EFFECT OF FINISHING AND AGEING TIME ON QUALITY ATTRIBUTES OF LOIN FROM THE MEAT OF HOLSTEIN-FRESIAN CULL COWS

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ABSTRACT

The effects of finishing time, (T0= 0, T1=30 and T2=60 days), on Holstein-Friesian cull cows (n=18) and *post-mortem* ageing, (1, 7, 14, 21, 35 and 42 days), under vacuum conditions of *Longisimus thoracis* (LT) muscles were investigated. The objective of this research was to study how finishing feeding (based on a commercial concentrate and corn silage), following a pasture period of 90 days, affected carcass and meat quality. Ageing time effect was also evaluated on the main quality attribute of added value pieces, such as "*striploin of ox*" from cull cows. Finishing treatment affected intramuscular fat content (IMF), moisture percentage, water holding capacity (WHC), colour parameters and shear force of meat at 24 hours *postmortem*, whereas ageing time enhanced meat tenderness, when this was measured by two textural tests, Warner-Braztler (WB) and textural profile analysis (TPA). A minimum shear force was achieved at 7 and 14 days of ageing for T1 and T2, respectively. No differences (P> 0.05) could be found in colour parameters from 7 to 42 days. The results show that a finishing time of two months is very beneficial, due to the increase in meat fatness, improved overall carcass quality and luminosity (L*). Furthermore, 14 ageing days were sufficient to improved tenderness. Ageing time did not have an effect on lipid oxidation (P> 0.05) and this leads us to conclude that meat shelf life exceeded 42 days under vacuum conditions'.

1. INTRODUCTION

The finishing of cull cows in the dairy herds can be an important activity to raise the profits of a cattle farm. The productive life of these cows is about five years. Then over 50% are culled for various reasons, none of which prevent them from being used for butchering. Finishing these animals increases their weight and improves their condition score and fatty state (Malterre, 1986; Cranwell, Unruh, Brethour & Simms, 1996), with a subsequent rise in price. This higher value can be very significant for fatty cows when they are sold to the special market of "*entrecote for gourmet*", as happens in the north of Spain. Therefore, this situation can give rise to an important increase in the price per kilogram of the meat carcass. This is due to a qualitative difference between carcasses of animals that are classified as O or P ,with a poor fat content, (C.E.E. nº 2273/91), compared to those ones classified as R or U, with good fat content (Carballo & Moreno, 2006). The economic interest of finishing cull cows has been studied primarily in beef breeds (Cranwell et al., 1996; Sawyer, Mathis & Davis, 2004). In Galicia (region of the north of Spain), there is a census of around 500,000 dairy cows (AEG, 2003), that mainly belong to the Holstein-Fresian breed. Therefore, we can estimate that about 50,000 cull cows from dairy and suckler herds are eligible to enter the beef supply chain. To produce "*entrecote for gourmet*" the carcass must have a fatness score of 4 or 5 (fatness scale 1 to 5) and it can not be finished off pasture during spring and summer due to a low body condition score. For this reason, the prolongation of finishing should be considered using conserved forages and concentrates. Furthermore, the sirloin, a highly appreciated piece of meat in Spain, is commercialized targeting consumers who exclusively value the sensory characteristics of the meat, in which the ageing process has an important effect. Tenderness is the most appreciated attribute by the consumer (Koohmaraie, 1996) and is affected by ageing. A minimum of tenderness is required to appreciate the flavour adequately. The instrumental measure best related to tenderness is the one obtained using the Warner-Braztler (WB) probe (Boleman et al., 1997). There are other measures of meat texture, such as the hardness or chewiness, measured with a compression probe, using a textural profile analysis (TPA). This test can be more useful in older animals, where connective tissue is more abundant, and which is not altered by ageing (Caine, Aalhus, Best, Dugan & Jeremiah, 2003). During ageing, we can obtain a satisfactory tenderness and flavour, however, a loss in meat coloration is also likely, changing from bright red to brown, due to the oxidation of the oxymyoglobin to myoglobin. Moreover, there can be damage due to lipid oxidation in the intramuscular fat content (IMF). Both types of oxidation are intimately related and are responsible for the appearance of smells and strange flavours of fat (Kanner & Harel, 1985) that can cause rejection by the consumer. These alterations are especially important in meats that with a have a high fat content. On the other hand, there is also a need for prolonged ageing owing to the cow's age and to the convenience of being able to access points of sale at long distances from the production site. It was, therefore, considered best to study the process of ageing under vacuum conditions because vacuum packaging of fresh meat provides sufficient shelf life for primal cuts for long-term storage and intercontinental transport (Lee & Yoon, 2001; Hotchkiss, 1994).

Therefore, the aim of this study is to investigate the effect of length of finishing on the daily gain and on the commercial parameters of the meat from the carcass of Holstein-Friesian culls cows. and the effect of ageing time on the main attributes of quality, such as textural properties, colour and fatty acid oxidation status.

2. MATERIALS AND METHODS

2.1. Animals: experimental design and live and post-slaughtered controls

Eighteen cows of the Holstein-Friesian breed, culled from the experimental herd of Agricultural Research Centre of Mabegondo, were used for this study. Thirteen cows were culled due to age, four due to problems related to the udder health and one due to reproductive. Cows were not pregnant when the study started, most of them had had their last calving between 10 and 13 months ago, two had had an abortion six and four months before being finished. The dry-off proceeding was as described: cows were separated from the herd and fed with hay and water only for a week. During this week, milk production decreased to 3-5 litres. At this time 12 grams of antibiotic (Cepravin ®) were administered. After veterinary treatment, cows were fed with hay for two or three days until they returned to the pasture. Animals were together in a single group, in spring pasture for at least three months before they were separated into three groups of six animals, blocked by live weight. Six of this animals, were immediately slaughtered, (control group or T0). This group was not used for ageing treatment and was not possible to include in *postmorten* study. Animals from the others groups were not finished indoors; they were finished in an area without pasture. One group spent two months (T2), while the second group spent only one month before being slaughtered (T1). Animals from T0, T1 and T2 were 8.8±2.3, 7.7±2.7 and 8.7±4.6 years-old, respectively. Live weight at start of pasture was 679±55, 653±77 and 633±58 for T0, T1 and T2, respectively. The concentrate ration consisted of corn silage "*ad libitum*" and three kilograms of concentrate per head per day. The chemical composition of grass and corn silage was respectively, in percentage (49.01 and 36.05 of dry matter (DM); 9.6 and 7.32 of crude protein (CP); 26.6 and 23.4 of acid detergent fiber (ADF); 49.7 and 44.94 of neutral detergent fiber (NDF)). The chemical composition of concentrate was 88.16 of DM, 16.22 of CP and 5.06 of FC. The net energy value of corn silage and concentrate, expressed as Unité Fourragere Viande (UFV) (Vermorel, 1978) was 0.64

and 1.14 respectively. The live weight of each animal was simple-weighing and measured during pasture (at start and end) and in the end of the finishing period. There were not any diseases or veterinary treatments during the experiment. Animals were conventionally slaughtered at a commercial abattoir four kilometres from the field where they had been grazing. Carcasses were classified using a conformation score, according to the EUROP scale (Conformation: P=1, O=2, R=3, U=4, E=5) (C.E.E. nº 2273/91), and a fatness score average, according to the European classification fatness score scale, which ranges from 1 (low fat) to 5 (high fat) (C.E.E. nº 2273/91). Immediately after slaughter, carcasses were weighed and chilled at 4°C in a cold chamber for 24 h. At this point, the *Longisimus thoracis* (LT) muscle was extracted from the left half of each carcass, between the fifth and the tenth rib. Samples were taken immediately to the laboratory under refrigerated conditions.

2.2. Analytical methods

2.2.1. pH, colour, myoglobin content and chemical composition

LT muscle was cut into seven steaks and all steaks were systematically assigned, the first steak was aged for one day, the second steak for seven days and so on and so forth for the other steaks". Steaks were cut using a cutting machine (Leader, Milano, Italy) into six steaks of 2.5 cm of thickness. On the first steak, pH, colour and proximate composition were determined. The other six steaks were individually packed under vacuum conditions (98%) (Tecnotrip EV-15-1CD, Terrasa, Spain) and were stored at 4 ºC until analysis at 7, 14, 21, 28, 35 and 42 days. The pH was measured using a pH-meter (Hanna Instrument HI-9024, Portugal) equipped with a glass probe for penetration. A portable colorimeter (Minolta CR-300 Osaka, Japan settings machine from CR-300 measuring head are: pulsed xenon arc lamp, angle of 0º viewing angle geometry and aperture size of 8 mm) was used to measure meat colour in the CIELAB space (Lightness, L*; redness, a*; yellowness, b* (CIE 1978). Hue (h_{ab}) and chroma (C*) were calculated from the a* and b* values according to expressions:

$$C^* = \sqrt{(a^*)^2 + (b^*)^2} \text{ and } h_{ab} = \arctan\left(\frac{b^*}{a^*}\right)$$

Samples were allowed to bloom for 1 h before measuring directly in contact with air (Insausti et al., 1999). All measurements were made in triplicate. Heminic pigments (expressed as myoglobin) were measured in duplicate, according to the methodology of Hornsey (1956). A near infrared spectrophotometer (Foss Tecator NIRS 6500, Denmark) was used to determine chemical composition, in duplicate, according to the methodology proposed by Moreno et al., (2007).

2.2.2. Texture analysis

To measure properties of texture, the meat was cooked in a water bath at 75 ºC for 1 h by immersion in water with automatic temperature control (Selecta Tectron Bio, Barcelona, Spain). Then samples were cooled to room temperature by placing the vacuum package bags in a circulatory water bath set at 18 ºC for a period of 30 minutes. The samples for WB shear test were obtained by cutting pieces of approximately 1x1x2.5 cm (height x width x length) of cross section, parallel to the muscle fibre direction. They were completely cut through using a WB shear blade with a triangular slot cutting edge and three parameters were measured. The first was the maximum shear force (MØller, 1980), represented by the highest peak of the force-time curve thus representing the maximum resistance of the sample to the cut. The second parameter measured was the firmness to the cut; the shear firmness (Brady & Hunecke, 1985), represented by the slope from the beginning of the cut up to the highest point of the force-time curve, and finally the total work required to cut the sample, represented by the area under the curve obtained. Textural parameters, measured using the WB probe (of 3 mm of thickness) were obtained with the sample at room temperature. Samples for TPA (Bourne, 1978) were obtained by cutting cubes of 1x1x1 cm approximately perpendicular to the muscle fibre direction and then compressing to 80 % with a compression probe of 19.85 cm^2 of surface contact. Between the first and second compression, there was an interval of 2 seconds. In this test the following variables were obtained: hardness, cohesiveness, springiness, gumminess and chewiness. A texture analyser (Stable Micro Systems TA-XT2, UK) was used for both tests, and all samples were cut or compressed perpendicular to the muscle fibre direction at a crosshead speed of 2.5 and 1 mm/s for WB and TPA test, respectively. The average value for each LT sample was recorded between six and eight times.

2.2.3. Water holding capacity

The water-holding capacity (WHC) was measured in two ways: Cooking loss (CL) and pressing loss (PL). CL was evaluated by cooking the LT muscle as described in the texture analysis. CL was calculated by measuring the difference in weight between the cooked and raw samples, as follows:

$$CL(\%) = \frac{(initial\ fresh\ meat\ weight - meat\ after\ cooking\ weight)}{(initial\ fresh\ meat\ weight)} \times 100$$

To determine PL, a sample of intact meat of 5 g was placed onto two disk of Whatman No. 1 filter paper (Filter Lab, Spain). After weighing the meat, a mass of 2.5 kg was applied for 5 min. The percentage of released water was calculated as:

$$PL\ (\%) = \frac{(initial\ fresh\ meat\ weight - meat\ after\ pressing\ weight)}{(initial\ fresh\ meat\ weight)} \times 100$$

2.2.4 Lipid oxidation analysis

Lipid stability was evaluated in the steaks using a small 2 g portion. Lipid oxidation, measured by aldehydes generated in the process of polyunsaturated fatty acid oxidation, was determined by measuring 2-thiobarbituric acid reactive substances (TBARS) using the method proposed by Vyncke (1970) with the modification that samples were incubated at 70 ºC in a forced oven (Selecta 2000210, Barcelona, Spain). Results are expressed as (mg malonaldehyde / kg of fresh meat).

2.3. Statistical analysis

For the statistical analysis of the results of animal performance and carcass quality an analysis of variance (ANOVA) using the General Linear Model (GLM) procedure of the SPSS package (SPSS, version 15.0, USA) was performed for all variables considered in the study (statistical analysis conditions: parameterization by sigma restricted model, sums of squares type III and ANOVA error term using residual term). Age was no blocked at the start of pasture period, however when we include age in the model as co variable they only have influence on average daily gain (ADG) pasture. The model used was:

$$Y_{ij} = \mu + T_i + A_{ij}(C) + \varepsilon_{ij}$$

where:

Y_{ij} is the observation of dependent variables, μ is the overall mean, T_i is the effect of finishing treatment, $A_{ij}(C)$ is the effect of age as co variable and ε_{ij} is the residual random error associated with the observation

When we studied the effect of ageing time, over meat quality a GLM procedure was carried out. Fixed effect of finishing treatment, ageing time and their interaction were included in the initial model. However, as only significant interactions of finishing treatment and ageing time were detected for L* and CL they were excluded for the final model. The model used was:

$$Y_{ij} = \mu + T_i + t_j + (T \times t)_{ij} + \varepsilon_{ij}$$

where:

Y_{ij} is the observation of dependent variables, μ is the overall mean, T_i is the effect of finishing treatment, t_j is the effect of ageing time, and $(T \times t)_{ij}$ is the interaction term of finishing treatment and ageing time and ε_{ij} is the residual random error associated with the observation.

The least squares mean (LSM) were separated using Duncan's t-test. All statistical test of LSM were performed for a significance level $\alpha<0.05$. Correlations between variables ($P<0.05$) were determined by correlation analyses using the Pearson´s linear correlation coefficient (SPSS 15.0)

3. RESULTS AND DISCUSSION

3.1. Live weight, daily gain during finishing feeding.

The finishing pasture period was 42 days for the three treatments, whereas the finishing concentrate period was for 34 and 62 days, for treatments T1 and T2, respectively. During the finishing period with concentrates, each cow ate an average amount of 1209 and 2540 kg of dry matter (DM) of corn silage (0.64 UFV) and 102 and 186 kg of feed concentrate (1.14 UFV) for T1 and T2, respectively. There were no significant differences in age and live weight between cows on different treatments (Table 1). As the finishing period increased, the average daily weight gain decreased and this is a widely reported result (Monserrat, 1994; Matulis, McKeith, Faulkner, Berger, & George 1987). During finishing, the growth performance was 1.31 and 1.07 kg/d for T1 and T2, respectively. This is in accordance with findings in other dairy Holstein cows (Jones,

1983) and beef cows studies (Graham & Price, 1982). Vestergaard et al. (2007) found an average daily gain value of 1.16 kg when they worked with culled Fresian dry dairy cows finishing over a period of two and four months.

3.2. Carcass quality characteristics

All carcass quality characteristics were improved with finishing period (T2 against T0) (Table 1). Carcass weight is a poor estimator of meat yield (Hopkins & Roberts, 1995), but the results are included for comparison with other researchers' findings. The effect of finishing time is more illustrative when the conformation, fatness score and carcass yield are considered. An important and significative difference ($P<0.01$) was found in carcass yield in cows from T2 against T0 (49.43 vs. 39.54). This result could be of importance for the live animal market price. These results were as expected, because it is known that a period of finishing improves the characteristics of the carcass and are similar to findings in other studies (Boleman, Miller, Buyck, Cross, & Savell, 1996). The carcass classification for a loin to be designated as “sirloin of ox” was obtained in all animal carcasses from T1 and T2 (100 %). A marketing of this carcass in a more demanding market (corresponding to carcasses with classification $\geq$ R3), was only obtained in zero of T0, one (16.7 %) of T1 and four (66.7 %) of the T2. This shows a substantial improvement in the level of consumer valuation according to Carballo and Moreno (2006), who also indicates a high difference in price, on the Spanish market, between carcasses of cows R and U as opposed to P and 0 (C.E.E. nº 2273/91).

3.3. Meat Quality

In Table 2 the effects of finishing time on the main physical-chemistry characteristics of the LT are shown. We found significant variations between treatments in the pH

(P<0.001), although these values were below 6, in a "normal" range of pH (Renerre, 1986). Even the maximum pH value recorded was only 5.69 (for T2) which, according to Thomson, Dobbie, Cox, and Simmons (1999) may be regarded as acceptable as it is lower than the 5.7, maximum value suggested.

With regard to the parameters of chemical composition studied, the percentage of protein, ash (P<0.05) and water, IMF (P<0.1) of LT was affected by finishing treatment. The percentage of IMF was increased by the finishing treatment, therefore the cows with T2 had 29 % more IMF than those of T0 (8.52 vs. 6.02 %). This result was expected, and also reported by Matulis et al., 1987): This is the main objective of finishing periods and it has been established that the meat percentages of protein and ash have a constant value, whereas IMF has large fluctuations. On the other hand, water content decreased with a longer finishing period, also to be expected, since it is accepted that the increase in IMF content in the meat means a decrease in water content (Varela, 2002). In this study the correlation between moisture content and IMF (r= -0.944) was highly significant (P<0.01).

As for the chromatic characteristics of the meat, we found significant differences between treatments in the meat colour parameters and subcutaneous fat (SCF), except for the b* of LT and SCF. Cows from the T2 group provided a meat with higher L* and less red meat than those ones from T1, whereas the a* of the SCF increased over the finishing period. The lighter, brighter and redder colour of meat from finishing-fed cows has also been detected by others (Cranwell et al., 1996). WHC, measured by CL was larger in T0 than in T2 (28.37 vs 25.97 %), whereas moisture content was higher in T2 than T0 (70.32 vs 72.57%; P<0.05). There is an inverse relationship between moisture content and CL, and this result has been widely reported (Jeremiah, Dugan, Aalhus, & Gibson, 2003). An inverse relationship is observed between WHC and IMF content, and as we have already indicated IMF was higher in T2 than in T0, whereas CL is higher in T0 than T2, this finding was reported by (Hildrum, Solvang, Nilsen, Froystein, & Berg, 1999).

Significant differences (10.62 vs 8.00 $P<0.05$) in maximum shear force at day 1 between animals from different treatments were found. Generally finishing feeding improves shear force values of meat (Boleman et al., 1996; Cranwell et al., 1996). However, Schnell, Belk, Tatum, Miller, & Smith (1997) worked with cull beef cows, in an identical finishing feeding as our work (28–56 days) and which did not improve tenderness and reduce shear force values compared with cows slaughtered immediately after purchase. Cows from T2 had lower shear force, which is undoubtedly related to the higher percentage of fat, from T2 than T1, as already indicated by these authors, as IMF provides a higher degree of tenderness to the muscle. The increased IMF may be responsible for the improved tenderness with finishing feeding as the correlation was negative and not very high for the improved between IMF and shear force value ($r=-0.35$). These correlations are lower to results obtained in other studies (Vestergaard et al., 2007; Wheeler, Cundiff, & Koch, 1994). In addition, moisture content was positively related to tenderness in feedlot finished (Galli et al., 2008). These authors found a negative correlation between moisture content and WB shear force of $r=-0.67$, whereas we obtained a correlation of $r=-0.38$ in this study.

However, analyses of consumer preferences have shown that the packing house should target a WB of 4.2 kg or below in meat in order to attain high levels of consumer acceptance (Huffman et al., 1996). This degree of acceptance will be increased to 5.1 kg, when meat is eaten in restaurants (Miller et al., 1995). Our results show that ageing time is necessary.

In general, we have an improvement in tenderness and meat colour characteristics of meat from finishing-fed cows (Table 2). This conclusion agrees with the one outlined by Vestergaard et al., (2007) indicating the beneficial effect of the finishing treatment.

3.4. Effect of finishing and ageing time on meat CL and textural properties, measured by WB test

Table 3 shows the values obtained from the CL and from each of the texture parameters measured by the WB method, for different days of ageing, for both treatments. CL was higher in meat from T1 than T2 for all ageing days, being significantly different ($P < 0.1$), with the exception of the last day of ageing. We can see how CL from T1 showed a greater range of variation, with a difference of 7.82 points between the lowest and highest values (23.25 vs. 31.07 %), than in T2 with 1.42 points (25.07 vs. 26.49 %) for the different ageing days. Comparable CL was found by Lepetit, Grajales, & Favier, 2000 in cooked meat from Fresian cull cows. These authors found that CL was higher as the temperature increased, and in the range of 70-80 ºC they found an increment in CL of 20 to 32 %. This situation can explain how small differences in the control of cooking temperature over a long time can affect the final result. Therefore, a rigorous control of temperature is necessary.

The finishing treatment affected the values of maximum shear force between days 1 and 7 post-slaughtering ($P<0.05$), and did not show significant changes for either treatment from the 14 days of ageing. The time of ageing only affects the first 15 days for the animals from T1, whereas the animals from T2, on the seventh day of ageing reached a shear force of 5.60 kg/cm^2. After these periods there was no further significant decrease ($P>0.05$) in either treatment. This is an interesting result, how animals with a longer finishing time and consequently with a higher IMF percentage reached the minimum shear force in a shorter ageing time. This outcome can also explain that the ageing time required to achieve the lowest shear force value in the cows of this study should be similar to that reported for younger animals by Campo et al. (2000), when it has been widely established that to obtain the maximum tenderness in meat from old animals a longer period of ageing compared to young animals is required (Young & Bass, 1984). Shear firmness and total work data are dependent on maximum shear force value and thus, the analysis of the result is analogous to shear force. Less shear firmness was obtained in the meat at 1 and 7 days of ageing for T2 against T1, although it was only significant ($P<0.05$) in 7 and 35 days. If we observe the total work necessary to cut the sample, we find that less work is required for all ageing days in the animals belonging to T2, with the exception of day 25 of ageing but that must be considered an anomalous value.

3.5. Effect of finishing and ageing time on meat textural properties measured by TPA test

The hardness of the meat showed significant differences ($P<0.01$) between treatments at 24 hours of ageing, though there were not significant differences for the rest of the ageing period between treatments (Table 4). An analogous situation existed for values of chewiness, gumminess and cohesiveness. There were significant differences at 24 hours between the two treatments ($P<0.05$). Meat hardness, a parameter related very closely to the connective tissue content, was higher in the meat of T2 than in T1, probably as a consequence of the unplanned higher age of the cows from group T2. It is well known that the age of the animal at the time of slaughtering is the factor that most influences the amount and chemical composition of the connective tissue (Sentandreu, Coulis, & Ouani, 2002). As chewiness is the product of hardness, cohesiveness and springiness, we can observe how the results for this parameter are affected by the value of hardness. If we compare the hardness values, with the ones found by other authors (Campo et al., 2000; Sañudo, Monson, Panea, Pardos, & Olieta, 2003), we can see that our values are higher. This is due to different factors, such as temperature/time of cooking, since this has an important effect on collagen solubilization (Martens, Staburvik, & Martens, 1982). The breed type is also of importance because meat breeds have lower collagen content compared to dairy production breeds (Hocquette, Renand, Levéziel, Picard, & Cassar-Malek, 2005) and also the age of the animal, itself, since the solubility and cross linking of the collagen fibres increases as the animal gets older (Aberle et al., 2001). The last factor is the most important and the age of the animals in this study was high. Our results for hardness are comparable to those found by Lepetit et al., (2000). The experiment was not similar to ours because these authors utilized a 95 % compression ratio, a different crosshead speed (50 mm/min) and used different mechanical devices: they used a longitudinal test (Lepetit,. 1989). These authors found maximum stress values of 25-30 kg/cm^2 for six-year-old Friesian cull cows, when LT was cooked at 75 ºC for 90 minutes.

3.6. Effect of finishing and ageing time on pH, colour parameters and lipid oxidation of meat

A summary of values for pH, colour parameter, the myoglobin content and IMF oxidation status is presented in table 5. Average values for pH measured in the meat varied between 5.45 and 5.80. The pH values of T2 were more constant than pH values of T1. We found significant differences between treatment at 24 hours ($p<0.001$) and at 21 and 42 days. However, at 21 and 42 days the differences are less significant, so the pH values of the meat were stable at 24 hour *post* -slaughtered.

Meat luminosity (L*) increased from day 1 to 42 in T1 (33.27 vs 35.20; P<0.05), whereas it decreased in T2 (36.91 vs 31.16; P<0.05). There were higher values in T1 than T2 at 1 day (p<0.01), but it was higher in T2 than T1 for the days 21, 35 and 42. (P<0.05). Index of red (a*), yellowness (b*) and chroma (C*) increased from day 1 to 7 and after maintained a constant value until day 42 for both treatments. In general meat from T1 cows was redder and had more yellowness and thus had a higher chroma than T2 cows, although there were no significant differences between the treatments. Hue (h_{ab}) increased from day 1 to 14 in T1 and from day 1 to 7 in T2 and then stayed constant until day 42 for both treatments. For T2, a* did not change significantly (P<0.05) over the 42 days of storage. This indicates that the myoglobin was not suffering alteration in the vacuum package. For T1 we had significant changes during storage days, but values of a* varied between 18.26 and 21.02, so red colour was not diminished. The effect of ageing time on a* and b* in the first days post-slaughter is a widely reported result. It has been reported that the increases in these values are more important during ageing process is under vacuum conditions (Oliete et al., 2006) due to the loss of respiratory activity of the mitochondria during the ageing. The content in heminic pigments indicates how the myoglobin is altered. Myoglobin content was always higher in T2 than T1 (Table 5). It has been established that heminic pigment of the muscle, increases with age (Cross, Durland, & Seideman, 1986; Gil, Serra, Piedrafita, Quintanilla, & Oliver, 1998). This is due to the fact that when animals get older, the IMF increases and the capillary permeability decreases, so a higher amount of myoglobin is required to ensure a suitable contribution to the cells (Renerre & Valin, 1979). For this reason the meat seems redder and in T2 the values of myoglobin are higher, with the exception of the value at 24 hours.

With regard to the lipid oxidation of IMF, we did not find significant changes during the whole ageing period. This outcome was not surprising, as the meat storage conditions during the storage period in a vacuum environment protect the meat from oxygen and light. Therefore the IMF did not undergo lipid oxidation. Our values are similar to the ones found by Realini, Duckett, Brito, Dalla Rizza, & De Mattos, 2004; Descalzo et al., 2005 in fresh beef meat at 24 hour *posmortem*.

CONCLUSIONS

The finishing period after pasture period is beneficial due to the increment of 1kg/day of live weight and to the improvement of the characteristics of the carcass. A finishing period of two months with concentrates can be advantageous, when the carcass is destined to a market with the basic end of commercializing one "*entrecote for gourmet* ". The meat has a major percentage of fat and is more luminous, with lower values on the index of red and yellow. An ageing time of 14 and 7 days for T1 and T2, respectively, can. be sufficient for the meat of cull cows of Holstein-Friesian breed to acquire optimum texture values. At this time, the shear force value for both treatments was low and indicated an overall good tenderness in these cows. The result from TPA was not clear and to verify that ageing period improved tenderness, a trained panel must be used to confirm this hypothesis.

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Table captions

Table 1. Age, live weight, average daily gain, carcass weight, EUROP conformation, fatness scores and loin weight in culled cows without (T0) and with 1 (T1) or 2 (T2) month finishing period.

Table 2. .Meat quality characteristics (chemical composition, colour parameters, WHC and maximum shear force of LT, from culled cows without (T0) and with 1 (T1) or 2 (T2) month finishing period.

Table 3. Cooking Losses shear force, shear firmness and total work of LT, from culled cows with 1 (T1) or 2 (T2) month finishing period during ageing time (1 to 42 days).

Table 4. Hardness, springiness, chewiness, gumminess and cohesiveness of LT, from culled cows with 1 (T1) or 2 (T2) month finishing period during ageing time (1 to 42 days).

Table 5 pH, colour parameter (L*, a*, b*, C* and h_{ab}) and lipid oxidation of LT, from culled cows with 1 (T1) or 2 (T2) month finishing period during ageing time (1 to 42 days).

Table 1.

	T0	T1	T2	SED	Sig
Age (year)	8.83	7.66	8.66	0.75	n.s
Live weight					
LW (at start pasture period) kg	679	653	633	15.03	n.s
LW (at end pasture period) kg	769	727	693	15.40	n.s
LW (at slaughtered) kg	769	762	751	13.64	n.s
Average daily increment					
ADG pasture period kg/d	1.46	1.51	1.22	0.08	n.s.
ADG finishing period kg/d	---	1.02	0.94	0.05	n.s.
ADG total period kg/d	1.46 a	1.31 ab	1.07 b	0.05	*
Carcass Characteristics					
Carcass weight (kg.)	305	330	333	7.78	n.s
Conformation	1.83	2.16	2.50	0.12	n.s
Fatness scale	3.00	4.00	4.00	0.16	n.s
Carcass yield (%)	39.54 a	43.40 b	49.43 c	1.14	**
Loin weight[a] (kg)	7.25	7.61	7.69	0.22	n.s

Significance: *** (p<0.001), ** (p<0.01), * (p<0.05), + (p<0.1), n.s (not significant).[a]rib weight 5-10 Conformation: P=1, O=2, R=3, U=4, E=5, S=6

Different letter after the mean value within the same row indicates significant differences (P<0.05) between treatment

Table 2.

	T0	T1	T2	SED	Sig
pH	5.53 a	5.52 a	5.69 b	0.02	***
Chemical Composition (%)					
Water	72.57 a	72.41 ab	70.32 b	0.45	+
Ash	1.07 a	1.03 ab	0.99 b	0.01	*
Protein	21.64 a	19.73 b	20.42 ab	0.30	*
Intramuscular Fat (IMF)	6.02 a	6.84 ab	8.52 b	0.44	+
Water-holding capacity (%)					
Cooking Losses (%)	28.37	28.54	25.47	0.72	n.s
Pressing Losses (%)	21.48 a	18.48 b	22.35 a	0.65	*
Maximum shear force (kg/cm^2)	7.91 a	10.62 b	8.00 a	0.50	*
Colour *Longisimus Thoracis*					
Luminosity (L*)	35.29 ab	32.27 a	36.91 b	0.52	**
Index of red (a*)	14.64 a	18.26 b	15.91 a	0.50	**
Index of yellow (b*)	7.17	8.76	8.06	0.29	n.s
Mioglobyn (mg/g fresh meat)	6.82	7.01	5.94	0.25	n.s
Colour Subcutaneous fat					
Luminosity (L*)	58.18	54.52	55.95	0.68	n.s
Index of red (a*)	5.98 a	6.49 a	9.00 b	0.51	*
Index of yellow (b*)	22.58	21.21	20.96	0.91	n.s

Significance: *** (p<0.001), ** (p<0.01), * (p<0.05), + (p<0.1), n.s (not significant) Different letter after the mean value within the same row indicates significant differences (P<0.05) between ageing time.

Table 3.

	Ageing Time (days)							
	1	**7**	**14**	**21**	**28**	**35**	**42**	**SED**
Cooking Losses (%)								
T1	28.54ab	31.07a	23.70 c	23.25 c	28.81ab	29.08ab	27.47 b	0.50
T2	25.47	26.49	26.28	25.89	26.13	25.82	25.07	0.38
Sig	+	**	+	*	+	**	n.s.	
Shear Force (kg/cm^2)								
T1	10.61 a	8.07 b	5.87 c	5.40 c	5.57 c	5.87 c	5.20 c	0.33
T2	8.00 a	5.60 b	5.70 b	5.93 b	5.18 b	5.09 b	5.20 b	0.27
Sig	*	**	n.s.	n.s.	n.s.	n.s.	n.s.	
Shear Firmness (kg/cm^2)								
T1	3.66 a	2.97 b	2.36 c	2.12 c	2.05 c	2.19 c	2.21 c	0.10
T2	3.05 a	2.28 b	2.35 b	2.25 b	2.19 b	1.80 b	1.86 b	0.09
Sig	n.s.	*	n.s.	n.s.	n.s.	+	n.s.	
Total work (kg*s)								
T1	35.51 a	32.88 a	21.46 b	17.20 b	16.02 b	16.05 b	20.07 b	1.35
T2	23.85 b	17.41 a	20.24ab	24.22 b	15.98 a	14.39 a	15.29 a	0.92
Sig	*	***	n.s.	**	n.s.	n.s.	*	

Significance: *** (p<0.001), ** (p<0.01), * (p<0.05), + (p<0.1), n.s (not significant). Different letter after the mean value within the same row indicates significant differences (P<0.05) between ageing time.

Table 4.

	Ageing Time (days)							
	1	**7**	**14**	**21**	**28**	**35**	**42**	**SED**
Hardness (kg/cm^2)								
T1	15.62 a	16.45 a	17.62ab	21.09cb	25.31 d	21.83cd	20.07 a	0.69
T2	20.39ab	16.24 a	18.30	19.84ab	21.96	22.34 b	19.10	0.63
Sig	**	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	
Springiness								
T1	0.49	0.51 ba	0.46	0.46 c	0.52	0.50 ba	0.49	0.004
T2	0.50	0.52 a	0.50	0.46 b	0.52	0.51 ab	0.50	0.006
Sig	n.s.	n.s.	+	n.s.	n.s.	n.s.	n.s.	
Chewiness (kg)								
T1	3.58	4.03 bc	4.02	2.91 c	6.47	5.08 ab	3.88	0.25
T2	4.93	4.11 a	4.42	3.98 a	5.30	5.42 a	4.48	0.20
Sig	**	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	
Gumminess (kg/cm^2)								
T1	7.37 bc	7.80 bc	9.15abc	6.00 c	12.13 a	9.90 ab	7.83 bc	0.47
T2	9.66 a	7.88 a	8.65 a	8.40 a	9.98 a	10.48 a	8.70 a	0.34
Sig	*	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	
Cohesiveness								
T1	0.47	0.45 a	0.46	0.45 a	0.45	0.45 a	0.46	0.002
T2	0.44b	0.43 ab	0.49	0.44 ab	0.45	0.46 ab	0.44	0.004
Sig	*	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	

Significance: *** ($p<0.001$), ** ($p<0.01$), * ($p<0.05$), + ($p<0.1$), n.s (not significant). Different letter after the mean value within the same row indicates significant differences ($P<0.05$) between ageing time.

Table 5.

	Ageing Time (days)							
	1	**7**	**14**	**21**	**28**	**35**	**42**	**SED**
pH								
T1	5.52 a	5.57 b	5.62 c	5.77 d	5.56 b	5.73 d	5.66 c	0.01
T2	5.69 ab	5.71 ab	5.67 ab	5.45 a	5.61 ab	5.80 b	5.73 ab	0.03
Sig	***	n.s.	n.s.	**	n.s.	n.s.	*	
Colour Parameters								
Luminosity (L*)								
T1	32.27bc	32.12ab	30.92 a	32.32ab	33.49bc	35.81 d	35.20cd	0.33
T2	36.91 b	32.04 a	30.98 a	30.24 a	32.92 a	31.07 a	31.16 a	0.44
Sig	**	n.s.	n.s.	*	n.s.	**	**	
Index of red (a*)								
T1	18.26 a	20.05ab	21.02 b	20.84 b	20.93 b	18.92ab	20.24ab	0.27
T2	15.91	19.83	19.99	18.90	19.44	18.42	19.70	0.49
Sig	*	n.s.	n.s.	+	n.s	n.s.	n.s.	
Index of Yellow (b*)								
T1	8.76 a	10.23 b	11.57 b	11.35 b	11.47 b	10.56 b	11.02 b	0.20
T2	8.06 a	10.99 b	11.34 b	10.40 b	10.05ab	10.35 b	10.77 b	0.29
Sig	n.s.	n.s.	n.s.	+	n.s.	n.s.	n.s.	
Chroma $\sqrt{(a^*)^2+(b^*)^2}$								
T1	20.15 a	22.52ab	23.98 b	23.74 b	23.87 b	21.67ab	23.05 b	0.33
T2	17.84 a	22.67 b	22.99 b	21.58ab	21.89ab	21.13ab	22.45ab	0.56
Sig	*	n.s.	n.s.	*	n.s.	n.s.	n.s.	
Hue ($\tan^{-1}(b^*/a^*)$)								
T1	27.50 a	29.66 b	32.55 c	32.23 c	32.47 c	33.29 c	33.21 c	0.34
T2	29.52 a	32.98 b	34.07 b	32.80 b	29.93 a	33.85 b	32.40 b	0.34
Sig	*	***	*	n.s.	*	n.s.	n.s.	
Myoglobin								
T1	7.01 ab	6.89 ab	6.67 ab	6.09 b	7.39 a	6.45 ab	6.69 ab	0.13
T2	5.94 d	7.32 bc	8.23 a	7.39 bc	8.01 ba	6.92 c	6.73 c	0.14
Sig	**	n.s.	*	***	n.s.	n.s.	n.s.	
Lipid Oxidation								
Index of TBA								
T1	0.25c	0.28abc	0.24 c	0.31 ab	0.23 c	0.26 bc	0.32 a	0.008
T2	0.19 b	0.23 ab	0.25 ab	0.31 a	0.29 ab	0.25 ab	0.27 ab	0.01
Sig	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	

Means with different setter in the same row show significant differences ($p<0.05$; Duncan test) for the effect ageing time.- (+= $p<0.1$, *=$p<0.05$, **=$p<0.01$, ***= $p<0.001$).

Units: myoglobin (mg myoglobin/ g fresh meat); index of TBA (mg MDA/kg fresh meat).

1