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EFFECTS OF WET AGEING OF BEEF MUSCLE *GLUTEUS MEDIUS* ON TEXTURAL AND TECHNOLOGICAL PARAMETERS

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Abstract: *The aim of this study was to observe the effects of wet aging time of beef muscle Gluteus medius on the textural and technological parameters. Meat samples (400 g) were aged by wet ageing process for 21 days and were periodically analyzed at 2, 7, 12, 17 and 21 days respectively. The pH value registered a slight increase during the 21 days of ageing. Cooking loss increased over the 21-day ageing period by 1.03%. The ageing time affected the instrumental colour measurements. The Cie-Lab parameters have changed slightly through in an increase in lightness, L^*, and yellowness, b^*, but they did not affect redness, a^*. The color difference, ΔE^*, between the control samples and the aged samples was highlighted, both in raw and cooked meat samples. Mechanical tests were performed on both raw and thermally treated samples. The results of Warner Bratzler mechanical test showed decreases as compared with control samples ($P < 0.05$). The TPA parameters such as: hardness, resilience, springiness, adhesiveness, chewiness, gumminess and cohesiveness) were signifficaly modified ($P < 0.05$), during 21 days of wet ageing.*

Keywords: *beef meat, Gluteus medius, tenderness, color, textural properties, cooking loss*

1. Introduction

Meat is an important source of valuable quality protein, whose amino acid composition compensates for the deficiencies of other food raw materials. Another important nutritional characteristic of the meat is its content in absorbable iron, zinc, selenium and in vitamins of group B, thiamine, riboflavin, niacin and vitamin B12, with an essential role in healthy nutrition [1]. Tenderness is one of the important assessment indices of beef quality. The meat industry aims for reliable meat quality monitoring through out the production process in order to guarantee a high quality of the final product [2],[3]. For this reason, the meat sector is interested in technology for accurate, fast and non-destructive determination of quality attributes. Both chemical (pH, color and fat content) and physical parameters (tenderness and juiciness) contribute to the meat appearance and eating experience and, therefore, to the final consumer acceptability [4]. Ageing is defined as storing meat for a certain period of time to improve its eating quality attributes, including tenderness, flavor, and juiciness [5],[6]. Wet ageing is performed on vacuum pre-packed meat in plastic sheets and maintained at refrigeration temperature. The advantages of wet aging process are: it is less expensive; it allows a faster distribution in the marketing units and ensures protection against microbiological contamination [7].
Controlling the key factors that influence the rate and extent of aging impacts is

highly relevant to the development of effective strategies to improve meat quality and value.

Meat tenderness is described as the most important factor influencing consumer satisfaction, which has led to a great deal of research on understanding and measuring beef tenderness [8]. Tenderness can be evaluated using objective methods, instrumental or sensorial methods with trained panels, or subjective methods with a consumer panel [9].

Warner–Bratzler shear test was one of the first instrumental methods developed to measure beef tenderness and, despite criticism, has remained the most commonly used globally [10]. The WBSF protocol measures the amount of force required to shear across entire muscle fibers. This method requires cooking the meat at an internal temperature of 71° C, cooling it at room temperature and cutting the samples into a round shape with a diameter of 1.27 cm.

The cutting knife speed is 200-250 mm / min until complete shearing of the samples, perpendicular to the orientation of the muscle fibers [9].

Two main components of meat, myofibres and connective tissue, are considered to be the main determinants of the shear force deformation curve [11]. A shear force curve always has a maximum positive peak shear force, but peaks of less importance are also, but not always, observed before and after maximum positive peak shear force. MF-SF and CT-SF is myofibrillar/ connective tissue peak shear forces (Fig. 1) [11], [12].

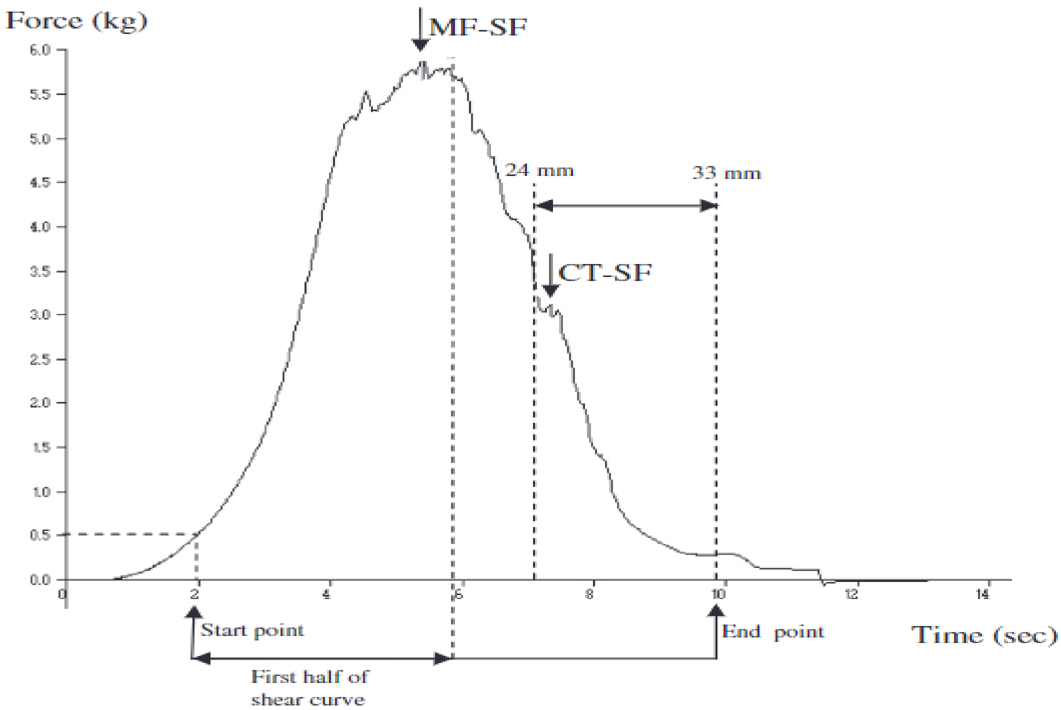
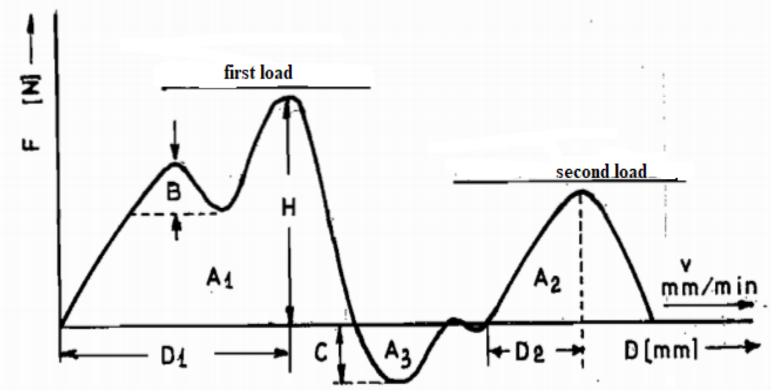


Fig.1. Example of a shear curve measured with a texture analyser [11], [12].

TPA is still widely used by industry and academic research to characterize the texture of solid and semisolid foods. The method is simply a double compression, which compresses the food material twice to a limited extent to avoid structural damage to the material [13].

Texture profile analysis (TPA) can be performed on either a raw sample or heat treated by boiling. The results of the TPA analysis may be significant in terms of hardness, succulence and chewiness, compared to the Warner-Bratzler test, where the elasticity is more significant than the texture parameter of meat [14]. In figure 2. is present the texture parameters according to texture profile analysis (TPA) [15].



Parameter texture	Notation
Viscosity	C
Fracturability	B
Hardness	H
Displacement	D_1
Adhesiveness	A_3
Cohesiveness	A_2/A_1
Springiness	D_2/D_1
Gumminess	$H \times A_2/A_1$
Chewiness	$H \times A_2/A_1 \times D_2/D_1$

Fig.2. Load diagram in two cycles used for texture profile analysis (TPA) [15].

The compression parameters obtained with TPA have been employed by many authors to evaluate meat products [16], [17], [18].

2. Matherials and methods

2.1. Materials

Beef meat (*Gluteus medius)* containing: 73.25 % moisture, 23.9 % protein, 2.29% fat, and 0.54% ash, and 5.69 pH) was purchased from a local slaughterhouse.

At 12 h postmortem, *Gluteus Medius* (GM) muscles were excised and six 2.5 cm steaks were obtained. Each meat sample was individually vacuum-packaged using Vacuum Sealer, 4.5 l/min, 120W, Peach PH310, produced by *Peach Industrial*, Romania, and assigned to aging times of 0, 2, 7, 12, 17 and 21 days at 4-5°C, to develop a wide range of possible tenderness.

After ageing, at the specified time intervals, each sample was analyzed both raw and heat treated. The heat treatment was performed on in batchesin a 71 °C water bath for 35 min. [19]. Meat samples were placed in polyethylene bags and cooked until reached a temperature of 71 °C. When the end-point temperature has been obtained, samples were removed from the water bath and cooled for 15 min. (adapted from Honikel, 1998) [20].

The sample coding according to meat aging duration is presented in table 1.

Table 1.

Sample coding, according to meat aging duration

Meat aging duration	0 days	2 days	7 days	12 days	17 days	21 days
Sample code	Control	m_1	m_2	m_3	m_4	m_5

2.2.Methods

2.2.1. pH-analysis

The changes in pH during wet ageing were monitored using a pH portable F2 Standard Mettler Toledo device.The pH values of each sample were measured in a homogenate prepared with 5 g of raw meat sample and distilled water. All determinations were performed in triplicate.

2.2.2. Cooking loss

Cooking loss was calculated as the percent weight difference between raw and cooked samples relative to the weight of raw samples according to Dominguez *et al.*, usind equation 1 [21].

$$Cooking\ loss(\%) = \frac{Raw\ meat\ weight(g) - Cooked\ meat\ weight(g)}{Raw\ meat\ weight(g)} \times 100 \quad (1)$$

2.2.3.CIE-Lab color determination

The color of the raw and heat treated meat was measured by means of the CIE-Lab method, where L* (100 = white, 0 = black) represents the brightness, and a* (+ red, - green) and b* (+ yellow, - blue) are color parameters. The determinations were performed using the Konica Minolta Chroma Meter CR-400 device.

Lightness (L*), redness (a*), and yellowness (b*) values were recorded. The hue angle ($H°$), color difference (ΔE^*) and chroma difference (ΔC^*), were calculated as follows equations [22]:

$$H° = arctan\ (b^*/a^*) \quad (2)$$

$$\Delta E^* = (\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})^{1/2} \quad (3)$$

$$\Delta C^* = (\Delta a^{*2} + \Delta b^{*2})^{1/2} \quad (4)$$

Color analysis is enhanced by increasing the number of measurements in a sample [23], therefore, three determinations were made at random on the surface of the measuring muscle. The color values for the three measurements were averaged and the average of each value was recorded for statistical analysis.

2.2.4. Warner- Bratzler shear force

The analyses were carried out on raw and cooked samples according to AMSA guidelines [9]. Samples were sheared perpendicular to the fibre direction using the Perten TVT 6700, from *Perten Instruments* fitted with a 20 kg tension/compression load cell and cross head speed of 1,5 mm/s. Maximum peak force recorded during the test was reported as shear force (WBSF). Seven cores per sample were analysed and following exclusion of the highest and lowest values, the average of five measurements was recorded for each sample.

The average peak sheer force of the seven cores was used for statistical analyses.

2.2.5. Texture profile analysis (TPA)

Using a texture analyzer, Perten TVT 6700, from *Perten Instruments*, the TPA parameters of raw and cooked meat beef was evaluated as described by Bourne (1978) [24]. The characterization of the texture profile was achieved using thetexturometer Perten TVT 6700 and software, TexCalc 5.

Briefly, three cylinders of 1 cm height and 1,27 cm diameter were prepared from every sample. A double compression cycle test was performed up to 50% compression of the original portion height with an aluminium cylinder probe of 2 cm diameter. A time of 5 s was allowed to elapse between the two compression cycles. Force–time deformation curves were obtained with a 20 kg load cell applied at a cross-head, speed of 2 mm/s. The data obtained from TPA curve were used for the calculation of textural parameters. Among the TPA parameters, hardness is expressed as maximum force for the first compression. Adhesiveness is expressed as negative force area for the first bite or the work necessary to pull the compressing plunger away from the sample. Springiness is calculated as the ratio of the time from the start of the second area up to the second probe reversal over the time between the start of the first area and the first probe reversal. Cohesiveness is a measure of the degree of difficulty in breaking down the samples internal structure. Gumminess and chewiness have been reported as products of hardness, cohesiveness. Chewiness is calculated as hardness × cohesiveness × springiness. Resilience reflects the redeformation capacity of samples tissue after penetration. The texture analysis conditions were used as described by Ben Slima et al. (2017) [25], texture parameters (hardness, springiness, adhesiveness, chewiness, and cohesiveness) were quantified during 21 days of storage at 4-5°C. The force versus time/displacement plots were used to calculate TPA values, such as: hardness, chewiness, gumminess, adhesiveness, springiness and cohesiveness [24].

2.2.6. Statistical analysis

The statistical analysis was made using Microsoft Excel 2007 and Unscrambler X 10.1 software system (Camo, Norway).

3. Results and discussion

3.1. pH and Cooking loos results

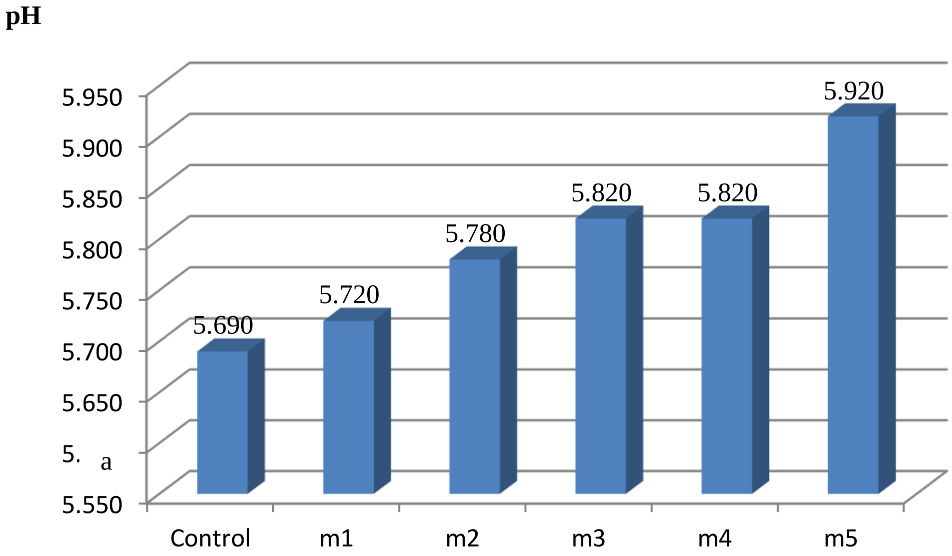
The cooking loss results and the variation of the pH of the meat samples during the ageing time, are shown in Table 2.

Table 2.

pH and Cooking loss results

Samples	**Control**	**m_1**	**m_2**	**m_3**	**m_4**	**m_5**
pH	5.690±0.1	5.720±0.12	5.780±0.1	5.820±0.2	5.820±0.1	5.920±0.15
Cooking loss(%)	25.754±0.2	25.758±0.3	25.988±0.22	26.031±0.3	26.349±0.12	26.776±0.25

Figure 3 (a) shows the evolution of meat pH over the 21 days of aging, and the cooking loss (b) measured at the specified intervals: 0, 2, 7, 12, 17 and 21 days.
The pH value registered a slight increase between 5.69 and 5.92 during the 21 days of maturation. Small differences indicate pH stability during wet ageing, except for day 21, where a slight increase in pH was observed (Table 2), which is in acord to Minh Ha *et al.* [26].
In figure 3(b) is registred the values of cooking loss of meat samples after cooking method. The difference between the cooking loss of the control sample and the meat sample aged 21 days it was of 1.03%. Although the cooking losses show no clear trend, all samples increased in their percentage of moisture lost during cooking over the total ageing period. An increase in cooking loss was reported in their study and Wyrwisz *et al.* [27].
The increments of Cooking loss are due to the degradation of proteins in the aging process [28].



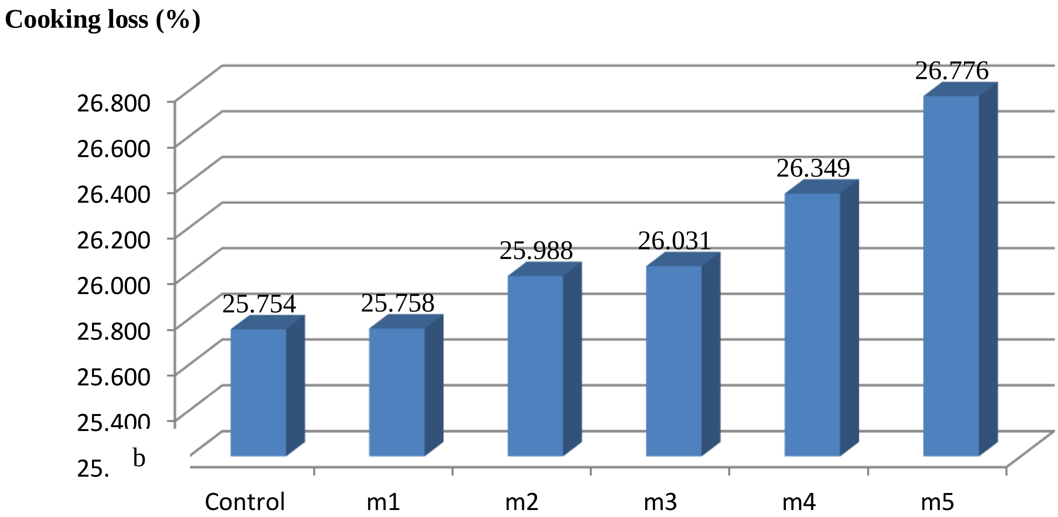


Fig.3. Evolution of pH on the meat during aging period (a) and Cooking loss (%) (b).

Lopes *et al.* studied the influence of cooking methods on amino acid and mineral content of veal and reported that cooking method affected the chemical composition and nutritional value of meat [29]. Therefore, is registered the slight increase of the cooking loss on the meat wet aged for 21 days, this increase has been ascribed to the denaturation of intramuscular collagen or changes in the myofibrilar structure due to cooking.

3.2. CIE-Lab color parameters

CIE-Lab color parameters of the raw meat samples are shown in Table 3.

Table 3.

The CIE-Lab color parameters of raw meat samples

Sample	Color parameters					
	L^*	**a^***	**b^***	**ΔC^***	**$H°$**	**ΔE^***
Control	38.640±0.10	16.686±0.12	9.216±0.10	19.57±0.20	28.91±0.12	-
m_1	40.938±0.21	16.544±0.16	9.296±0.20	18.98±0.17	29.33±0.22	2.30±0.12
m_2	41.274±0.31	16.406±0.21	9.614±0.21	19.02±0.14	30.37±0.18	2.68±0.14
m_3	41.676±0.13	16.226±0.16	9.700±0.14	18.90±0.21	30.87±0.19	3.11±0.20
m_4	42.204±0.14	16.328±0.17	9.902±0.12	19.10±0.18	31.23±0.10	3.65±0.14
m_5	42.434±0.20	16.155±0.12	9.987±0.15	18.99±0.15	31.72±0.12	3.91±0.10

The a*, b*, hue angle and chroma of beef meat were influenced by the ageing period, showing a trend for the colour of muscles to become lighter ($P < .0001$), more yellow ($P < .001$) and more saturated ($P < .0001$) over time.

Ageing time affected the instrumental colour measurements of the wet aged raw samples through in an increase in lightness, L^*, and yellowness, b^*, but did not affect redness, a^*.Color difference, ΔE^*, between control meat sample and sample aged for 21 days, it was of 3,91 value. Changes in color parameters during wet ageing were also reported by Dikeman *et al*. [30]. Hue angle, *H*°, which has a strong correlation with visual colour, represents the meat colour change from red to yellow and a larger hue angle value generally indicates a shift to lower redness and higher yellowness [31].

The increased beef color values after aging are related to the influence limited by the enzymatic activity during vacuum aging, which resulted in a deeper O2Mb layer that is created in the presence of air oxygen, and blooming process occurs faster and more intensively [32]. Moreover, a higher lightness L*, after aging, can be explained by the proteindegradation process during aging, leading to weakening of the protein structures, which results in higher light dispersion, thus increasing the lightness of meat [33]. The color parameters of the cooked meat samples are shown in Table 4.

Table 4.

The CIE-Lab color parameters of cooked meat samples

Sample	Color parameters					
	L^*	**a^***	**b^***	**ΔC^***	**$H°$**	**ΔE^***
Control	36.598±0.20	7.098±0.22	14.424±0.10	16.08±0.12	63.80±0.20	-
m_1	36.233±0.12	6.752±0.18	14.478±0.20	15.98±0.20	65.00±0.18	0.51±0.10
m_2	35.948±0.14	6.338±0.18	14.802±0.22	16.10±0.14	66.82±0.10	1.07±0.12
m_3	35.698±0.20	5.888±0.22	15.52±0.18	16.60±0.10	69.22±0.10	1.86±0.10
m_4	35.670±0.12	5.618±0.14	16.204±0.18	17.15±0.12	70.88±0.14	2.49±0.12
m_5	34.122±0.12	4.867±0.10	16.333±0.10	17.04±0.14	73.41±0.12	3.84±0.20

Ageing time affected the instrumental colour measurements of the wet aged cooked samples through in an decrease in lightness, L^*, and redness, a^*. Yellowness, b^*, recorded a slight increase. Color difference, ΔE^*, between control meat sample and sample aged for 21 days, it was of 3.84 value.

3.3. Warner Bratzler shear force measurement

The textural properties of the effect of wet aging duration of meat on the Warner Bratzler parameters of raw meat samples can be observed in Table 5.

Table 5.

Warner Bratzler shear force of raw and cooked meat samples

Samples	Control	m_1	m_2	m_3	m_4	m_5
WBSF(N)raw	13.100±0.1	12.17±0.13	10.95±0.14	9.869±0.1	8.676±0.1	8.218±0.1
WBSF(N) cooked	45.692±0.20	37.957±0.16	36.059±0.24	33.362±0.2	31.983±0.25	29.580±0.20

The Warner–Bratzler Shear Force values ranged from 13.100 N (first days aged) to 8.218 N (21-days aged) (Table 5). Between control sample and 21th day of ageing, WBSF values significantly decreased in beef muscle, *Gluteus medius* ($P < 0.05$). For WBSF, both factors (ageing time and temperature) affected the results.

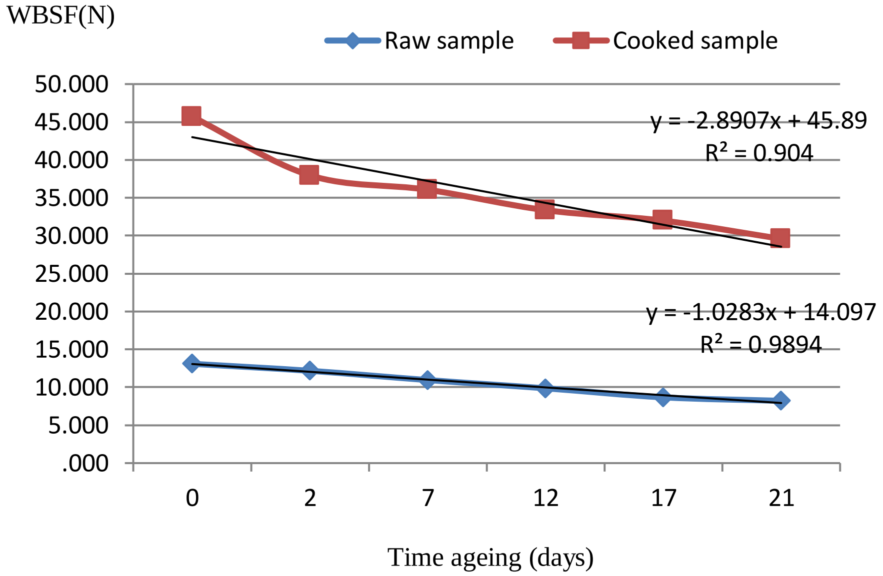


Fig.4. The correlations between WBSF of de raw and cooked meat samples and time wet ageing

Figure 4 shows the correlation between WBSF of de raw and cooked meat samples, and time ageing. Thus, the WBSF of the beef muscle reached a good correlations, $r^2 = 0.983$, for the raw sample and $r^2 = 0.898$ for the cooked sample. Cooking causes heat-induced denaturation of both myofibrillar proteins and connective tissue.

Koohmaraie *et al*, have been reported to reach maximum tenderness at approximately 11 to 14 days of ageing beef meat, they tend to experience a much smaller decrease in shear force values compared with game meat.

Thus, the higher degree of tenderization in eland muscles compared to beef may support the conclusion that game species may have increased proteolytic enzyme activity and a more efficient proteolytic system; an aspect that warrants further research [34].

3.4. TPA parameters results

The textural properties of the effect of wet aging duration of meat on the TPA parameters of raw meat samples can be observed in Table 6.

Table 6.

TPA parameters of *Gluteus medius* muscles on raw and cooked meat samples

TPA parameters*	Samples											
	Control		**m_1**		**m_2**		**m_3**		**m_4**		**m_5**	
	Raw	**Cooked**	**Raw**	**Cooked**	**Raw**	**Cooked**	**Raw**	**Cooked**	**Raw**	**Cooked**	**Raw**	**Cooked**
H (N)	15.36	23.13	13.73	22.79	12.49	20.53	12.74	19.67	10.92	18.47	9.66	17.96
R	2.29	2.25	2.35	2.55	2.39	2.98	2.78	3.00	2.80	3.01	2.85	3.07
A(N*s)	-0.06	-0.001	-0.08	-0.001	-0.11	-0.002	-0.12	-0.002	-0.13	-0.004	-0.19	-0.004
S	1.000	1.000	0.998	0.998	0.999	0.998	0.997	0.997	0.996	0.997	0.996	0.996
Co	0.443	0.566	0.436	0.582	0.435	0.601	0.434	0.636	0.439	0.630	0.394	0.644
G (N)	6.810	13.10	5.995	13.26	5.430	12.35	5.535	12.30	4.789	11.64	3.809	11.58
Ch(N)	6.810	13.10	5.988	13.24	5.429	12.32	5.519	12.26	4.774	11.60	3.796	11.53

*H: Hardness, R: Resilience, A: Adhesineness, S: Springiness, Co: cohesiveness, G: gumminess and Ch: chewiness

As it can be seen, all the textural parameters (hardness, resilience, chewiness, gumminess, adhesiveness, springiness and cohesiveness) were affected by the wet aging duration of meat.

The hardness for raw meat samples varied from 15.356 N to 9.66 N, for the cooking meat varied from 23.13 N to 17.96 N, thus registering a significant decrease ($P = 0.05$). The resilience of the meat samples, both raw and cooked ones, registered slight increases, from 2.29 and 2.83 for raw meat and from 2.25 to 3.07 for cooked meat.

The modifications for adhesiveness and springiness are insignificant, the variations of this parameters being very small. The values for cohesiveness were between 0.443 and 0.394, for the raw meat samples, and from 0.566 to 0.644 for the cooked meat samples. Another important texture parameter in meat products targeted at older consumers is chewiness. Wet ageing had significantly reduced chewiness ($P = 0.05$) compared with control sample. Furthermore, trends for gumminess were the same as for chewiness values, and depend slightly from hardness.

Some studies indicated that hardness accounted approximately 40.6 and 45.7 in tenderness and overall palatability [35]. Furthermore, they also noted that TPA springiness and chewiness were highly related to intramuscular fat content and consequently tenderness and juiciness. To elucidate our experimental design which examined texture profiles as a function of different ageing days, springiness, cohesiveness and chewiness were also determined, and the data was extensive explored during data mining process. Springiness of meat is probably associated to fibre swelling and diameter [36].

3.5. Statistical analysis

Tables 7 and 8 show the Pearson correlations between the wet ageing duration and the textural parameters obtained by the TPA and Warner Bratzler methods.

Table 7.
Pearson correlation between the wet aging time and textural parameters of raw meat samples

Parameters	Time(days)	WBSF(N)	H(N)	R	A(N*s)	S	Co	G(N)	Ch(N)
Time(days)	1.000								
WBSF(N)	-0.992	1.000							
H(N)	-0.956	0.959	1.000						
R	0.948	-0.948	-0.835	1.000					
A(N*s)	0.952	-0.933	-0.959	0.853	1.000				
S	-0.895	0.896	0.799	-0.970	-0.808	1.000			
Co	-0.704	0.643	0.750	-0.566	-0.866	0.567	1.000		
G(N)	-0.947	0.941	0.994	-0.820	-0.978	0.789	0.817	1.000	
Ch(N)	-0.948	0.942	0.994	-0.823	-0.978	0.792	0.816	1.000	1.000

H: Hardness, WBSF: Warner Bratzler Shear Force, R: resilience, Co: cohesiveness, G: gumminess and Ch: chewiness values varying between different timesof wet ageing were used to perform the correlation analysis (P< 0.05).

The statistical analysis showed significant negative correlations (p< 0.05) between time ageing and: WBSF (coefficient-0.992), hardness TPA (coefficient -0.948), springiness (coefficient -0.895), cohesiveness (coefficient -0.704), chewiness (coefficient -0.948) and gumminess (coefficient -0.947), and positive correlations (p< 0.05) of resilience (coefficient 0.948) and adhesiveness (coefficient 0.952).

Table 8.
Pearson correlation between the wet aging time and textural parameters of cooked meat samples

Parameters	Time(days)	WBSF(N)	H(N)	R	A(N*s)	S	Co	G(N)	Ch(N)
Time(days)	1.000								
WBSF(N)	-0.916	1.000							
H(N)	-0.973	0.913	1.000						
R	0.853	-0.942	-0.886	1.000					
Adh(N*s)	0.980	-0.885	-0.930	0.799	1.000				
Spg	-0.936	0.991	0.943	-0.929	-0.888	1.000			
Co	-0.687	0.633	0.667	-0.568	-0.794	0.586	1.000		
G(N)	-0.909	0.853	0.914	-0.803	-0.943	0.843	0.912	1.000	
Che(N)	-0.910	0.856	0.915	-0.806	-0.944	0.846	0.910	1.000	1.000

H: Hardness, WBSF: Warner Bratzler Shear Force, R: resilience, Co: cohesiveness, G: gumminess and Ch: chewiness values varying between different time of wet ageing were used to perform the correlation analysis (P< 0.05)

For the cooked meat samples, the statistical analysis showed significant negative correlations (p<0.05) between time ageing and WBSF (coefficient-0.916), hardness TPA (coefficient -0.973), hardness Warner Bratzler (coefficient –

0.951), springiness (coefficient -0.936), cohesiveness (coefficient -0.687), chewiness (coefficient -0.910) and gumminess (coefficient -0.909), and positive correlations (p <0.05) of resilience (coefficient 0.853) and adhesiveness (coefficient 0.980).

Resilience can be used as detection indicator for beef freshness in storage.

This study provides a method for rapid detection of beef freshness, and provides the basis for beef fresh keeping during production and transportation.

4. Conclusion

This study evaluated the effects of wet ageing on raw and cooked beef meat, *Gluteus medius* during 21 days of storage at 4-5 °C as regards textural, physico-chemical and color parameters.In conclusion we can remark that the anticipation of textural parameters in non-cooked, raw and cooked muscle has become more important for the consumers in terms of meat choice and satisfaction. The current data indicated that the magnitude of thermal toughening greatly varied between beef muscles where hardening of muscle samples by heating was more obvious.Therefore, the current data indicated that estimation of meat texture from raw material to cooked meats varies depending on the muscle type and its interaction with wet ageing day. In addition, the results mirror the importance of wet ageing time for objective measurements which ultimately estimate sensory tenderness and other quality traits.

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