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Effect of freezing method and frozen storage duration on instrumental quality of lamb throughout display

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ABSTRACT

This study evaluated the effect of freezing method (FM) (air blast freezer, freezing tunnel, or nitrogen chamber) and frozen storage duration (FSD) (1, 3, or 6 months) on the instrumental measurements of quality of thawed lamb, aged for a total of 72 h, throughout a 10-d display period, compared to the quality of fresh meat. pH, colour, lipid oxidation, thawing, and cooking losses in *Longissimus thoracis* and *lumborum* muscle, were determined following standard methods. FM affected yellowness, FSD redness and thawing losses, and both affected oxidation (increased as freezing rate decreased and/or as storage duration increased). When compared with fresh meat, the main differences appeared on oxidation (where a significant interaction between treatment (3FM × 3FSD + fresh meat) with display duration was detected), and on total losses (thaw + cook losses). Oxidation was lower in fresh meat, but values were not significantly different from those stored frozen for 1 month. Fresh meat had smaller total losses than did thawed meat, but losses were not significantly different from meat frozen in the freezing tunnel and stored frozen for 1 month. Display duration had a greater effect on instrumental quality parameters than did FM or FSD. pH, b^*, and oxidation increased, and L^* and a^* decreased with an increase in the number of days on display. In conclusion, neither freezing method nor frozen storage up to 6 months influenced extensively the properties of lamb when instrumental measurements of quality were measured in meat that had been displayed for 1 d after thawing. The small deterioration shown in this study should not give consumers concerns about frozen meat.

1. Introduction

In Mediterranean countries, sheep breeding is much larger than it is in most of the other countries in the northern hemisphere (Sañudo, Sanchez, & Alfonso, 1998). Thus, in 2003, Spain, France, Italy, and Greece provided 45% of the ovine heads and 48% of the sheep meat produced within the European Union (EU-15). In addition, those countries represented more than 55% of the sheep and goat meat consumption in 2003 (FAOSTAT, www.fao.org). With the exception of those in tropical regions, small ruminants enter a period of sexual inactivity (anoestrous) that can last for several months, typically, from late winter to early spring (Chemineau et al., 1995). This fact can lead to an increase in the price of lamb meat because of its lower availability in the markets in certain periods. An increase in the production of frozen meat would help to stabilize markets and provide retailers with a greater flexibility (Pietrasik & Janz, 2009; Wheeler, Miller, Savell, & Cross, 1990). In addition, freezing is widely used because it can increase the long-term shelf life of meat (Campañone, Roche, Salvadori, & Mascheroni, 2006), while retaining properties similar to those of fresh meat (Smith, Spaeth, Carpenter, King, & Hoke, 1968).

Despite the advantages of freezing fresh meat, frozen meat has a stigma because freezing is perceived to reduce meat quality (Lagerstedt, Enfält, Johansson, & Lundström, 2008), even though this perception is not clearly supported by scientific evidences (Pietrasik & Janz, 2009). The quality of frozen meat depends on the specific procedures used to freeze, store, and thaw the meat (Jasper & Placzek, 1980). Freezing rate can affect the quality of meat (Berry, 1990; Smith et al., 1968; Uttaro & Aalhus, 2007) through the structural changes that occur during freezing because of the formation of ice crystals (i.e., nucleation). Nucleation is temperature-dependent: a fast freezing rate causes the formation of extra- and intra-cellular ice nuclei (Ballin & Lametsch, 2008). In addition, the shape and size of ice nuclei depends on freezing rate. For instance, a conventional freezing (−20 °C) leads to the formation of irregular, and relatively large ice crystals (Zhu, Bail, Ramaswarny, & Chapleau, 2004), which increases the structural damage to the meat (Devine, Graham, Lovatt, & Chrystall, 1995).

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When meat thaws, ice crystals can cause physical damage to the microstructures in meat, and thawing plays a major role in the processing of frozen meat, because the amount of exudates generated in the thawing process is one of the measures of the quality of frozen meat (Añón & Calvelo, 1980). In addition, the rate of thawing may influence the amount of water losses (Lind, Harrison, & Kropf, 1971; Uttaro & Aalhus, 2007).

The conditions in which frozen meat is stored and displayed can have significant effects on its quality (Jasper & Placzek, 1980). Duration of storage (Berry, 1990; Haenian, Mittal, & Usborne, 1989; Méndez, 1999), temperature or fluctuations on it (Berry, 1990; Moore, 1990b; Méndez, 1999), exposure to light and/or air (Bhattacharya, Hanna, & Mandigo, 1988), and packaging (Brewer & Harbers, 1991; Moore, 1990b; Méndez, 1999; Smith et al., 1968) can affect meat quality. Although frozen foods are microbiologically stable, they are prone to deterioration during storage due to chemical reactions (Akköse & Aktas, 2008), since enzymatic activity slows down, but does not cease (Devine et al., 1995; Jiménez & Carballo, 2000). The main deterioration of frozen meat, is due to the processes of lipid oxidation and protein degradation (Zhang, Farouk, Young, Wieliczko, & Podmore, 2005), muscle tissues being especially susceptible. These processes can determine the end point of the display life of frozen products (Jiménez & Carballo, 2000).

Normally, meat is aged before it is frozen (Crouse & Koohmaraie, 1990), but many commercial processes have been developed with frozen meat, which subsequently is kept in refrigerated storage between the time the meat is processed and when consumers select the meat from the retailer's display (Wanous, Olson, & Kraft, 1989). Short shelf life is a major concern in the marketing of lamb (Wulf et al., 1995) and, therefore, there is considerable interest in finding ways to increase its shelf life.

This study evaluated the effects of freezing method and frozen storage duration on the instrumental measurements of quality of commercial lamb, and assessed the effects of display duration in chilled conditions on the quality of thawed and fresh meat.

2. Materials and methods

2.1. Slaughtering, freezing, and frozen storage

The study (Fig. 1) used 100 lamb carcasses of the Rasa Aragonesa, a medium wool breed, rustic type, that is reared for meat purpose in Aragón, Spain (for more details see Sañudo (2008)). The animals were reared intensively and fed with concentrate and cereal straw *ad libitum* until they reached a fixed slaughter weight (at 90–100 d post weaning).

Animals were slaughtered in an EU-licensed abattoir following standard protocols. The slaughter date was 6, 3, or 1 month (frozen storage duration, FSD) before the quality of the meat was to be measured. For each FSD, 30 carcasses (cold carcass weight of 11–13 kg) were selected randomly among commercial lambs slaughtered on the corresponding slaughter date. Within 15 min of dressing, carcasses were transported in refrigerated conditions (0–2 °C, 85–90% relative humidity (RH), 0–0.2 m/s air speed) to the facilities of Pastores Group. At 18 h post-slaughter, the left side of the carcasses, minus the neck, shoulder, and leg, were refrigerated (0–4 °C) for 30 h more before they were cut into 12-mm-thick chops (between the 4th thoracic and 5th lumbar vertebrae), which were randomly allocated (10 carcasses for each FSD) to one of three freezing methods (FM): air blast freezer (−30 °C, 90% RH, 1–2 m/s, 30 h), freezing tunnel (−40 °C, 96% RH, 1–2 m/s, 15 min), and nitrogen chamber (−75 °C, 99% RH, 0–0.1 m/s, 15 min). Keeping the order by animal and vertebra location on the carcass side, chops were grouped based on the amount of meat required for each measure of instrumental quality. To prevent freezer burn and water losses, each group of chops was over-wrapped in a retractile oxygen-permeable plastic film (permeability 10 g/m^2 water, 200 cc/m^2/24 h O_2, and 650 cc/m^2/24 h CO_2). After being frozen using one of the FM, the chop groups were transported in cardboard boxes to the laboratory and stored at −18 °C, allocated for each FM for 6, 3, or 1 months.

To perform the instrumental measurements of quality of the meat, the chop groups were thawed in a refrigerator (2–4 °C) for 24 h inside their over-wrap plastic. Analyses were performed at 0, 1, 4, 7, and 10 d after thawing (display duration), and removal of the over-wrap plastic film. The water-holding capacity was evaluated in two chops from each group at the start of the display (after 24 h of thawing = 0 d display duration). The remaining chops were stored on polystyrene trays (one per each display duration), covered with an air-permeable plastic film (permeability 5–7 g/m^2 water, 40–50 cc/m^2/24 h O_2, and 40–50 cc/m^2/24 h CO_2), and refrigerated (2–4 °C) in the dark.

The remaining 10 carcasses were not frozen. Animals followed the same slaughter, chilling, splitting, chopping, and display procedure as described above, but instead of freezing, the samples of fresh meat were aged in a refrigerator (2–4 °C) for 72 h, which equates with the total time of ageing of thawed meat at 0 d of display (48 h previous freezing + 24 h during thawing).

2.2. Instrumental measurements

To determine instrumental characteristics of raw meat before freezing, pH and colour analyses were performed prior to chopping. A portable *CRISON 507* pH-meter equipped with a penetrating electrode was used to measure the pH of the left *Longissimus thoracis et lumborum* (LTL) at the level of the 4th thoracic vertebra. To quantify meat colour, we used a *Minolta CM 2002* reflectance spectrophotometer with a illuminant D_{65} and a 10° standard observer, following the CIE $L^*a^*b^*$ system (CIE, 1976). Results were expressed as the average of three measurements. Colour was measured at the level of the 5th lumbar vertebra on the LTL cut surface area.

After thawing (0 d of display for fresh meat), pH was measured on the 4th thoracic vertebra chop on the *Longissimus thoracis* muscle at 0, 1, 4, 7, and 10 d of display. To quantify meat colour after thawing (0 d of display for fresh meat), colour was measured on the cut surface of the 5th thoracic vertebra chop of the *Longissimus thoracis* muscle at 0, 1, 4, 7, and 10 d of display. To assess lipid oxidation, meat samples were obtained from the 6th to the 13th thoracic vertebra, and from the 3rd to the 4th lumbar vertebra of the LTL muscle, using two chops as meat sample for each display duration (0, 1, 4, 7, and 10 d). The assay was performed using the thiobarbituric acid-reactive substances method (TBARS) (Pfalzgraf, Frigg, & Steinhart, 1995). To quantify water-holding capacity, we measured the thawing losses (ThL) and cooking losses (CL) in two chops of the *Longissimus lumborum* muscle (1st and 2nd lumbar vertebra). ThL was expressed as the average proportion (% ThL = [(frozen weight − thawed weight)/frozen weight] × 100) of the two samples. To determine CL, chops were wrapped individually in aluminium foil, and cooked at 200 °C on a pre-heated, double-grill hotplate until the internal muscle temperature reached 70 °C, which was monitored by an internal thermocouple, *JENWAY 2000*. CL was expressed as the average proportion (% CL = [(thawed weight − cooked weight)/thawed weight] × 100) of the two samples, which were weighed immediately after cooking. Total losses (TL) were calculated as the addition of thawing and cooking losses. For fresh samples, as there were no thawing losses, only cooking looses were measured, being considered as total losses.