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Meat quality comparison between fresh and frozen/thawed ostrich *M. iliofibularis*

Coleen Leygonie [a,b], Trevor J. Britz [a], Louwrens C. Hoffman [b,*]

[a] Department of Food Science, University of Stellenbosch, Stellenbosch 7600, South Africa
[b] Department of Animal Sciences, University of Stellenbosch, Stellenbosch 7600, South Africa

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ABSTRACT

A pairwise comparison of the meat quality between fresh and frozen/thawed *Musculus iliofibularis* was conducted. Thirty-two (16 left; 16 right) muscles were collected and allocated to two treatments: fresh and frozen/thawed. Frozen vacuum-packed samples were stored for 1 month at −20 °C before thawing. The fresh samples had higher pH ($P<0.05$), water binding capacity ($P<0.05$), CIE L^* ($P<0.0001$), CIE a^* ($P<0.05$) and Chroma values ($P<0.05$) than the frozen/thawed samples, indicating the fresh samples were bright red in appearance and had minimal exudate. The frozen/thawed samples lost 5.09 ± 0.21% moisture during thawing and had a greater drip loss ($P<0.0001$) and shear force ($P<0.001$). No differences were obtained with regard to cooking loss, CIE b^*, hue and TBARS. Protein oxidation (mM carbonyls/mg protein) was lower ($P<0.05$) in the frozen/thawed samples, which was attributed to the higher ($P<0.0001$) protein concentration negating the higher ($P<0.001$) carbonyl content. Industrial freezing and thawing regimes negatively affected the quality of ostrich meat.

1. Introduction

The South African ostrich meat industry has grown considerably over the past years, predominantly in the export sector, which exports approximately 90% of all meat produced (Anonymous, 2011). Frequently, the meat is exported in a frozen state and thawed on arrival before being processed further. The latter normally consists of cutting the muscles into steaks and packaging them in various forms (MAP, oxygen permeable) for retail sales. Freezing the meat is economically feasible as it increases the shelf-life of the product and allows less expensive transportation options (e.g. ship) to be used, compared to chilled meat (air transport).

Freezing and thawing of meat has been found to reduce its quality (Vieira, Diaz, Martínez, & García-Cachán, 2009). During freezing, ice crystals are formed between and within the fibres that physically damage the ultra-structure of the meat because as water freezes out it leads to an increase in the concentration of the solutes surrounding the sensitive protein structure. The ice crystals that form draw water from the intracellular spaces to the intercellular spaces that lead to excessive moisture loss during thawing, causing changes in the sensory profile as well as influencing the tenderness (Añón & Calvelo, 1980; Ngapo, Babare, Reynolds, & Mawson, 1999). The moisture loss further increases, as the damage to the ultra-structure of the meat fibres does not allow uptake of moisture into the intracellular spaces upon thawing. In addition, the increase in solute concentration increases the susceptibility for protein denaturation. Myoglobin is one of the proteins that denatures during freezing and thawing. The globin fraction of the myoglobin denatures leading to a loss in colour stability (Añón & Calvelo, 1980; Jeong, Kim, Yang, & Joo, 2011). As freezing does not cause all biological processes to stop, oxidation is a major contributor to quality deterioration in frozen/thawed meat. Lipid oxidation tends to accelerate post thawing due to peroxidation during frozen storage that yields reactive oxygen species (ROS), which in turn also increases protein oxidation (Leygonie, Britz, & Hoffman, 2011a; Xiong, 2000).

The majority of the studies on the effect of freezing and thawing of meat have been conducted on traditional red meat species such as pork and beef. These species differ considerably from ostrich meat, primarily in the distribution, content and composition of fat and the amino acid composition (Paleari et al., 1998; Sales, 1998). The myoglobin content and the pH of the ostrich meat are also higher than in other red meat species (Sales & Hayes, 1996). These properties influence the overall characteristic of the meat, potentially causing the meat to be more or less sensitive to freezing and thawing.

The aim of this study was to establish if ostrich fillets (*Musculus iliofibularis*) that are frozen and thawed, using commercial parameters, differ from the fresh fillets from the same bird. This ensures that the "bird effect" is constant and only the treatment effect is measured. The differences investigated include the fillets' physical properties (pH, moisture retention, colour and shear force) and the muscles' lipid oxidation (TBARS) and free carbonyl production (protein oxidation).

* Corresponding author. Tel.: +27 21 808 4747; fax: +27 21 808 4750.
E-mail address: lch@sun.ac.za (L.C. Hoffman).

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2. Materials and methods

2.1. Sample preparation

2.1.1. Birds, slaughter and transport

Sixteen South African Black (*Struthio camelus* var. *domesticus*) ostriches raised in the Oudsthoorn district were slaughtered at 14–15 months of age at the EU approved Klein Karoo ostrich abattoir. Although all the birds weighed ≈90 kg, they were reared by different producers and under different feeding regimes. The objective of the investigation was to source birds that would be representative of commercial ostriches slaughtered and therefore common animal production factors that are known to influence the chemical composition of ostrich muscle were not included as main effects. The dressed carcasses were cooled within *ca.* 45 min after exsanguination in a cooling chamber at 0–4 °C for 24 h before deboning.

The *M. iliofibularis* (Fan Fillet) was removed from the left and right leg of the carcass, and after removal of the external fat and epimysial connective tissue, the samples were vacuum packaged and transported (*ca.* 5 h) under chilled (±0 °C) and hygienic conditions to the Department of Animal Sciences (University of Stellenbosch). Immediately upon arrival, the muscles were split into two groups, left and right. The left *M. iliofibularis* was allocated to the freezing treatment and the right to the fresh treatment. It was assumed that the left and the right side's muscles were homogenous. The samples allocated to the freezing treatment were immediately frozen and the samples allocated to the fresh treatment were prepared for analysis.

In preparation for analysis (drip loss; cooking loss and shear force; colour, pH, water binding capacity and oxidation) of the fresh and frozen/thawed muscles, three ±1.5 cm thick steaks were cut perpendicularly to the muscle fibres. These steaks were cut from the centre of each muscle and packaged in a polystyrene tray wrapped with air permeable cling wrap (10 micron Versafilm (Crown National, Montague Gardens, Cape Town, South Africa)) with a moisture vapour transfer rate of 585 g/m²/24 h/atm, O_2 permeability 25,000 cm³/m²/24 h/atm and a CO_2 permeability of 180,000 cm³/m²/24 h/atm to allow blooming and to minimise desiccation before analysis.

2.1.2. Freezing and thawing

The left *M. iliofibularis* was frozen in a blast freezer set at −20 °C with a wind speed of 2.6 m/s. Thermocouples were inserted at two sites in the muscles (prior to freezing), the thermal centre and ±1 cm below the surface (EBI-6, Ebro Electronic GmbH & Co. KG, Ingolstadt data logger with thermocouple attached). Freezing was stopped when the thermal centre reached a temperature of −20 °C. The samples were stored for 1 month at −20 °C before thawing. Prior to thawing, one thermocouple was inserted in up to the thermal centre (using an electric drill) and the frozen muscles were placed in a refrigeration unit at 4 °C with a wind speed of 1.2 m/s until the thermal centre reached 0 °C. The muscles were then packaged as noted above and prepared for analysis.

2.2. Physical analysis

2.2.1. Surface colour

The surface colour of the ostrich steaks was measured according to the CIE $L^*a^*b^*$ colour system using a Color-guide D65/10° (daylight illumination, aperture opening) 45°/0° colorimeter (BYK-Gardner GmbH, Gerestried, Germany). Five measurements were taken on the steaks after allowing the cut steaks to bloom for 4.5 h after packaging, under fluorescent light illumination (L 58 W/20, Osram, Germany; 870 lux (MT 940, Major) at 4 °C (Leygonie, Britz, & Hoffman, 2010). The average of the five readings was used in the statistical analysis. The Hue angle (h_{ab}) (°) and the Chroma (C^*) were calculated using the a^* and b^* values: $\text{Hue} = \tan^{-1}(b^*/a^*)$ and $\text{Chroma} = (a^{*2} + b^{*2})^{-0.5}$.

2.2.2. pH

The pH of the centre of the steak was measured using a Testo 205 pH meter (Testo AG, Germany) fitted with a glass meat probe (automatic adjustment for temperature) that was inserted into the steak perpendicular to the muscle fibres.

2.2.3. Moisture loss

For thawing, the whole frozen muscles were placed in a refrigeration unit at 4 °C with a wind speed of 1.2 m/s until the thermal centre reached 0 °C. Thaw loss was determined by weighing each whole muscle prior to freezing and again after thawing and blotting dry with tissue paper. Thaw loss of the whole muscle was expressed as a percentage of initial weight prior to freezing.

The water holding capacity (or expressible water, WHC) was determined using one of the steaks in the package using the press method. A cube of meat weighing 500 mg was cut from the centre of the steak, diced with a sharp scalpel and placed on a filter paper (Whatman #2), sandwiched between two Perspex plates and pressed at a standard pressure (588 N) for 1 min. The WHC was calculated by determining the ratio of meat area to the liquid area after compression. The measurement was taken in duplicate. Photos taken of the two areas were used to measure the two circumferences by means of the Image J 1.41 computer package (Trout, 1988). The ratio of the expressed water area over the meat area was used as an indication of WHC of the meat.

Drip loss was determined by suspending the weighed second steak in inflated polyethylene bags (taking care that samples did not touch the sides of the bags) for 24 h at ±4 °C. After 24 h, samples were removed, blotted dry and weighed; drip loss was calculated as the percentage of weight lost (Honikel, 1998).

To determine cooking loss, the third steak was weighed and cooked in a polyethylene bag in a water bath at ±80 °C for 60 min (Honikel, 1998). Samples were then removed from the water bath, the water drained from the bags and the samples (still in the bags) cooled under running water to ±20 °C after which they were blotted dry with tissue paper and weighed. Cooking loss was calculated as the percentage of weight lost.

2.2.4. Shear force

Meat tenderness was determined on the cooking loss-steaks. Meat tenderness was evaluated using a Warner Bratzler device (load cell of 2.000 kN) attached to a model 4444 Instron texture machine (Apollo Scientific cc, South Africa). The machine has a measuring speed of 200.0 mm/min. Five core samples (1.27 cm in diameter) were cut with a core-borer parallel to the muscle fibre axis to ensure the blade of the Warner Bratzler device cuts at right angles to the fibres. The mean values (N) attained from the five samples were used in the statistical analysis.

2.3. Lipid oxidation

Lipid oxidation was assessed by the 2-thiobarbituric acid (TBARS) extraction method of Lynch and Frei (1993). Core samples (1.0 × 1.0 × 1.0 cm meat block from the centre of the steak) from each sample, wrapped in tinfoil and snap frozen in liquid nitrogen, were kept frozen (−20 °C) until analysed (<two weeks). Analysis was conducted on 1 g of frozen core sample and the TBARS concentrations were calculated using 1,1,3,3-tetramethoxypropane (0–20 μM) as a standard and expressed as milligram malonaldehyde (MDA) per kilogram of meat.

2.4. Protein oxidation

Protein oxidation was assessed by estimating the protein carbonyl content with the derivatization of 2,4-Dinitrophenylhydrazine (DNPH) as described by Oliver, Ahn, Moerman, Goldstein, and