Journal of Agricultural Science and Technology A 8 (2018) 323-332
doi: 10.17265/2161-6256/2018.05.008

Effect of Postmortem Ageing on Quality Parameters, Contents of Proteins, Lipids and 25-Hydroxyvitamin D and Oxidative Stability in the Camel Meat during Cold Storage

Rabab Tabite[1], Kaoutar Barka[1], Mohamed Farh[1], Fouad Riad[1], Najia El Abbadi[2], Elhassane Tahri[1], Abderrahmane Belhouari[1], Bernard Faye[2] and Mohammed El Khasmi[1]

1. Laboratory of Physiopathology and Molecular Genetics, Ben M'Sik Faculty of Sciences, Hassan II University of Casablanca, BP 7955 Sidi Othmane, Casablanca, Morocco

2. FAO/CIRAD-ES, Campus International de Baillarguet, TA C/dir B 34398 Montpellier, France

Abstract: The effect of ageing was evaluated on quality parameters (pH, electrical conductivity (EC), osmolality, drip loss (DL) and cooking loss (CL)), proteins, fat and 25-hydroxyvitamin D (25-OH-D) total levels and antioxidant status (malondialdehyde (MDA) and catalase (CAT) activity) in meat of camels during storage at 4 ± 1 °C. Samples were taken from the brachial triceps muscle (*triceps barchii*) and were stored at 4 ± 1 °C for 10 d. Quality parameters, chemical composition and antioxidant status were assessed at 3 h and 24 h postslaughter and 5, 7 and 10 d postmortem during cold storage. CAT activity significantly decreased while osmolality, EC, DL, CL and MDA contents significantly increased, from the 5th or 7th postmortem day of cold storage of the camel meat. However, proteins, lipids and 25-OH-D total contents showed no significant differences during all period of ageing. In conclusion, in the dromedary camel, ageing time of triceps muscle influenced significantly its quality characteristics and antioxidant status from the 5th or 7th postmortem day of refrigerated storage, without any variation of proteins, fat and 25-OH-D contents.

Key words: Camel, cold storage, chemical composition, quality, 25-hydroxyvitamin D, lipid oxidation, catalase activity, meat.

1. Introduction

The dromedary camels occupy an essential place in the life in the desert regions of Africa and Asia where they remain a potential purveyor of milk and meat, in acceptable quantity and quality when other ruminants cease all production and fail not to survive [1]. Camel meat is known by lower levels of fat and cholesterol, and higher amounts of essential amino acids, vitamins, minerals and polyunsaturated fatty acids (PUFAs) in comparison to other red meats [2]. Camel meat, compared to other red meats, is known to be beneficial for health because of its low fat and cholesterol content, but is relatively rich in PUFAs [2]. The camel meat is also rich in myoglobin and other heme compounds (Hb) that could act as pro-oxidants and thus promote the oxidation of lipids [3].

During the installation of postmortem cadaveric rigidity, water retention depends essentially on the degree of lateral narrowing of the myofibrils and the change of water compartmentalization in muscle tissue [4]. In addition, chilling improves the texture, juiciness and aroma of meat, however, drip loss (DL) occurs throughout the cold chain and represents a considerable economic loss to the red meat industry. The potential for DL is inherent in fresh meat and is related to the development of *rigor mortis* in the muscle after slaughter and its effect on pH [5]. The postmortem ageing of meat is a very important factor able to influence significantly the structure and

Corresponding author: Mohammed El Khasmi, Ph.D., research field: animal physiology.

chemical properties of meat [6]. This phenomenon depends on physicochemical parameters of meat, essentially extent and rate of acidification, osmolality, glycolysis and proteolysis [7]. After slaughtering, there is a decrease in temperature and pH and an increase in osmotic pressure and expressible juiciness resulting in an improvement of some quality parameters such as texture, water-holding capacity and tenderness of most muscles [4].

Lipid oxidation of food generates undesirable products and causes the degradation of fat-soluble vitamins and essential fatty acids and it interferes with the integrity and safety of foods through the formation of potentially toxic compounds such as malondialdehyde (MDA) [8]. The oxidation of lipids in the muscle takes place just after the slaughter of the animal and to prevent these reactions, it would be necessary to put in place systems that can maintain or improve the antioxidant/pro-oxidant balance in the muscle [8].

The dromedary meat could be a significant source of vitamin D [9]. This vitamin D was able to influence function, metabolism, hypertrophic growth, composition and size of the skeletal muscle [10]. In addition, dietary vitamin D3 supplementation increased ultimate pH (pHu), decreased DL and cooking loss (CL) [11] and ameliorated the antioxidant activity [12].

Studies on the effect of preslaughter conditions (transport stress), season, age and shelf life on the postmortem metabolic characteristics of muscle and meat quality in the camel are fragmentary [13-15] and in the literature, no study has analyzed vitamin D in meat during its cold storage in this species. Thus, the objective of this investigation was to study the effect of the duration of postmortem ageing during a cold storage of 10 d, on the characteristics of quality (pH, osmolality, electrical conductivity (EC), DL and CL), biochemical composition (proteins, lipids total and 25-hydroxyvitamin D (25-OH-D) total contents) and antioxidant status (MDA and catalase (CAT) activity) of the *triceps brachii* muscle in the dromedary camel.

2. Materials and Methods

2.1 Animals

This study was conducted on eight male and female camels (*Camelus dromedarius*), in apparent good health, aged 6-14 years and weighing 260-390 kg. These animals were exposed to normal preslaughter handling and road transportation conditions and subsequently held in a lairage for 12-16 h and were intended for slaughter and dressing at the Casablanca Municipality slaughterhouse in the west of Morocco according to ethical procedures.

2.2 Samples Collection and Processing

After veterinary inspection, the brachial triceps muscle (*triceps barchii*) samples (500-520 g) of the right side of each of the camel carcass were removed within 3 h postslaughter. These samples were kept in zipped plastic bags and transported aseptically within 10 min, in insulated box filled with ice to the Laboratory of Pathophysiology and Molecular Genetics at the Faculty of Sciences Ben M'Sik in Casablanca, Morocco, and then were kept in the refrigerator at 4 ± 1 °C. The muscle samples were divided into 10 parts (1-30 g), packaged in a sterile polythene bags, labelled and then were stored in the refrigerator at 4 ± 1 °C for 10 d. Extracts were prepared at 3 h and 24 h postslaughte and 5, 7 and 10 d postmortem cold storage stages and then stored at -80 °C awaiting biochemical and oxidation analysis. All measurements were assessed in duplicate and all reagents were of analytical grade.

2.3 Meat Quality Measurements

Quality characteristics of muscles included pH, EC, osmolality, DL and CL.

2.3.1 Muscle pH

The pH of the muscle was measured at 20 °C for each postmortem storage period using a pH meter standardized at pH 4 and pH 7. For determination of

the pH, 2 g of ground meat was blended with 20 mL distilled water for 1 min and the homogenate was filtered and the pH value of the filtrate was determined. Readings were recorded in triplicates for each measurement.

2.3.2 Measurement of EC

The EC was recorded at each postmortem storage period with an EC meter model Hanna EC 215 provided with an electrode of the four rings HI 76303. The conductivity meter used is microprocessor type LF 196 equipped with a conductivity cell. The device is calibrated with potassium chloride solution (0.01 mol/L) whose the EC is known for a reference temperature of 25 °C. The muscle samples (5 g) were very coarsely chopped for 8 s and then centrifuged at 18,000× g for 30 min. The volume of juice recovered is supplemented to 20 mL with pure water to have a sufficient volume to plunge the conductivity cell. The conductivity values were adjusted automatically in relation to the temperature of the sample. Measurements were also made on pure water used to dilute meat juices. This value has been deduced from the conductivity values and EC was expressed in mS/cm.

2.3.3 Measurement of Osmolality

Osmolality was measured on extracted meat juice after centrifugation for 30 min at 100,000× g. The measurement is carried out using an automatic osmometer (Gonotec Osmomat 030) and the osmolarity is expressed in mOsm/kg H_2O. The osmometer determines the freezing point of aqueous solutions. The lowering of the freezing point relative to pure water is a direct measure of the osmolar concentration. Pure water solidifies at 0 °C, a solution at 1 mOsm/kg solidifies at -1.858 °C. For each measurement, blanks were made with pure water that is generally used to dilute the samples. The osmolality value of samples was deduced from the values obtained on the meat juice.

2.3.4 Drip Loss

The DL was determined using the method described by Honikel [16]. The DL was recorded on meat samples free of external fat and connective tissue. The samples were weighted (30 g) before and after each storage period at 4 °C. During storage, the samples were hung by a nylon cord in a plastic bag, ensuring the meat had no contact with the juice in the bag. The DL was expressed as percentage of weight loss after cold storage and was calculated from the difference in muscle weight before and after ageing using the following formula:

$$DL\% = [(\text{weight before storage} - \text{weight after storage})/\text{weight before storage}] \times 100 \quad (1)$$

2.3.5 Cooking Loss

The CL was determined by method as described by Honikel [16]. At each post-slaughter storage period, the samples (30 g) were placed in polyethylene bag and totally immersed in a water bath at 70 °C for 90 min. After cooking, each sample was cooled in running tap water for 20 min in its exuded fluids and then removed and dried with paper towel. CL was determined as the difference in weight of sample before and after cooking and was expressed as a percentage of the weight before cooking by using the following formula:

$$CL\% = [(\text{weight before cooking} - \text{weight after cooking})/\text{weight before cooking}] \times 100 \quad (2)$$

2.4 Biochemical Parameters

2.4.1 Proteins and Lipids Analysis

Total proteins (g protein/100 g sample) and lipids (g fat/100 g sample) contents were determined according to the standard methods of Association of Official Analytical Chemists (AOAC, 2000) [17]. Fat was determined by weight loss after a six-cycle extraction with petroleum ether in a Soxhlet apparatus. Proteins were analyzed according to the Kjeldahl method using the factor 6.25 for conversion of nitrogen to crude proteins.

2.4.2 Analysis of 25-OH-D Total

Pieces of meat (1.5-2 g) were cut into thin sections with a scalpel and homogenized in a food processor

(300 mL mini-bowl, France) with four to six runs, 6-10 s each in order to achieve an even mix to obtain a homogeneous mixture. The latter was extracted with 2.5 mL of acetonitrile diluted with distilled water (10v/4v) for 3 h, during which the mixture was vigorously shaken at 30 min intervals to facilitate the extraction. The extracts obtained were then centrifuged for 5 min at 4,000 rpm and the supernatant was aliquoted and stored at -20 °C until the subsequent 25-OH-D total analysis. This analysis was carried out using a radioimmunoassay kit designed for use with serum from Biosource (Biosource Europe SA., Belgium; Product KIP1961) [9, 18]. The extraction protocol was an adaption of the method used to extract 25-OH-D in serum samples as specified by the kit manufacturer. The concentration range covered by the assay kit standards was from 1.5 ng/mL to 172 ng/mL and the range encountered for meat extracts in this study was 1.6 ng/mL to 50 ng/mL. According to the manufacturer the lower detection limit of 25-OH-D was 0.6 ng/mL. Average coefficients of variation for typical runs of meat samples were 9.2%.

2.5 Assessment of Lipid Oxidation

2.5.1 MDA Dosage

The test was performed by the method of Botsoglou *et al.* [19]. As a marker of lipid oxidation, MDA was extracted from muscle homogenized powder (1 g). Briefly, 5 mL of 0.8% butyl hydroxytoluene in hexane and 8 mL of 5% thiobarbituric acid in H_2O were added to camel meat sample. After crushing and adding 2 mL of hexane, the mixture was centrifuged for 10 min at 10,900× g to recover the aqueous phase. Then 0.7 mL of 5% trichloroacetic acid and 1.5 mL of 0.8% thiobarbituric acid were added to the previously filtered aqueous phase. The sample was heated in a water bath at 70 °C for 30 min, cooled in an ice bath and, after addition of 1 mL n-butanol, centrifuged for 10 min at 680× g to recover the complex MDATBA2 present in the upper phase. Finally, the optical density of the supernatant was measured at a wavelength of 530 nm against white. The concentration of MDA was calculated according to the formula:

$$C = 103OD/\varepsilon\chi LD \quad (3)$$

where C: concentration of MDA in μmol/mL; OD: optical density read at 530 nm; ε: molar extinction coefficient of the MDA = 1.56×10^5/M/cm; L: optical path length = 0.779 cm; χ: volume of the sample (mL); D: dilution factor.

2.5.2 Evaluation of CAT Activity

CAT activity was measured using the method of Aebi [20]. An enzyme fraction was prepared from 2 g of the sample which was cut and homogenized in three volumes of phosphate buffer (0.1 M, pH 7.4) by homogenizer. The homogenate obtained was centrifuged at 2,000 rpm for 30 min at 4 °C and on the final supernatant the activity of the CAT was analyzed. The disappearance of the hydrogen peroxide was monitored spectrophotometrically at 240 nm for 2 min according to the following formula:

$$(2.3033/T) \times (\log A_1/A_2) \quad (4)$$

where A_1: absorbance at the first minute; A_2: absorbance at the second minute; T: time interval in minutes.

A molar extinction coefficient of 0.041/mM/cm was used to determine CAT activity defined as the decrease of H_2O_2/min/g of muscle.

2.6 Statistical Analysis

All values were expressed as Mean ± Standard Error of the Mean (SEM). Data were analyzed using analysis of variance (ANOVA) of the general linear models procedure of the Statistical Analysis System software (SAS, 2005) [21]. Duncan's multiple range test was used to determine if significant differences existed among ageing times; $p < 0.05$ was considered as the level of significance.

3. Results

3.1 Meat Quality Measurements

3.1.1 The pH, Osmolality and EC

The results of this investigation showed that the mean postmortem values of pH in the triceps muscle pH showed a significant ($p < 0.05$) decrease from 3 h to 24 h postmortem (6.71 ± 0.12 vs. 5.61 ± 0.23) and then settled down after 24 h (Table 1). The osmolality (mOsm/kg H_2O) in this muscle increased significantly ($p < 0.05$) at the 24 h postmortem stage compared to 3 h stage (309.12 ± 16.97 vs. 284.62 ± 22.67) and then tended to stabilize between 24 h and the last day of cold storage (Table 1). In the same muscle, EC (mS/cm) increased significantly ($p < 0.05$) at the 24 h postmortem stage compared to 3 h stage (6.23 ± 2.65 vs. 3.12 ± 1.13), but beyond 24 h postmortem there is no significant variation (Table 1).

3.1.2 Drip Loss and Cooking Loss

DL (%) and CL (%) increased significantly from the 5th postmortem day of cold storage in triceps and were higher at this stage than those observed at the 3rd postmortem day (9.23 ± 1.12 vs. 6.45 ± 1.37 and 28.25 ± 2.21 vs. 24.22 ± 2.54, respectively) (Table 1).

3.2 Biochemical Analysis

The mean postmortem values of total proteins, lipids and 25-OH-D contents in triceps did not show any significant variation during the whole period of cold postmortem storage (Fig. 1). In the triceps muscle, the levels of 25-OH-D total (ng/g) were 3.39 ± 1.47, 2.99 ± 0.81 and 3.89 ± 0.91, respectively, 3 h, 7 d and 10 d postmortem (Fig. 1).

Table 1 Effect of ageing on quality parameters (pH, electrical conductivity (EC), osmolality, drip loss (DL) and cooking loss (CL)) in triceps muscle (*triceps brachii*) of camels at 3 h and 24 h postslaughter and 5, 7 and 10 d postmortem during storage at 4 ± 1 °C.

	3 h	24 h	5 d	7 d	10 d
pH	6.71 ± 0.12	5.61 ± 0.23*	5.86 ± 0.24*	5.72 ± 0.33*	5.76 ± 0.32*
Osmolality (mOsm/kg H_2O)	284.62 ± 22.67	309.12 ± 16.97	333.25 ± 17.26*	340.62 ± 19.44*	350.75 ± 17.61*
EC (mS/cm)	3.12 ± 1.13	6.23 ± 2.65	9.34 ± 2.74*	10.22 ± 2.86*	11.53 ± 2.75*
DL (%)	6.45 ± 1.37	7.34 ± 2.01	9.23 ± 1.12	10.76 ± 1.85*	11.21 ± 1.82*
CL (%)	24.22 ± 2.54	23.87 ± 2.64	28.25 ± 2.21	31.47 ± 3.36*	33.56 ± 3.32*

Mean ± SEM, * $p < 0.05$, comparison with 3 h postmortem stage.

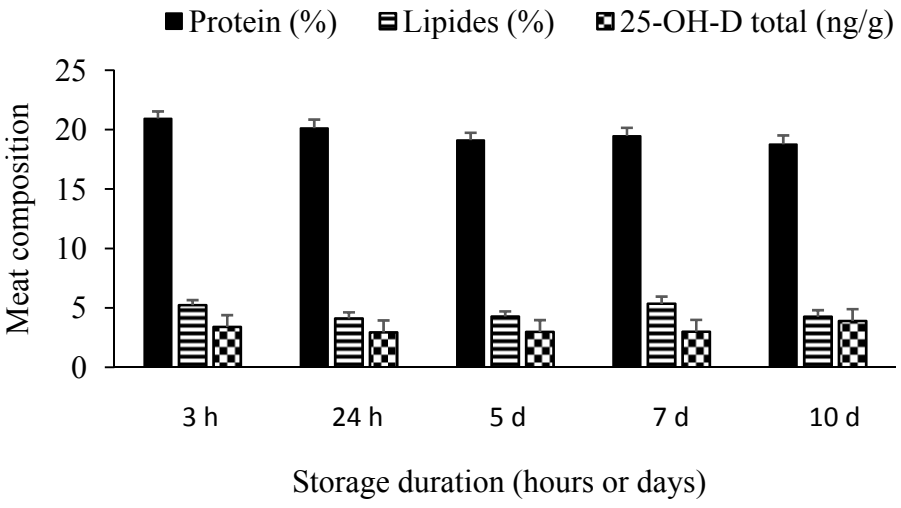

Fig. 1 Effect of ageing on protein, lipides and 25-hydroxyvitamin D (25-OH-D) total content in triceps muscle (*triceps brachii*) of camels at 3 h and 24 h postslaughter and 5, 7 and 10 d postmortem during storage at 4 ± 1 °C.
Mean ± SEM.

Table 2 Effect of ageing on malondialdehyde (MDA) and catalase (CAT) activity in triceps muscle (*triceps brachii*) of camels at 3 h and 24 h postslaughter and 5, 7 and 10 d postmortem during storage at 4 ± 1 °C.

	3 h	24 h	5 d	7 d	10 d
MDA (mg/kg)	0.45 ± 0.12	0.87 ± 0.64	1.15 ± 0.75*	2.63 ± 1.14*	3.76 ± 1.23**
CAT (UI/g)	231 ± 56	186 ± 41	167 ± 32	123 ± 22*	62 ± 15**

Mean ± SEM, * $p < 0.05$, ** $p < 0.005$, comparison with 3 h postmortem stage.

3.3 Assessment of Oxidative Stability

The MDA (mg/kg) content in triceps muscle measured at the 10th postmortem day was significantly ($p < 0.05$) higher compared to that analyzed at the 5th postmortem day (3.76 ± 1.23 vs. 1.15 ± 0.75) (Table 2). However, in the same muscle, CAT activity analyzed at the 10th postmortem day was significantly ($p < 0.005$) higher compared to that observed at 3 h postmortem stage (62 ± 15 vs. 231 ± 56) (Table 2).

4. Discussion

The results obtained in this study showed that ageing time of triceps muscle influenced significantly quality characteristics and oxidative stability from the 5th or 7th postmortem days of ageing onwards. The pH and CAT activity significantly decreased while osmolality, EC, DL, CL and MDA contents significantly increased during postmortem cold storage (4 ± 1 °C) of camel meat, however, no differences were found in proteins, lipids and 25-OH-D total contents.

According to Smili *et al.* [22], the pH drop of camel meat is gradual to reach an ultimate value in the range of 5.71 h to 24 h postmortem. In the dromedary, the muscle pHu ranged from 5.7 to 6.0 and was higher than that of other animal species [2, 13]. Some authors have explained this difference by a low level of glycogen stores at slaughtering, a low level of glycolysis enzymes and significant gluconeogenesis in the dromedary [13]. The pHu of meat is influenced by several parameters such as preslaughter handling, postmortem treatment and muscle physiology and its high values may be explained by a low level of muscle glycogen stores [13].

The final postmortem level and rate of pH drop in the muscle could impact the water retention and processing ability of meat. In fact, a significant and positive correlation had been found between pHu and water retention capacity and tenderness in beef [23] and pig [24]. In addition, the red index (a^*), DL and shear force decrease while CL increase with increasing residual glycogen concentration in muscle. Moreover, in studies on beef by Villarroel *et al.* [25] and on dromedary camel [26], it was shown that meat with a higher pH had greater water-holding capacity than that with a low pH.

The significant increase in DL, osmolality and EC during cold storage observed in the present study could be attributed to several phenomena such as: (i) acidification of the muscle which, by approaching the isoelectric point of the muscular proteins, causes the decrease of their charges and the increase of their hydrophobicity [27], (ii) postmortem degradation of transverse cytoskeletal structures in muscles [8], (iii) alteration of certain sarcolemma proteins [28] and (iiii) retraction of apoptotic cells which begins the first hour postmortem and becomes maximal around 10 h postmortem [29].

DL appears to be influenced by many factors such as breed, diet and physiological history, rate of chilling, storage temperatures, freezing, thawing, species and muscle type. Generally, beef tends to lose proportionately more drip than pork and lamb [5].

Benaissa *et al.* [26] had reported a significant positive correlation between the mean values of muscle pH and EC of the *triceps brachii* muscle at different postmortem times in adult dromedary camels. This trend may be attributable to the relationship between electrical properties and glycolytic rate. In addition, DL increased in summer in camels [15], cattle [30] and lambs [31]. DL is of great importance

for determining the technological performance and market value of meat. In the camel, the biochemical characterization of the meat showed higher DL, mainly explained by the rate and extent of pH fall [22].

According to Dawood [32] and Gheisari *et al.* [33], the DL in the camel meat had been found influenced by freezing, age and cutting type. DL of camel and cattle muscles significantly increased during frozen storage time and the two animal species often had the same DL [34]. In parallel with the acidification of the muscle, there is an increase in the osmotic pressure of the tissues following the accumulation of lactic acid in the medium and the increase of the mono and divalent ions thus from a physiological value of 300 mOsm to values close to 550-600 mOsm [29]. The increase of the osmolality of a muscle is directly and linearly related to the drop in pH and the speed of contraction (480-500 mOsm for slow-twitch muscles and 550 mOsm for fast-twitch muscles) [29].

EC had been largely used to assess the quality of meat; in the camel, EC measured at 48 h was significantly lower in winter than in summer [15]. Farouk *et al*. [34] indicated that frozen storage of cattle meat decreases the water-holding capacity (WHC) slightly, but after nine months WHC has a rapid fall. This phenomenon has been attributed to the mechanical loosening of muscle tissue by the formation of ice crystals. Also, decreasing pH due to freezing may account for reduced WHC. Farouk *et al*. [34] showed that slowly frozen and thawed beef meat has higher amounts of thaw drip loss compared with fast frozen samples. The difference in thaw drip between the two freezing regimes was greater in the early storage period and narrowed during storage time. More drip in slowly frozen meat may have resulted from greater structural damage associated with larger intracellular ice crystals produced during slow freezing [5, 8].

In camel meat, many factors were previously reported to affect the CL including age, degree of marbling and moisture content [2], ageing and electrical stimulation [35], storage time [36] and muscle type [2]. According to Hamm [37], changes in CL of meat is essentially related to water transfers between intra- and extra-cellular compartments, or to retraction of connective tissues, but not alterations of the myofibrillar system. Some authors, such as Offer and Knight [4], consider that the movements of water in the myofiber are essentially related to myofibrillar expansion or retraction. In addition, Bouton *et al.* [23] had suggested that the best tenderness at high pH is probably due to the greater amount of water remaining in the meat after cooking.

In the study reported here, MDA contents were significantly higher, whereas CAT activity was significantly lower at the last postmortem stages than those measured at the 3rd hour of cold storage. One of the main factors limiting the quality and acceptability of meat and meat products is lipid oxidation. The oxidation of oxymyoglobin and lipids, as well as microbial contaminations leads to discoloration, DL and the production of potentially toxic compounds [5]. Endogenous and/or exogenous proteolytic enzymes decompose the structural meat proteins and produce nitrogenous compounds. The meat levels of MDA as indicators of oxidative rancidity were continuously increased during the first 10 d of cold storage due to the generation of free short-chain fatty acids by microbial enzymatic hydrolysis, which are very susceptible to oxidation and form unstable lipid hydroperoxide [33].

In the camel, lipid peroxidation is one of the main causes of deterioration in the quality of raw and cooked meat products during refrigerated or frozen storage [38]. During the preservation of fresh meat, the development of pathogenic or altering microorganisms and the oxidation of lipids and pigments, causes rancid flavors and discoloration on the surface which limits the storage time [8] and remains a major concern for industry and the consumer. Lipid oxidation is a complex phenomenon

that results in the formation of volatile and non-volatile compounds, including aldehydes such as pentanal, hexanal and MDA, the dosage of which is widely used in laboratories [8].

Maqsood *et al.* [39] studied protein and lipid characterization of fresh camel meat during 9 d of refrigerated storage at 4 °C. They found that camel meat undergoes a lipid oxidation at a more pronounced level on the 3rd day of cold storage, then a decrease in the peroxidation index, the 9th day. In addition, they were able to deduce a rapid oxidation resulting in an increase in the peroxidation index and the level of MDA. In the same context, a decrease in pigments of total heme was observed during refrigerated storage of beef meat [40]. This decrease is associated with a release of iron capable of accelerating lipid oxidation and reacting with peroxides to stimulate the formation of compounds capable of initiating and propagating it [40]. These reactions would be all the more important as the antioxidant levels were reduced during the slaughtering periods. Furthermore, rearing factors are likely to impact certain characteristics of the animal and its meat, thus contributing to the appearance of oxidation phenomena during the storage of meat [8].

In the present study, during cold storage of camel meat for 10 postmortem days, the levels of proteins, lipids and 25-OH-D total showed no significant variation. The proteins concentration of drip is about 140 mg/mL, about 70% of that of meat itself. These proteins are the intracellular, soluble proteins of the muscle cells. The red colour is due to the protein myoglobin, the main pigment of meat [41]. Several decades ago, Nasr *et al.* [42] already pointed out that camel meat was relatively lean, containing between 0.92% and 1.02% fat compared to 1.2% to 4.88% in cattle, with a fat disposition in the bump and abdominal cavity. The total saturated fatty acids and unsaturated fatty acids content of this meat were 58.46 mg/100 g and 41.5 mg/100 g, respectively. The results observed here and those reported in a previous investigation [9] showed that the camel meat may be a source of 25-OH-D. Vitamin D status impacts skeletal muscle function, metabolism and hypertrophic growth and muscle fibre composition and size [10]. Vitamin D might influence the postmortem muscle pH values and consequently it's WHC. In fact, previous studies in beef steers and pork reported that dietary vitamin D3 supplementation increased pHu and WHC, decreased DL, squeezable water and CL [11] and participated in antioxidant activity [12].

5. Conclusions

These results indicate that, during a refrigerated storage of meat for 10 d, ageing time influenced significantly its quality characteristics and oxidative stability from the 5th or 7th postmortem day, without any variation of proteins, fat and 25-OH-D contents in the dromedary camel.

Acknowledgments

The authors are very much thankful to the staff of Casablanca Municipality slaughterhouse especially the veterinary inspector Dr. Abouhafs R. for assisting in meat sample collections. The authors also thank the president of the urban communes of Casablanca and the director of the municipal slaughterhouse.

References

[1] Faye, B. 2014. "The Camel Today: Assets and Potentials." *Anthropozoologica* 49 (2): 167-76.

[2] Kadim, I. T., Mahgoub, O., Al-Marzooqi, W., Al-Zadijali, S., Annamalai, K., and Mansour, M. H. 2006. "Effects of Age on Composition and Quality of Muscle *Longissimus Thoracis* of the Omani Arabian Camel (*Camelus dromedaries*)." *Meat Sci.* 73: 619-25.

[3] Maqsood, S., and Benjakul, S. 2011. "Retardation of Haemoglobin-Mediated Lipid Oxidation of Asian Sea Bass Muscle by Tannic Acid during Iced Storage." *Food Chemistry* 124: 1056-62.

[4] Offer, G., and Knight, P. 1988. "The Structural Basis of Water-Holding in Meat: General Principles and Water Uptake in Meat Processing." In *Developments in Meat Science.* New York: Elsevier Applied Science Publishing Co., Inc., 63-171.

[5] Aidani, E., Aghamohammadi, B., Akbarian, M., Morshedi, A., Hadidi, M., Ghasemkhani, N., and Akbarian, A. 2014. "Effect of Chilling, Freezing and Thawing on Meat Quality: A Review." *Inter. J. Biosci.* 5 (4): 159-69.

[6] Dawood, A. A., and Alkanhal M. A. 1995. "Nutrient Composition of Najdi-Camel Meat." *Meat Sci.* 39 (1): 71-8.

[7] Ouali, A. 1991. "Sensory Quality of Meat as Affected by Muscle Biochemistry and Modern Technologies." In *Animal Biotechnology and the Quality of Meat Production*. Amesterdam: Elsevier, 85-105.

[8] Kanner, J. 2007. "Dietary Advanced Lipid Oxidation Endproducts Are Risk Factors to Human Health." *Mol. Nutr. Food Res*. 51: 1094-101.

[9] El Khasmi, M., Bergaâ, R., Riad, F., Safwate, A., Tahri, E. H., Farh, M., El Abbadi, N., Abouhafs, R., and Faye, B. 2013. "Meat Levels of 25-Hydroxyvitamin D3 in Moroccan One-Humped Dromedary Camels (*Camelus dromedarius*)." *Emir. J. Food Agric.* 25 (4): 267-73.

[10] Ceglia, L., and Harris, S. S. 2013. "Vitamin D and Its Role in Skeletal Muscle." *Calcif. Tissue Int*. 92: 151-62.

[11] Wilborn, B. S., Kerth, C. R., Owsley, W. F., Jones, W. R., and Frobish, L. T. 2004. "Improving Pork Quality by Feeding Supranutritional Concentrations of Vitamin D3." *J. Anim. Sci*. 82 (1): 218-24.

[12] Duffy, S. K., Kelly, A. K., Rajauria, G., Jakobsen, J., Clarke, L. C., Monahan, F. J., Dowling, K. G., Hull, G., Galvin, K., Cashman, K. D., Hayes, A., and O'Doherty, J. V. 2018. "The Use of Synthetic and Natural Vitamin D Sources in Pig Diets to Improve Meat Quality and Vitamin D Content." *Meat Sci*. 143: 60-8.

[13] Abdelhadi, O. A. M., Babiker, S. A., Picard, B., Jurie, C., Jailler, R., Hocquette, J. F., and Faye, B. 2012. "Effect of Season on Contractile and Metabolic Properties of Desert Camel Muscle (*Camelus dromedarius*)." *Meat Sci.* 90 (1): 139-44.

[14] Barka, K., Farh, M., Riad, F., Tahri, E. H., Belhouari, A., and El Khasmi, M. 2016. "Impact of Transport Distance on Some Stress Biomarkers Levels in Camel Meat." *MOJ Food Process Technol*. 2 (4): 130-4.

[15] Hamad, B., Aggad, H., Hadef, L., Beddada, A., and Faye, B. 2018. "Effect of Slaughter Season on Postmortem Metabolic Characteristics of Muscle in the Dromedary Camel (*Camelus dromedarius*)." *Emir. J. Food Agric*. 30 (4): 304-11.

[16] Honikel, K. O. 1998. "Reference Methods for the Assessment of Physical Characteristics of Meat." *Meat Sci*. 49: 447-57.

[17] Association of Official Analytical Chemists (AOAC). 2000. *AOAC Official Methods of Analysis.* Gaithersburg, Md, USA: AOAC International.

[18] Purchas, R., Zou, M., Pearce, P., and Jackson, F. 2007. "Concentrations of Vitamin D3 and 25-Hydroxyvitamin D3 in Raw and Cooked New Zealand Beef and Lamb." *J. Food Compost Anal.* 20: 90-8.

[19] Botsoglou, N. A., Fletouris, D. J., Papageorgiou, G. E., Vassilopoulos, V. N., Mantis, A. J., and Trakatellis, A. G. 1994. "Rapid, Sensitive, and Specific Thiobarbituric Acid Method for Measuring Lipid-Peroxidation in Animal Tissue, Food and Feedstuff Samples." *J. Agric. Food Chem*. 42: 1931-7.

[20] Aebi, H. 1974. "Catalase." In *Methods of Enzymatic Analysis,* 2nd ed., edited by Bergmeyer, H. U. Academic Press Inc., New York, 673-80.

[21] SAS. 2005. *Statistical Analysis System Package*. Cary, NC: SAS Institute, Inc.

[22] Smili, H., Gagaoua, M., Becila, S., Ider, M., Babelhadj, B., Adamou, A., Picard, B., Ouali, A., and Boudjellal, A. 2014. "Preliminary Study of the Exudation of Camel Meat in the Algerian Dromedary of the Saharawi Population". *Viandes & Produits Carnés* 30 (5): 1-9. (in French)

[23] Bouton, P. E., Carroll, F. D., Harris, P. V., and Shorthose, W. R. 1973. "Influence of pH and Fibre Construction State upon Factors Affecting the Tenderness of Bovine Muscle." *J. Food Sci*. 38: 404-7.

[24] Fernandez, X., Lefaucheur, L., Gueblez, R., and Monin, G. 1991. "Paris Ham Processing: Technological Yield as Affected by Residual Glycogen Content of Muscle." *Meat Sci*. 29: 121-8.

[25] Villarroel, M., Maria, G. A., Sańudo, C., Olleta, J. L., and Gebresenbet, G. 2003. "Effect of Transport Time on Sensorial Aspects of Beef Meat Quality." *Meat Sci*. 63: 353-7.

[26] Benaissa, A., Ould El-Hadj-Khelil, A., Adamou, A., Babelhadj, B., Mehirig, M., Boufaghes, B., Attoussi, M., Samili, H., and Becila, S. 2014. "Quality of Camel Meat in Slaughterhouses of Ouargla in Algeria: Some Physico-chemical Characteristics of Meat during Ripening." *Rev. Elev. Med. Vet. Pays Trop*. 67: 223-8. (in French)

[27] Huff-Lonergan, E., and Lonergan, S. M. 2007. "New Frontiers in Understanding Drip Loss in Pork: Recent Insights on the Role of Postmortem Muscle Biochemistry." *J. Anim. Breed. Genet*. 124: 19-26.

[28] Astruc, T., Marinova, P., Labas, R., Gatellier, P., and Santé-Lhoutellier, V. 2007. "Detection and Localization of Oxidized Proteins in Muscle Cells by Fluorescence Microscopy." *J. Agric. Food Chem.* 55: 9554-8.

[29] Ouali, A. 1990. "Meat Tenderization: Possible Causes and Mechanisms. A Review." *J. Muscle Foods* 1 (2): 129-65.

[30] Kim, Y. H. B., Stuart, A., Nygaard, G., and Rosenvold, K.

2012. "High Pre Rigor Temperature Limits the Ageing Potential of Beef That Is Not Completely Overcome by Electrical Stimulation and Muscle Restraining." *Meat Sci*. 91 (1): 62-8.

[31] Warner, R. D., Kerr, M., Kim, Y. H. B., and Geesink, G. 2014. "Pre-rigor Carcass Stretching Counteracts the Negative Effects of High Rigor Temperature on Tenderness and Water Holding Capacity-Using Lamb Muscles as a Model." *Anim. Prod. Sci*. 54: 494-503.

[32] Dawoo, A. A. 1995. "Physical and Sensory Characteristics of Najdi-Camel Meat." *Meat Sci*. 39 (1): 59-69.

[33] Gheisari, H. R., Aminlari, M., and Shekarforoush, S. H. 2009. "A Comparative Study of the Biochemical and Functional Properties of Camel and Cattle Meat during Frozen Storage." *Veterinarski Arhiv*. 79 (1): 51-68.

[34] Farouk, M. M., Wieliczko, K. J., and Merts, I. 2003. "Ultra-fast Freezing and Low Storage Temperatures Are Not Necessary to Maintain the Functional Properties of Manufacturing Beef." *Meat Sci*. 66: 171-9.

[35] Kadim, I. T., Al-Hosni, Y., Mahgoub, O., Al-Marzooqi, W., Khalaf, S. K., Al-Sinawi, S. S. H., Al-Lawati, A. M., and Al-Amri, I. S. 2009. "Effect of Low Voltage Electrical Stimulation on Biochemical and Quality Characteristics of *Longissimus Thoracis* Muscle from One-Humped Camel (*Camelus dromedarius*)." *Animal and Veterinary Sciences* 82 (1): 77-85.

[36] Suliman, A. M. E., Fadlalmola, S. A., Babiker, A. S. A., Yousif, H. S., Ibrahim, S. M., Abdelrahim, Y. M., and Arabi O. A. 2016. "Influence of Season and Storage Period of Camel Meat on the Quality Characteristics of Burger." *J. Food Nutr. Desor*. 5: 1.

[37] Hamm, R. 1994. "The Influence of pH on the Protein Net Charge in the Myofiblillar System." In *Proceedings of the 47th Annual Reciprocal Meat Conference,* 5-9.

[38] Abdelhadi, O. M. A., Babiker, S. A., Hocquette, J. F., Picard, B., Durand, D., and Faye, B. 2013. "Effect of Ageing on Meat Quality of the One Humped Camel (*Camelus dromedarius*)." *Emir. J. Food Agric*. 25 (2): 150-8.

[39] Maqsood, S., Abushelaib, A., Manheem, K., and Kadim, I. T. 2015. "Characterisation of the Lipid and Protein Fraction of Fresh Camel Meat and the Associated Changes during Refrigerated Storage." *J. Food Compos. Anal.* 41: 212-20.

[40] Maqsood, S., and Benjakul, S. 2010. "Preventive Effect of Tannic Acid in Combination with Modified Atmospheric Packaging on the Quality Losses of the Refrigerated Ground Beef." *Food Control* 21: 1282-90.

[41] James, S. J., and James, C. 2009. "Chilling and Freezing of Meat and Its Effect on Meat Quality." In *Improving the Sensory and Nutritional Quality of Fresh Meat,* 1st ed. University of Bristol, UK: Woodhead Publishing Limited, 539-60.

[42] Nasr, S., El Bahay, G., and Noursy, A.W. 1965. "Studies on Camel Meat: The Effect of Age and Sex on the Components of Camel Meat." *Journal of Arab Veterinary Medicine Association* 25: 253-8.