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THE QUALITY OF BEEF FROM ABERDEEN ANGUS X HOLSTEIN-FRIESIAN CROSSBREEDS

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Abstract

The aim of this study was to evaluate the quality of beef from Aberdeen Angus x Holstein-Friesian crossbreeds. The research material was the longissimus thoracis et lumborum muscle from carcasses of young bulls. Colour parameters and pH value of the muscles were measured during post-mortem chilling of carcasses. During meat ageing was determined drip loss, cooking loss, peak shear force (WBSF) as well as sensory analysis was also carried out. The results confirmed the beneficial effect of crossbreeding on all of the examined meat quality characteristics. Moreover, peak shear force was reduced and tenderness was improved by about 50% due to the use of the 14-days ageing.

Key words: *beef, quality, tenderness, colour, cattle, cross-breeding, Aberdeen Angus.*

1. INTRODUCTION

Beef is a major source of high quality protein, micronutrients, particularly iron, zinc and biologically active substances, such as Coenzyme Q10, or CLA as well as B vitamins. In addition to the biological quality, consumers buying meat pay special attention to its palatability. Palatability of beef is related to its three main distinguishing quality features, such as tenderness, juiciness and flavour. Among these three features, tenderness has been identified as the most important factor in determining consumer satisfaction (Goodson et al., 2002). Over the past few decades, much research has been focused on improving beef tenderness and successfully identified many aspects. However, the problem of insufficient beef tenderness is still current.

Meat quality depends on many factors: genetic, environmental, nutritional, animal welfare, technological during slaughter and post-mortem ageing. In Poland, most of beef is obtained from dairy cows. Such meat is dark, though, unpalatable with strongly perceptible taste of liver and milky flavour (Cierach et al., 2009a,b; Niedźwiedź et al., 2013). Effective method of improving the quality of Polish beef could be crossbreeding. Sires of Continental European breeds are used most often for crossbreeding on dairy cows. Continental breeds are large, and therefore their use to crossbreeding with small females is not recommended, because increases the risk of complications during birth. Moreover, these breeds are relatively difficult to maintain and often have a sharp temperament (e.g. Limousin). Good alternative could be the use of Scottish breeds, such as Aberdeen Angus or Highland. These are relatively small breeds, with a calm temperament and well adapt to harsh environmental conditions.

Furthermore, extremely important for meat quality is the correct course of post-mortem changes, which occur in muscle tissue during carcass chilling and meat storage. The course of post-mortem changes depends on technological factors. These factors are even more important because improper control of slaughter operations and regimes of carcass chilling, as well as meat ageing may negate the whole breeder's effort to produce animals characterized by a potentially beneficial slaughter value. Therefore, the aim of this study was to evaluate the effect of crossbreeding of Aberdeen Angus and Holstein-Friesian cattle and post-mortem handling of carcasses on beef quality.

2. MATERIALS AND METHODS

2.1 Samples

The *longissimus thoracis et lumborum* muscle of five Aberdeen Angus x Holstein-Friesian (AAxHF) young bulls were obtained from slaughterhouse located in the north-eastern Poland. Cattle were slaughtered at the age

of 23 months, according to the current EU regulations (COUNCIL REGULATION (EC) No 1099/2009). Chilling of the carcasses was performed by a one-stage method in the temperature of 2±1°C up to 48 h post-mortem. The meat temperature at 48 h was ≤7°C. Muscles were excised from carcasses after 48 h post-mortem, next divided into four cuts and separately vacuum packed. Samples were transported to the laboratory and subjected to ageing for 2, 3, 7 and 14 days post-mortem. All analyses were performed at appropriate time intervals.

2.2 pH value measurement

Measurements of pH value were performed using a pH-meter HI 99161 (HANNA instruments US Inc.) with an electrode FC232D (HANNA instruments US Inc.). Prior to each series of measurements the pH-meter was calibrated to pH 4.01 (HI 5004L, HANNA instruments US Inc.) and 7.01 (HI 5007L, HANNA instruments US Inc.). To read the pH value, electrode was placed directly in the central part of each cut (to a depth of about 2.5 cm) (Niedźwiedź et al., 2012). Measurements were taken during carcass chilling (1, 3, 6, 12, 24 h post-mortem) and during meat ageing (2, 3, 7 and 14 day's post-mortem). Three measurements were performed on each cut at each time interval.

2.3 Colour parameters measurements

Colour parameters were measured in colour-opponent space CIE L*a*b*, by SPECTRO-COLOR portable spectrophotometer (HACH LANGE, UK), calibrated against black and white calibration plates (HACH LANGE, UK). L* - lightness, a* - redness and b* - yellowness were determined. Conditions of measurement were: 8° standard observer, measuring area 8 mm Ø, illuminant D65, 8° diffuse illumination. Measurements were taken during carcass chilling (1, 3, 6, 12, 24 h post-mortem) and during meat ageing (2, 3, 7 and 14 day's post-mortem). Measurements were taken immediately after cutting off 2.5 cm thick slice of meat. Three measurements were performed on each cut at each time interval.

2.4 Drip loss

Drip loss was evaluated at 2, 3, 7 and 14 days post-mortem. Drip loss was assessed as the weight loss of three 2.5 cm thick slices of muscle. After cutting, the slices were weighted, vacuum packed and stored at 4±1°C. After the certain period of time meat slices were unpacked, dried with a paper towel and reweighed. Drip loss was presented as a percentage of the original weight of meat slice (before packing).

2.5 Cooking loss

Cooking loss was evaluated at 2, 3, 7 and 14 days post-mortem. Cooking loss was assessed as the weight loss of 2.5 cm thick steak (weight approx. 300g) during cooking. After cutting, the steaks were weighted, vacuum packed and subjected to cooking. The cooking conditions for tested steaks were: 45 mins in a pre-heated water bath (80±5°C) until the core temperature had reached 70°C and then cooled to reach a core temperature below 7°C. After cooling, the steaks were unpacked, dried with a paper towel and reweighed. Cooking loss was presented as a percentage of the original weight of meat slice (before cooking).

2.6 Warner-Bratzler shear force (WBSF)

Cooked samples subjected to evaluation of cooking loss were also subjected to WBSF determination. Cores 1.27 cm in diameter were prepared from cooked steaks and sheared perpendicularly to the muscle fibre orientation using the Warner-Bratzler shear V-blade (type HDP/BS) attached to the TA – XT2i texturometer (Stable Micro Systems, UK) with a crosshead speed of 1 mm/s. Nine replications were done from each steak. The peak force values which were measured of the shearing through the centre of each core were used to determine instrumental WBSF of the steaks. Samples temperature during measurements was approx. 7°C.

2.7 Sensory analysis

A nine-member panel experienced in sensory analysis of meat products was employed to evaluate the cooked steaks using the protocol of Polish Standard (PN-ISO 4121:1998). For the test session proper three samples (cores 1.27 cm in diameter and length of 2 cm) for each steak were presented in random order. Samples were rated on descriptive hedonic scales (9-point) for appearance, flavour, tenderness and juiciness. The temperature of samples subjected to evaluation was the same as in WBSF measurements (approx. 7°C). Between individual sessions, water and bread were provided to clean the palate.

2.8 Statistical analysis

In the first stage was determined whether the tested variables in the comparing groups were normally distributed. For this purpose, the normal probability plots were created for the comparing groups and the normality test of Shapiro-Wilk were performed. If there was no reason to reject the normality assumption, the equality of variance tests were conducted for the comparing groups (Levene and Brown-Forsythe test). If the assumptions of normality and variance were met then F-test was used for statistical comparison of differences in the particular values occurred over the time. To determine the significance of differences between measurements performed at certain time intervals, post-hoc multiple comparison tests were performed (Duncan's test was selected).

3D surface plots were made in order to discover the relationship between: (1) colour parameters, pH value and ageing time; (2) instrumentally and sensorially evaluated meat texture, colour parameters and ageing time; (3) instrumentally and sensory evaluated meat texture, cooking loss and ageing time. Quadratic smoothing procedure was used to fit a second-order polynomial surface to the points in the 3D scatterplot. All statistical analyses were conducted at $p<0.05$ using Statistica 10.0 (StatSoft Inc., Tulsa, OK, US).

3. RESULTS AND DISCUSSION

The initial pH value of examined meat (measured 1 h post-mortem) was 6.65 and gradually decreased significantly up to 24 h post-mortem to 5.57 (Table 1). In a further stage of ageing process of meat statistically significant changes in pH value was not detected. The measured pH values at the time of carcasses chilling and meat storage indicate the correct course of glycolytic changes in muscle tissue. Proper acidification of meat is extremely important both for the development of its final quality and shelf life.

Table 1. pH value and values of colour parameters of *longissimus thoracis et lumborum* muscle during carcasses chilling and meat ageing

Time (h)	pH value		L*		a*		b*	
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
1	6.65a	0.12	31.29a	0.95	12.55a	2.45	2.37a	0.84
3	6.60a	0.05	31.35a	1.85	14.79b	2.59	3.51b	0.68
6	6.37b	0.13	30.91a	2.08	13.64a,b	2.15	3.97b	0.86
12	6.16c	0.24	30.85a	1.28	13.15a	1.01	3.99b	0.78
24	5.57d	0.05	34.25b	1.82	14.57b	0.80	3.73b	0.53
48	5.50d	0.04	36.63c	0.86	16.30c	1.76	5.14c	1.73
72	5.50d	0.05	39.11d	1.40	18.26d	1.80	8.64d	1.15
168	5.51d	0.05	40.73e	2.50	20.17e	1.68	10.14e	1.39
336	5.54d	0.06	41.47e	2.14	19.26d,e	1.32	9.49e	1.30

a, b, c, … – means in a column with the same superscript letter are not different ($p<0.05$).

There was no significant changes in L * parameter of LTL muscle up to 12 h post-mortem. L* value was at that time around 30. Next up to 14 day of ageing, L* value gradually increased to about 41.

Analysing the losses of meat juice, both during refrigerated storage of meat as well as during the heat treatment, significant changes were not noted up to 7 day of ageing. Drip loss ranged from 1.19% to 1.60%, and cooking loss from 32.34% to 32.91% (Table 2). Significant increase in weight losses were observed between 7 and 14 day of ageing. Drip loss and cooking loss noted at 14 day post-mortem were respectively 2.63% and 34.39%. One of the major factors affecting water-holding capacity is pH value (Huff-Lonergan and Lonergan , 2005). After slaughter due to glycolysis process, pH of meat reaches the value of isoelectric point of the major muscle proteins. In this way, the degree of water binding by protein structures of meat is reduced. Due to development of *rigor mortis*, spaces where water is collected shrink, which causes losses of cellular juice outside the cells and fibre bundles. Also, cytoskeletal protein degradation which occurs during ageing may result in relaxation of the muscle cell structures, thereby creating more capillary spaces where water can collect (Huff-Lonergan and

Lonergan , 2005). Girolami et al., (2009) demonstrated that progressive degradation of myofibrillar proteins during post-mortem ageing contributes to reduction of the amount of cooking loss. In this study, different relationship was noted. Amount of cooking loss observed after 14 days of ageing was more than 1 percentage point higher than in the other time intervals. The reason for this may be a large variability in the results obtained at 14 day post-mortem, as confirmed by high value of the standard deviation (1.60).

Table 2. Drip loss, cooking loss, WBSF and sensory of *longissimus thoracis et lumborum* muscle during meat ageing

		Time post-mortem (days)			
		2	3	7	14
Drip loss (%)	$\bar{x}$	1.60a	1.19a	1.52a	2.63b
	SD	0.30	0.31	0.76	1.60
Cooking loss (%)	$\bar{x}$	32.91a	32.44a	32.34a	34.39b
	SD	2.36	1.14	1.16	1.32
WBSF (N)	$\bar{x}$	73.53a	60.39b	42.67c	31.02d
	SD	7.61	12.11	8.84	5.29
Appearance (pts)	$\bar{x}$	6.80a	7.13a	7.67b	7.93b
	SD	0.56	0.64	0.49	0.59
Flavour (pts)	$\bar{x}$	6.53a	7.20b	7.87c	8.33d
	SD	0.52	0.56	0.52	0.62
Tenderness (pts)	$\bar{x}$	5.93a	6.73b	7.73c	8.47d
	SD	0.59	0.59	0.80	0.52
Juiciness (pts)	$\bar{x}$	6.67a	7.07a,b	7.40b	7.60b
	SD	0.72	0.70	0.74	0.63
Acceptability (pts)	$\bar{x}$	6.40a	6.93b	7.47c	8.20d
	SD	0.51	0.26	0.52	0.56

a, b, c, … – means in a row with the same superscript letter are not different ($p<0.05$).

Peak shear force of examined meat, measured at 48 h post-mortem was 73.53 N. Meat mechanical resistance decreased significantly with time of ageing. After 14 days of slaughter, WBSF value was 31.02 N. Reduction of meat toughness and simultaneous improvement of its tenderness with the time of ageing are confirmed by the results of sensory evaluation. *Longissimus thoracis et lumborum* muscle was rated at 5.93 points at 2 day post-mortem while at 14 day post-mortem at 8.47 points. Similarly, the scores given to other sensory characteristics increased significantly with ageing time. Calkins and Hodgen, (2007) indicated advancement of oxidative changes of basic components of meat, fat and heme pigments content, pH value, nutrition, age and breed of animal as the factors influencing flavour profile of beef. Koohmaraie, (1996) stated that improvement of meat tenderness during ageing results from advancement of intracellular structures and protein degradation. These changes are the result of endogenous proteolytic enzymes activity. In the present study was observed a positive effect of crossbreeding Holstein-Friesian and Aberdeen Angus cattle in conjunction with the 14-days ageing process of meat on all assessed quality features of meat.

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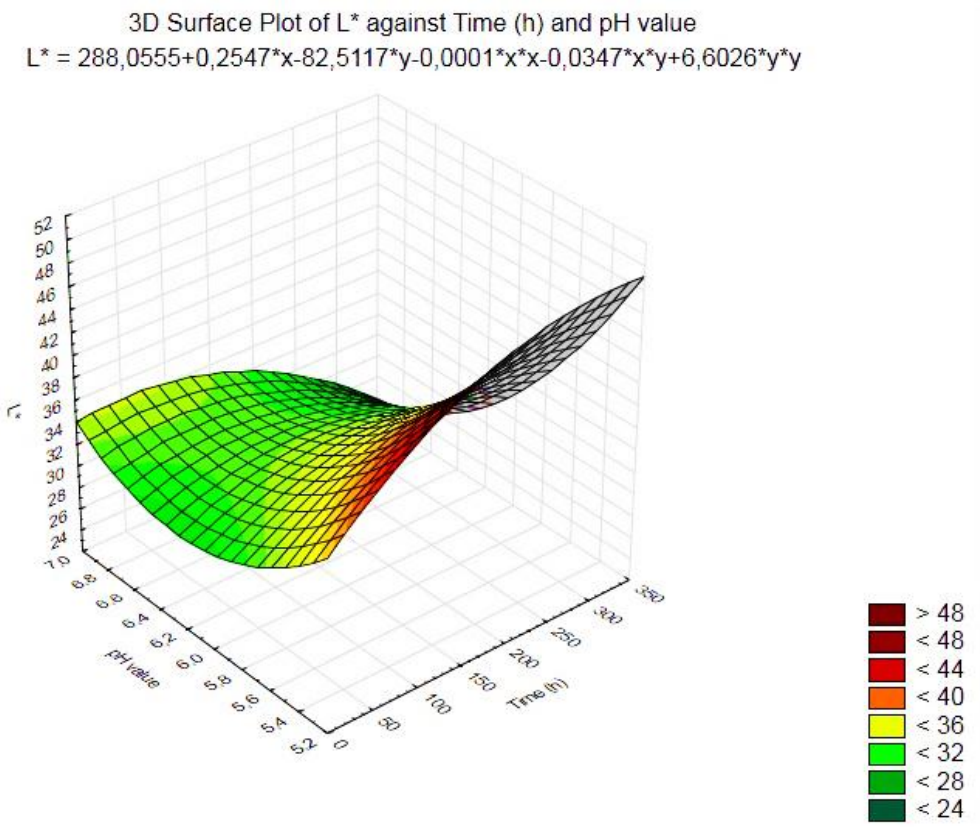


Figure 1. L* value against ageing time and pH value

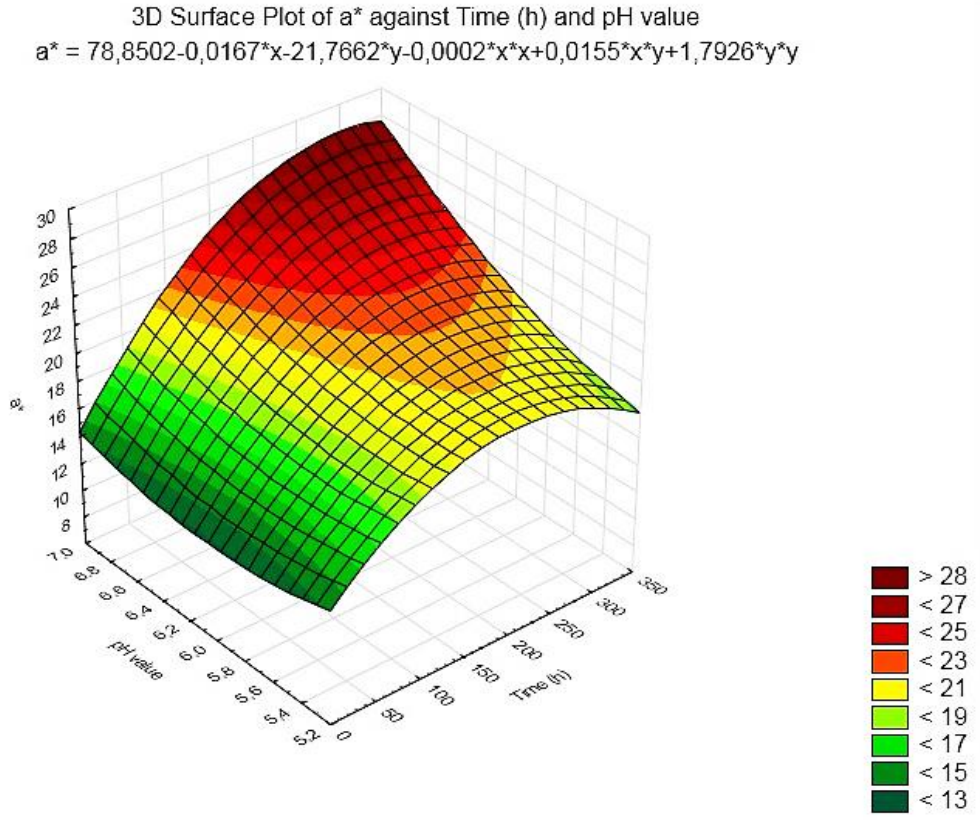


Figure 2. a* value against ageing time and pH value

Implementation of 3D surface plots enabled the detection of relationship between L* value, ageing time and pH value (Figure 1). L* increases with pH reduction and simultaneously with the time of ageing. However, when pH of meat is high and the time of ageing is extended, value of L* parameter is gradually reduced. Therefore it can be expected that such meat will be characterized by unacceptably dark colour

Relationship between a* parameter, ageing time and pH value (Figure 2) indicates that meat of high pH (greater than 6.0) is characterized by higher values of a* parameter than meat with pH below 6.0. At the same time value of a* parameter increases with the time of meat ageing. It was also observed that meat characterized by the highest a* value and therefore the greatest redness (Figure 2) is also the darkest - the lowest L* value (Figure 1). A similar relationship was also reported by Phung et al., (2013). The authors indicate significant effect of pH on meat colour and also factors such as carcass weight, slaughter animal age. Boakye and Mittal, (1996) demonstrated that all colour parameters change during meat ageing. Girolami et al., (2009) found that values of all colour parameters increased significantly with the time of ageing, which positively influenced the perception of meat colour by consumers.

An interesting relationship was observed by examining Figure 3 (WBSF against ageing time and L* value). This simulation shows that WBSF of meat with lower L* value will decrease to a greater extent during ageing. Therefore darker meat will be less tough after 14 days of ageing than a brighter. This relationship was also confirmed by the simulation prepared for the sensorially evaluated tenderness (Figure 4) which shows that darker meat will be more tender with the time of ageing than a brighter meat. This is evident from the analysis such relationship can be observed from about 7 day of ageing.

Considering the value of a* parameter - meat redness, as indicator of meat tenderization (Figure 5, Figure 6) it can be concluded that the meat characterized by moderate redness - a * value about 16-20 is more tender than the meat of a smaller or larger redness.

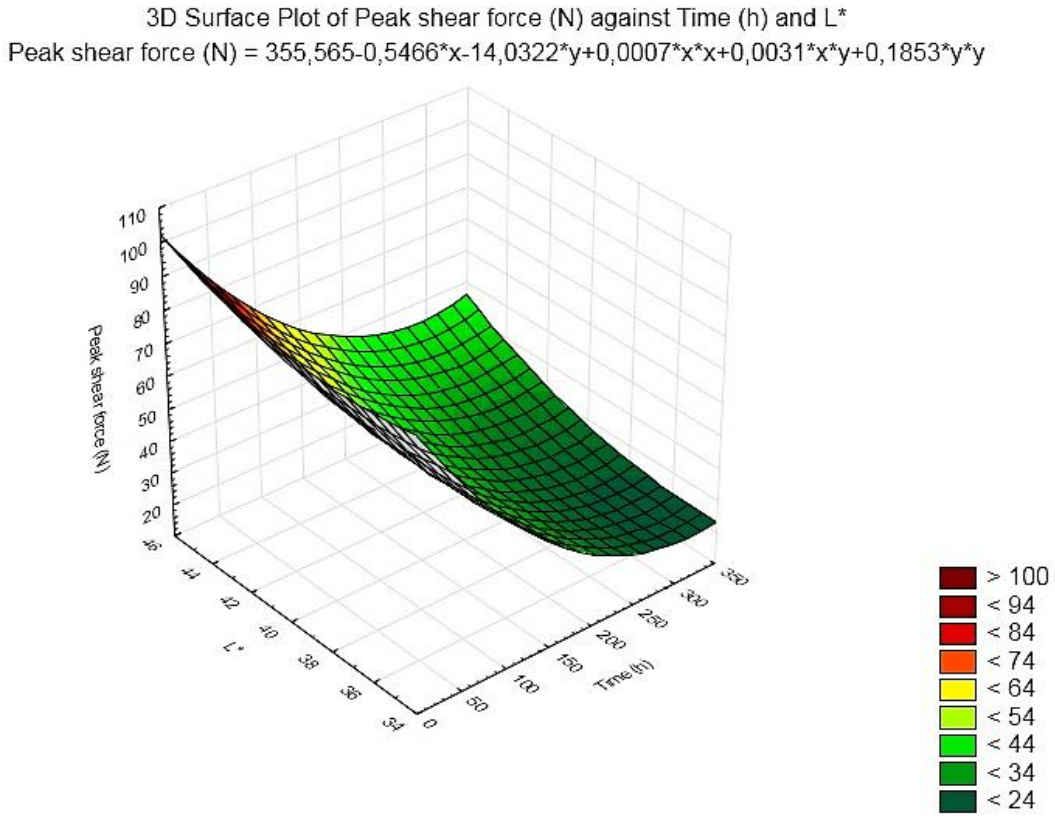


Figure 3. Peak shear force (WBSF) against ageing time and L* value

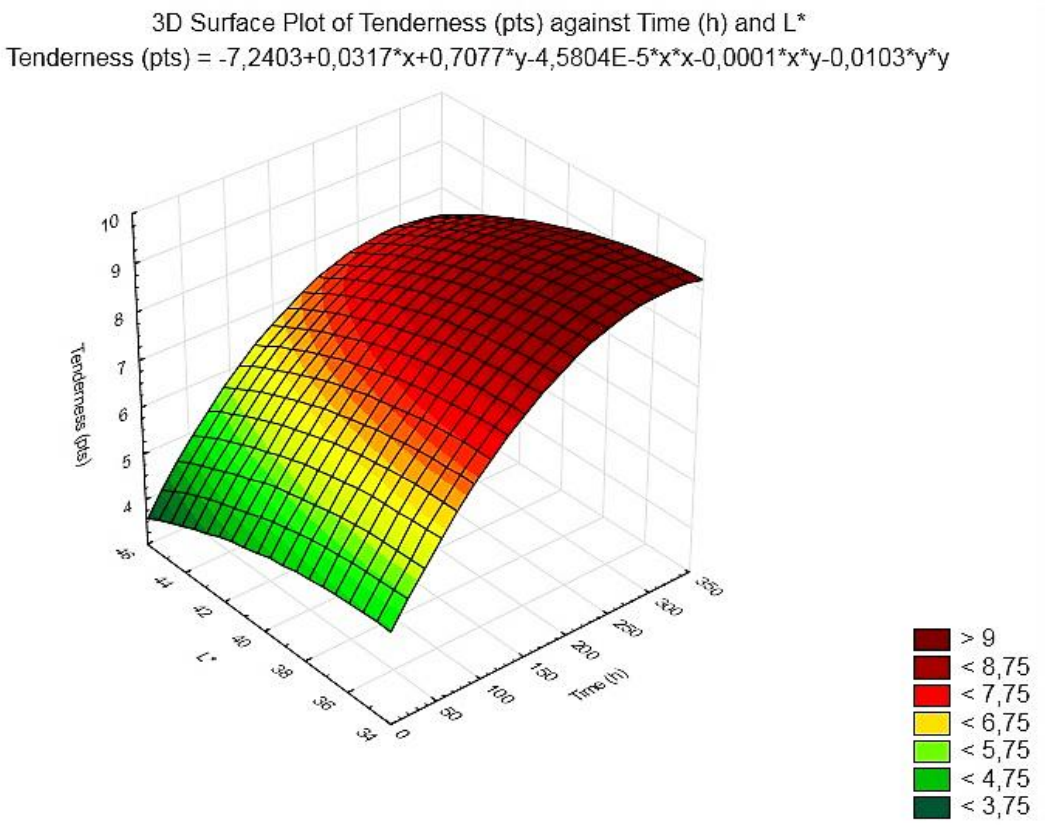


Figure 4. Tenderness against ageing time and L* value

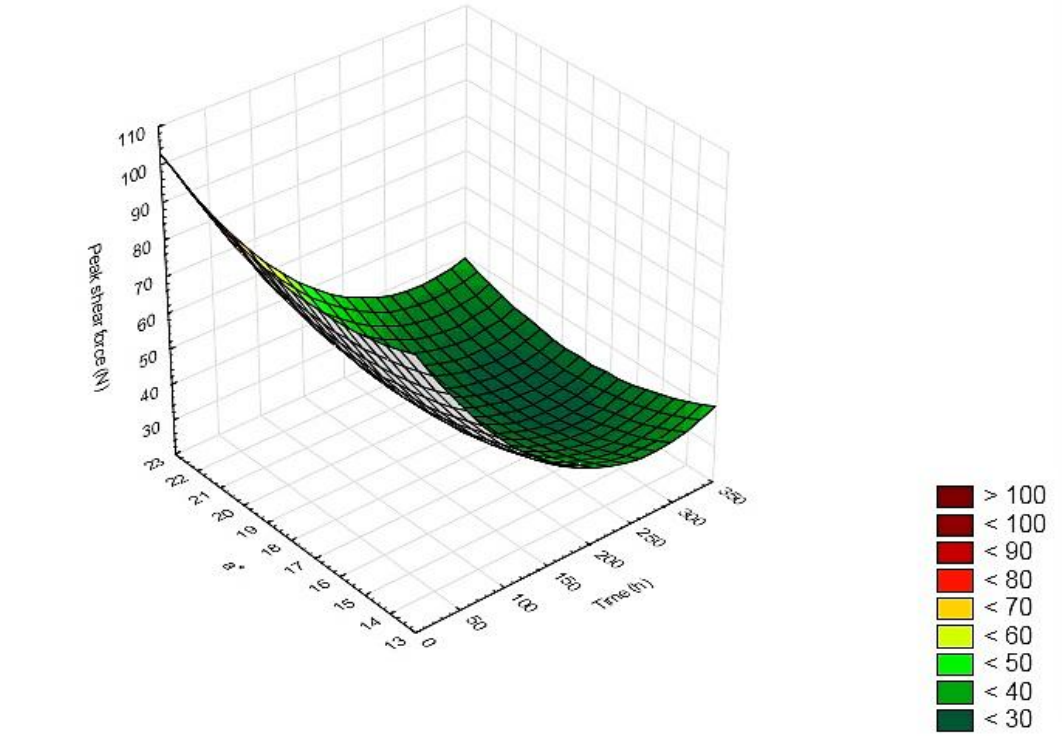


Figure 5. Peak shear force (WBSF) against ageing time and a* value

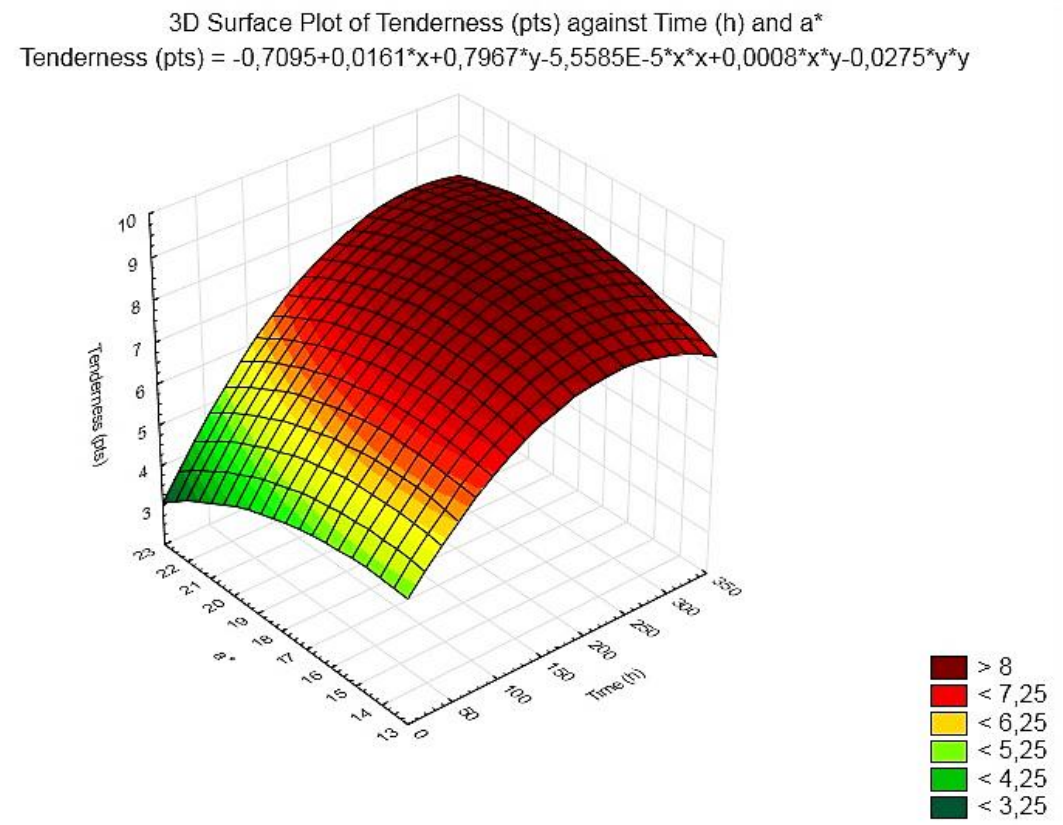


Figure 6. Tenderness against ageing time and a* value

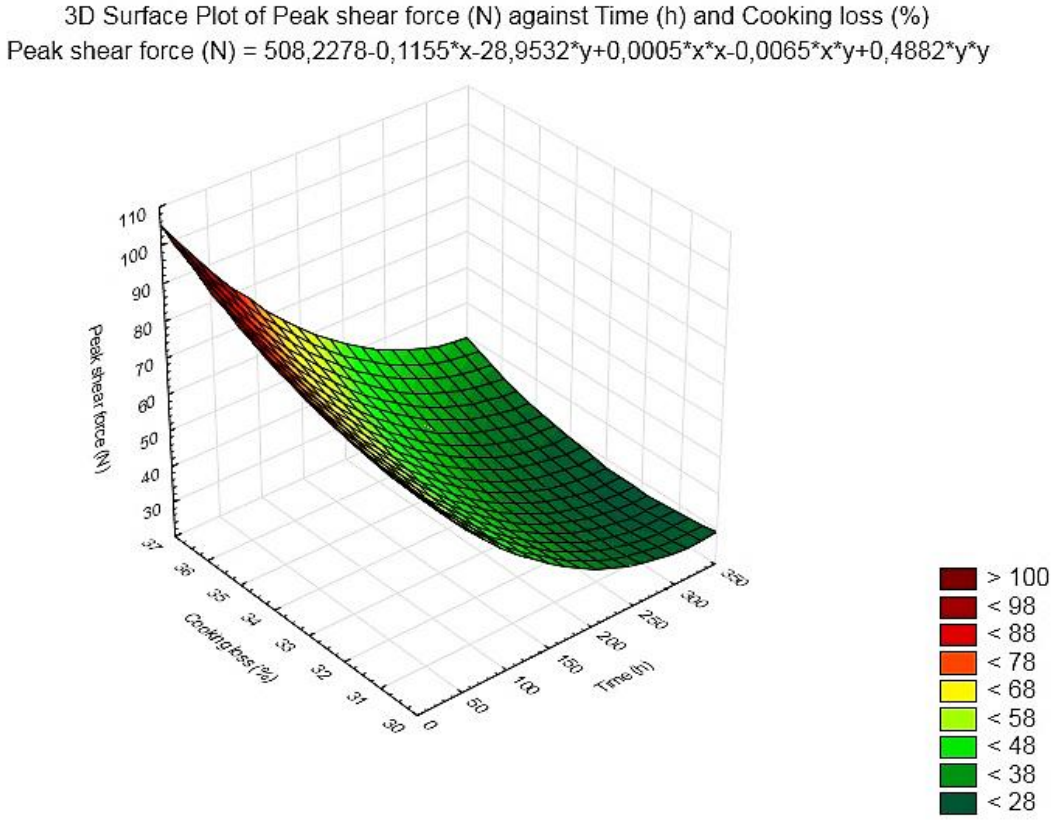


Figure 7. Peak shear force (WBSF) against ageing time and cooking loss

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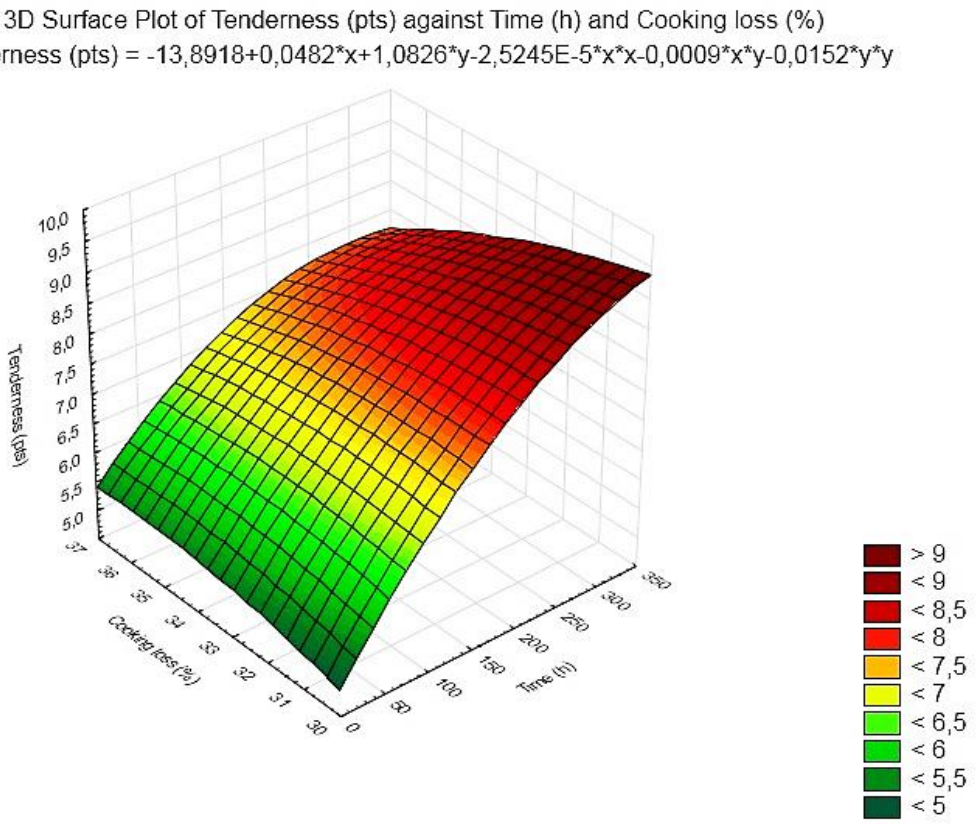


Figure 8. Tenderness against ageing time and cooking loss

The data presented in Figure 7 shows that the reduction of meat WBSF is influenced not only by ageing time but also by the amount of cooking loss. Meat with a lower cooking loss will be more tender than the meat with a greater cooking loss (Figure 8). Therefore it can be concluded that meat tenderness and also its hardness after heat treatment is inherently related to the amount of cooking loss and thus meat juiciness.

Hwang and Thompson, (2001) found that the optimal pH lowering to obtain the most tender meat depends on the time of ageing. However, Park et al., (2007) found that the changes of pH value, which are dependent on the initial glycolytic potential of muscles, do not affect the texture of meat, but only meat colour. A similar relationship was also observed in this study. Analysing the correlation coefficients between studied traits (Table 3), a high negative correlation between the values of colour parameters L*, a*, b* and pH value was confirmed (respectively r = -0.77 , r = -0.61 , r = -0.57). The correlation between pH value and WBSF as well as between pH value and tenderness was low (respectively r = -0.26 and r = 0.40). A significant correlation was observed between L*, a* and WBSF (respectively r = -0.51 and r = -0.44), and between L *, a * and tenderness (respectively r = 0.42 and r = 0.33). Calculation of the correlation coefficient did not confirm a significant relationship between amount of cooking loss and tenderness, both sensorially and instrumentally evaluated (shown in Figure 7, Figure 8). However, a high negative correlation between WBSF and other distinguishing features of meat quality sensorially evaluated was noted.

4. CONCLUSION

From above results it can be concluded that the crossbreeding of Holstein-Friesian and Aberdeen Angus cattle have a positive impact on the improvement of all sensorially evaluated quality features of meat. Furthermore, WBSF reduces and tenderness improves by about 50% due to the use of the 14-days ageing.

The observed relationship between WBSF, ageing time and values of colour parameter, and the relationship between tenderness, ageing time and values of colour parameters indicate the potential use of colour parameters measurements as an indicator of beef tenderness. However, additional studies should be conducted to assess the

usefulness of colour parameters measurements in the estimation of beef tenderness, taking into account other differentiating factors, such as: different breeds of cattle - not just HFxAA crossbreeds and also age, sex or feeding of animals.

Table 3. Significant ($p < 0.05$) correlation coefficients between the studied quality features

		X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9
pH value	X_1	-								
Drip loss (%)	X_2		-							
Cooking loss (%)	X_3	0.26	0.43	-						
Peak shear force (N)	X_4	-0.26	-0.33		-					
Appearance (pts)	X_5		0.44	0.42	-0.51	-				
Flavour (pts)	X_6	0.31	0.39	0.32	-0.66	0.73	-			
Tenderness (pts)	X_7	0.40			-0.88	0.58	0.74	-		
Juiciness (pts)	X_8	0.31			-0.51		0.29	0.47	-	
Acceptability (pts)	X_9	0.39	0.35	0.35	-0.76	0.73	0.80	0.84	0.49	-
L*	X_{10}	-0.77			-0.51	0.40	0.53	0.42	0.26	0.43
a*	X_{11}	-0.61			-0.44		0.37	0.33	0.40	0.32
b*	X_{12}	-0.57				0.41	0.59	0.50	0.35	0.49

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