., Sañudo, C., Campo, M. M., Medel, I., & Beltrán J. A. (2010). Effect of freezing method and frozen duration on instrumental quality of lamb throughout display. Meat Science 84: 662-669.
- Fernández, J., Pérez-Álvarez, J. A. & Fernández-Lope, J. A. (1997). Thiobarbituric acid test for monitoring lipid oxidation in meat. Food Chemistry 59: 345-353.
- Zhu, L. G. & Brewer, S. (1998). Discoloration of fresh pork as related to muscle and display conditions. Journal of Food Science, 63: 763-767.
- Insausti, K., Beriain, M. J., Purroy, A., Alberti, P., Gorraiz, C. & Alzueta, M. J. (2001). Shelf life of beef from local Spanish cattle breeds stored under modified atmosphere. Meat Science 57: 273-281.
- Crouse, J. D. & Koohmaraie, M. (1990). Effect of freezing of beef on subsequent postmortem ageing and shear force. Journal of Animal Science 55: 573-574.