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CARCASS AND MEAT QUALITY OF MALE AND FEMALE WATER BUFFALOES FINISHED UNDER AN INTENSIVE PRODUCTION SYSTEM

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Abstract

Carcass and meat quality of male and female Anatolian water buffaloes were investigated using 10 carcasses from each gender. Gender had no influence on carcass characteristics, except warm carcass weight, which was 13% higher in males compared to females. Meat from male water buffaloes had higher ultimate pH and lightness (L*), but lower redness (a*) values than females. Meat samples aged for 21 days had lower values for expressed juice, cooking loss and Warner Bratzler shear force compared with those of 7-day aged ones. Meat samples aged for 21 days had higher L* value at 1 h and 24 h after cutting, a* value at 1 h after cutting compared with those of 7-day aged meat samples. Gender had no effect on meat sensory characteristics. Meat from male water buffaloes had higher proportions of C14:0, C18:3 *n-3*, C20:2 *n-6*, C20:3 *n-3* and C20:4 *n-6* and ∑*n-3* fatty acids and lower ∑*n-6*/∑*n-3* ratio compared with female water buffaloes.

Key words: gender, ageing, tenderness, meat colour, fatty acids

Water buffalo (*Bubalus bubalis*) is an important genetic resource in many Asian and Mediterranean countries, and reared as a multipurpose animal producing milk, meat and draught power (Soysal, 2014). Water buffalo population in the world was about 195 million heads in 2014 and their milk (102 million tonnes) constituted approximately 13.2% of total milk production (FAO, 2016).

Almost all reared water buffalo population in Turkey is from Anatolian water buffalo breed, which is classified as 'Mediterranean' type (Soysal, 2009). Anatolian water buffalo is an indigenous breed with low milk and carcass yield. Adult body weight is approximately 400 kg. Milk yield is estimated to be 800–900 kg per lactation. Coat colour varies from dark black to light black or brown. Body coat is covered with long hairs (Akdağ and Çelik, 2006; Atasever and Erdem, 2008; Soysal, 2009;

Yilmaz et al., 2012). Water buffaloes had been used as draught animals in Balkan, Mediterranean and Middle-East countries for centuries. Water buffaloes are well adapted to extensive production system with poor feeding and management conditions, and have relatively better disease resistance than cattle (Soysal, 2014; Yilmaz et al., 2012). Although the number of water buffaloes in the world slightly increased during past three decades, water buffalo population in certain Balkan countries (Turkey, Romania, Bulgaria) has decreased drastically (Borghese and Mazzi, 2005; FAO, 2016). The primary reasons for this decrease in population of water buffaloes are the increasing demand for Holstein-Friesian cattle breed instead of low-yielding buffaloes, increasing mechanization in agriculture (i.e. the substitution of draught animals with tractors) and insufficient demand for buffalo products (Borghese and Mazzi, 2005; Soysal, 2014). On the other hand, a gradual increase (approximately 43.8%) in the number of water buffaloes was observed after 2011 in Turkey (FAO, 2016). This rise in population might be related with increasing demand for cream of buffalo milk, which is favourable as an additive to the famous Turkish desserts (Soysal, 2014).

Water buffalo production in Turkey is carried out traditionally by small scale family enterprises (1–5 head) and based mainly on the use of natural grassland and poor quality roughage under the extensive conditions. Mostly, male water buffaloes are slaughtered at low weights (200–250 kg) at 12–18 months of age without application of any fattening programme. Female water buffaloes are used for milk production during 8–10 lactations, and then they are slaughtered without application of any fattening programme (Soysal, 2009; Şahin et al., 2013).

In order to increase the profit of the low income farmers and to ensure the sustainability of water buffalo farming, marketing buffalo meat as a more valuable commodity as well as its milk is essential. Low quality carcasses and meat are obtained from the male water buffaloes slaughtered at low weights and female water buffaloes slaughtered after they complete their productive lives (Soysal, 2009). This leads to the perception in consumers that water buffalo meat is of low quality. Therefore, marketing of water buffalo's meat is difficult. Meat from Anatolian water buffaloes is commonly used as a raw material in the manufacturing of some sub-products, like Turkish style fermented sausage and pastrami. This practice consequently causes a decrease of income for the breeders (Soysal, 2014). In beef cattle intensive feeding programmes are generally applied in order to improve carcass quality. It has been widely demonstrated that carcass quality in cattle was positively affected by feeding intensity (Realini et al., 2004; Sami et al., 2004). Similar effects of intensive feeding programmes can also be expected for buffaloes. Lambertz et al. (2014) reported that supplementation of pasture with concentrate feed results in an improvement of growth and production of carcasses with superior dressing percentage and better muscling in swamp buffaloes. One of the possible solutions to raise the incomes of the breeders is to increase the meat production of water buffaloes by intensive fattening programmes. In recent years, large scale enterprises (nearly 100 head) were started to be established near the cosmopolite cities in Turkey. Water buffaloes are mostly fed by concentrate feed in addition to roughage in these enterprises (Soysal et al., 2007). Some recent reports indicate that tenderness of young water buffalo meat is similar to beef (Carbone et al., 2008). Also Neath et al. (2007) found that shear force values of water buffalo meat was lower than that of beef for *semimembranosus* and *longissimus thoracis* (LT) muscles. Spanghero et al. (2004) observed redder and more tender meat for water buffalo than beef. Moreover, Infascelli et al. (2004) noted that water buffalo meat had lower saturated and higher monounsaturated and polyunsaturated fatty acids percentages than beef. In another study, a number of beneficial effects of water buffalo meat consumption on cardiovascular risk profile, including lower carotid atherosclerotic burden and susceptibility to oxidative stress were reported (Giordano et al., 2010). Therefore, the studies, which revealed the quality characteristics of the young water buffalo meat can contribute to the improving image and price of water buffalo meat.

Although limited number of studies on meat quality of water buffalo is available, there are no published articles regarding the meat quality of Anatolian water buffaloes up to now. The aim of the study was to determine the carcass and meat quality characteristics of male and female Anatolian water buffaloes. The effects of ageing time (7-day or 21-day) on certain instrumental quality characteristics (expressed juice, cooking loss, Warner Bratzler shear force value and colour parameters) of LT muscle were also investigated.

Material and methods

All procedures in the study were carried out according to the national legislations, which are mainly prepared in harmony with EU legislation, and the procedures of the study were reviewed and approved by the Ethic Committee of Istanbul University, Turkey (Approval number: 54–13.05.2009).

Animals and carcass characteristics

Data were obtained from carcasses of 20 Anatolian water buffaloes. Water buffaloes at the age of 1–1.5 years were purchased from different local farms, and then finished at the same private farm (Coskun Sucuk Farm). The target finishing strategy in the farm was to obtain approximately 300 kg carcass weight from each buffalo. During the first 9–10 months of finishing, water buffaloes were kept at feedlot and fed *ad libitum* with a diet consisting of 35–40% roughage (maize silage and alfalfa hay) and 60–65% commercial concentrate feed (30% crude protein and 6.70 MJ/kg metabolizable energy) on as fed basis, which was supplemented with different grains due to seasonal availability. Afterwards, animals were moved to tether stalls, and fed *ad libitum* with a diet consisting of 25% roughage and 75% commercial concentrate feed for 2.5 months. Male and female water buffaloes were raised under loose housing system in separate pens during whole finishing period. Average space allowances per animal in pens were 24 m^2.

Buffalos from both genders were slaughtered at the age of 2–2.5 years in a licensed traditional, private slaughterhouse by severing the throat and major blood vessels in the neck. After bleeding, head, skin, feet, internal organs were removed, and then warm carcasses were weighed within 1 h after bleeding.

Carcasses used in the study were obtained from 10 female and 10 male water buffaloes slaughtered at the same day in the abattoir. Carcasses were selected randomly among the 61 male (mean weight=321.9±6.55) and 20 female (mean weight=295.35±7.95) buffaloes slaughtered at the same day in the slaughterhouse. After carcasses were refrigerated for 24 h at 4°C, carcass length (measured from the anterior edge of symphysis pubis to the middle of the anterior edge of the visible part of the first rib), leg length (measured from the medial malleolus of the tibia in a straight line to the anterior edge of the symphysis pubis), leg width (measured with a calliper on the maximum width as the horizontal distance between the outmost points on the medial and the lateral surface of the leg), chest depth (measured from the ventral edge of the spinal canal at the level of the 5th rib to the ventral aspect of the middle of the body of the 6th sternebra) were measured on the intact carcass as described by de Boer et al. (1974). Each carcass was classified by using EUROP classification scale for conformation and fatness according to the standards established by European Community (2006). In order to evaluate the conformation and fatness classification characteristics statistically, the scores given to water buffalo carcasses were changed into a 1–15 scale (Ozcan et al., 2014). Back fat thickness was measured at the same section by a digital calliper. Fat colour was assessed by using a Minolta CR 400 chromometer (Minolta Camera Co., Osaka, Japan) between 12th and 13th ribs at 12–15 cm lateral of median line to determine the CieLab values.

Muscle sampling

At 24 h post-mortem, LT muscle between 7th and 13th thoracic vertebrae from the left side of carcass was removed in order to assess meat instrumental quality and sensory evaluation. Afterwards, LT muscle was sliced to following samples (from posterior to anterior):

1. Two 3 cm thick steaks from the posterior side of the LT muscle were sliced for measurement of expressed juice and colour characteristics. These steaks were vacuum packaged, and randomly chosen for 7-day or 21-day ageing groups.
2. Two 3.5 cm thick steaks were cut for cooking loss and Warner Bratzler shear force (WBSF) analyses. These steaks were vacuum packaged, and randomly chosen for 7-day or 21-day ageing groups.
3. A 2.5 cm thick section of the anterior side of the LT muscle was cut for sensory evaluation and fatty acid analyses. 50–60 g sample from distal part of this steak was removed for fatty acid analyses, packaged under vacuum and immediately frozen and stored at –18°C until analyses. The rest of this steak was used for sensory evaluation. Samples chosen for sensory analyses were vacuum packaged at 24 h post-mortem and then kept at 4°C for 7 days. Afterwards, these samples were frozen and stored at –18 °C until panel evaluation.

Samples in vacuum bags for cooking loss, WBSF, expressed juice and colour measurements were aged at 4°C for 7 or 21 days.

Meat instrumental quality and laboratory analyses

The ultimate pH (pH_u) of the LT muscle between ribs 12 and 13 were measured at 24 h post slaughter using a digital pH meter (Testo 205, Testo AG, Lenzkirch, Germany), equipped with a penetrating electrode and thermometer. pH meter was calibrated in chiller temperatures at 30 minutes before the first carcass pH measurement.

Expressed juice (%) was measured by the modified Grau and Hamm pressure method described by Ekiz et al. (2012 b). Cooking loss was determined after the cooking of meat samples in a water bath at 75°C for 1 h as described previously by Hoffman et al. (2003). Cooked meat samples that were used for cooking loss analysis were then used to measure WBSF value. Six sub-samples were cut from each cooked sample. WBSF values of sub-samples were determined using an Instron Universal Testing Machine (Model 3343, Instron Corp., Norwood, MA) equipped with a WBSF apparatus. The average of six sub-samples was accepted to be the WBSF value of that sample.

LT samples (3 cm thick) taken at 24 h post mortem and then aged at 4°C for 7 or 21 days were used for determination of meat colour characteristics of Anatolian water buffaloes. 2.5 cm thick slice from each sample was cut. Slices were placed in a polystyrene tray, over-wrapped with oxygen permeable PVC film to allow blooming, and kept at 4°C for 24 h under continuous fluorescent lighting (750 lx). Meat colour was measured at 1 h and 24 h after cutting on cut surface of slices from fat-free area (Ekiz et al., 2012 b). A Minolta chromometer (Minolta CR 400, Minolta Camera Co., Osaka, Japan) was used to measure meat L* (lightness), a* (redness) and b* (yellowness) values. Light source, observation angle and aperture size were illuminant D65, 2° and 8 mm.

Meat sensory assessment

One day prior to panel sessions, the samples were removed from the freezer and thawed in refrigerator for 24 h. The samples were cooked in a 175°C oven until the internal temperature reached 80°C. Thermocouples of Testo 177-T4 data logger (Testo AG, Lenzkirch, Germany), which were placed in geometric centres of the samples were used in order to monitor internal temperatures of meat samples. Seven sub-samples from each sample were prepared. Sensory characteristics were evaluated by 8-point category scale (Ekiz et al., 2012 b). The evaluations were made by seven panellists, who had at least two years experience for meat sensory assessment. The panellists were asked to assess odour intensity, tenderness, juiciness, flavour intensity, flavour quality and overall acceptability (Ekiz et al., 2012 c).

Meat fatty acid analyses

Gas chromatography-mass spectrometry (HP Agilent 6890/5972, Santa Clara, CA, USA) was used to determine the fatty acid composition of the LT muscle. Meat fat was extracted according to Bligh and Dyer (1959) and extracted fat was saponified with 2% methanolic NaOH and methylated with boron trifluoride 35% in methanol. Organic phase was collected into n-heptane. Fatty acid methyl ester extracts in heptane phase were kept in the freezer at –20°C until GC analyses. Separations of fatty acids were performed with a HP-88 Capillary Column (100-m length, 0.25 mm i.d. × 0.20-µm film). Both injector and the detector's temperature were set at 250°C. Split ratio was 1:50 with a total injection volume of 1 µL. Injector was washed three times with n-heptane. Oven temperature was programmed initially at 150°C and held for 3 min. Then, the temperature was increased to 240°C with a 3°C/min ramp rate. Chromatographic peaks, which were identified with mass spectrometers, were also verified by comparison of the retention times of internal standards (FAME Mix C4-C24, Sigma Chemical Co. Ltd., Poole, UK). Total separation was continued for 40 minutes. Helium was used as a carrier gas and its flow rate was 0.8 ml/min.

Statistical analyses

In order to determine the effect of gender on carcass quality characteristics, pH_u and fatty acid composition, independent sample t-test was used. GLM procedures were used to analyse data for expressed juice, cooking loss, WBSF and meat colour variables. The model used in the analyses of these characteristics included fixed effects of gender (male and female), ageing time (7 and 21 days), and gender × ageing time interaction. GLM procedures were also used to analyse data for sensory characteristics. The model used in the analyses of these characteristics included gender, session, panellist as fixed effect and significant two-way interactions between these effects. Bivariate correlation was applied between meat pH_u and WBSF value, expressed juice, cooking loss and colour variables.

Results

Results concerning certain carcass quality characteristics are given in Table 1. The average warm carcass weight was 13% higher in males compared to females ($P<0.001$). Female water buffaloes had higher carcass length ($P<0.05$) and lower leg length ($P<0.01$) than male buffaloes. On the other hand, differences between carcasses of male and female water buffaloes in terms of leg width, chest depth, back fat thickness, subjective conformation and fatness scores were not significant ($P>0.05$). Gender had no influence on back fat redness (a*) and yellowness (b*) values ($P>0.05$) while fat of female carcasses had lower lightness (L*) value than male carcasses ($P<0.05$).

Influences of gender and ageing time on expressed juice, cooking loss, WBSF and colour variables of LT muscle are presented in Table 2. There were no significant interactions for any instrumental meat quality traits between gender and ageing time. Gender had no significant effect on expressed juice, cooking loss, WBSF value and meat yellowness (b*) value ($P>0.05$). However, meat samples of male buffaloes had higher lightness (L*) and lower redness (a*) values than female ones ($P<0.001$). Moreover, LT muscle of female carcasses had lower pH_u value than male carcasses ($P<0.001$). Ageing time significantly affected the expressed juice ($P<0.05$), cooking loss ($P<0.01$) and WBSF ($P<0.01$) values. Meat samples aged for 21 days had lower values for these characteristics than those of 7-day aged ones. Moreover, 21-day ageing of LT muscle samples resulted in increased L* value at 1 h and 24 h after cutting compared with those of 7-day aged meat samples ($P<0.05$). Meat samples aged for 21 days had also higher a* value at 1 h after cutting and lower yellowness (b*) value at 24 h after cutting than 7-day aged samples.

Table 1. Carcass quality traits of Anatolian water buffaloes in terms of gender (Mean±SE)

Traits	Male	Female	P-value
Warm carcass weight (kg)	325.40±2.65	288.20±5.99	<0.001
Carcass length (cm)	127.07±1.00	132.16±1.93	0.031
Leg length (cm)	72.62±1.30	67.87±0.84	0.007
Leg width (cm)	29.96±0.65	28.99±0.61	0.290
Chest depth (cm)	45.37±0.43	46.26±0.60	0.244
Back fat thickness (mm)	19.84±1.69	19.77±2.06	0.979
Conformation score[a]	5.20±0.42	5.50±0.40	0.610
Fatness score[b]	7.70±0.47	7.30±0.68	0.636
Fat colour parameters			
L*	64.00±1.04	60.03±0.96	0.012
a*	6.14±0.49	7.01±0.89	0.407
b*	7.03±0.63	7.08±0.59	0.958

[a]Conformation score was graded according to the EUROP classification system. Sub scales are P-, P, P+, O-, O, O+, R-, R, R+, U-, U, U+, E-, E, E+. Raw scores were converted on 1–15 scale. 1 (P-): very bad conformation; 15 (E+): very high conformation.

[b]Fatness scores were determined in a 1–5 classification system. Sub scales are 1-, 1, 1+, 2-, 2, 2+, 3-, 3, 3+, 4-, 4, 4+, 5-, 5, 5+. Raw scores were converted on 1–15 scale. 1 (1-): very low fatness; 15 (5+): very high fatness.

Table 2. Instrumental meat quality traits of *longissimus thoracis* muscle in Anatolian water buffaloes in terms of gender and ageing time (LSMean±SE)

Traits	Gender (G)		Ageing Time (AT)		P-value		
	male	female	7-day	21-day	G	AT	G × AT
pH_u	5.49±0.008	5.44±0.009	-	-	0.001	-	-
Expressed juice (%)	9.81±0.40	9.98±0.40	10.57±0.40	9.23±0.40	0.771	0.023	0.154
Cooking loss (%)	27.40±0.48	27.93±0.48	28.84 ±0.48	26.49±0.48	0.437	0.001	0.846
WBSF[a] (k)g	3.26±0.13	3.18±0.13	3.54±0.13	2.90±0.13	0.707	0.002	0.844
Colour parameters at 1 h							
$L^*_{1 h}$	39.33±0.36	36.49±0.36	37.35±0.36	38.48±0.36	<0.001	0.035	0.821
$a^*_{1 h}$	21.78±0.40	22.98±0.40	21.29±0.40	23.47±0.40	0.040	<0.001	0.939
$b^*_{1 h}$	7.48±0.27	7.56±0.27	7.30±0.27	7.74±0.27	0.825	0.256	0.591
Colour parameters at 24 h							
$L^*_{24 h}$	40.87±0.30	38.23±0.30	38.82±0.30	40.29±0.30	<0.001	0.002	0.585
$a^*_{24 h}$	23.99±0.37	25.89±0.37	25.30±0.37	24.58±0.37	<0.001	0.179	0.625
$b^*_{24 h}$	7.84±0.28	7.91±0.28	8.90±0.28	6.85±0.28	0.869	<0.001	0.204

[a]Warner Bratzler Shear Force value.

Results concerning the meat sensory characteristics are presented in Table 3. Panellists gave similar scores for meat odour, tenderness, juiciness, flavour intensity, flavour quality and overall acceptability to meat from male and female water buffaloes (P>0.05).

Table 3. Sensory characteristics of *longissimus thoracis* muscle during 7-day ageing in Anatolian water buffaloes in terms of gender (LSMean ± SE)

Traits	Male	Female	P-value
Odour intensity	4.54±0.12	4.53±0.12	0.934
Tenderness	4.67±0.12	4.68±0.12	0.958
Juiciness	4.29±0.12	4.23±0.12	0.728
Flavour intensity	4.87±0.12	4.96±0.12	0.618
Flavour quality	4.79±0.12	4.79±0.12	0.999
Overall acceptability	4.66±0.12	4.69±0.12	0.866

scale 1 = no odour, extremely tough, extremely dry, no flavour, dislike extremely flavour and dislike extremely; scale 8 = very strong odour, extremely tender, extremely juicy, very strong flavour, like extremely flavour and like extremely.

Table 4. Fatty acid composition (percentage of total fatty acid detected) of intramuscular fat from *longissimus thoracis* muscles in Anatolian water buffaloes in terms of gender (Mean ± SE)

Traits	Male	Female	P-value
C14:0	1.06±0.043	0.89±0.043	0.008
C14:1	0.23±0.020	0.21±0.034	0.678
C15:0	0.15±0.021	0.17±0.014	0.452
C15:1	0.17±0.036	0.15±0.032	0.744
C16:0	18.13±1.046	20.20±0.786	0.131
C16:1	3.12±0.363	2.87±0.354	0.634
C17:0	0.74±0.137	0.87±0.173	0.585
C17:1	0.31±0.074	0.43±0.100	0.352
C18:0	14.83±1.954	13.44± 0.974	0.532
C18:1	57.14±1.984	57.26±1.500	0.960
C18:2 *n-6*	2.95±0.162	2.98±0.166	0.884
C18:3 *n-3*	0.33±0.029	0.23±0.006	0.015
C20:0	0.32±0.039	0.26±0.039	0.254
C20:1	0.27±0.053	0.13±0.018	0.060
C20:2 *n-6*	0.15±0.002	0.10±0.007	<0.001
C20:3 *n-3*	0.23±0.024	0.16±0.013	0.024
C20:4 *n-6*	0.39±0.032	0.17±0.009	<0.001
C20:5 *n-3*	0.23±0.034	0.15±0.013	0.085
C22:1	0.17±0.083	0.15±0.053	0.807
C22:2 *n-6*	0.08±0.015	0.14±0.052	0.284
C22:6 *n-3*	0.12±0.037	0.12±0.023	0.874

Intramuscular fatty acid composition (percentage of total fatty acid detected) and sums and ratios based on fatty acid composition for intramuscular fat from LT muscle are given in Tables 4 and 5. The LT muscle of the male buffaloes contained a higher proportion of C14:0, C18:3 *n-3*, C20:2 *n-6*, C20:3 *n-3* and C20:4 *n-6* compared to that of the female buffaloes (Table 4). Meat from the male buffaloes had also higher ∑*n-3* fatty acids and lower ∑*n-6*/∑*n-3* ratio than females. However, except ∑*n-3* fatty acids and ∑*n-6*/∑*n-3* ratio, differences between male and female water buffaloes in terms of sums and ratios criteria based on fatty acid composition of intramuscular fat from LT muscles were not significant.

Table 5. Sums and ratios based on fatty acid composition of intramuscular fat from *longissimus thoracis* muscles in Anatolian water buffaloes in terms of gender (Mean ± SE)

Traits	Male	Female	P-value
∑SFA	34.87±1.945	35.48 ±1.553	0.810
∑MUFA	61.16±1.895	60.89 ±1.629	0.916
∑PUFA	3.97±0.239	3.63 ±0.252	0.341
∑UFA	65.13±1.945	64.52 ±1.553	0.810
∑PUFA/∑SFA	0.12±0.012	0.10 ±0.008	0.316
∑UFA/∑SFA	1.95±0.168	1.87±0.132	0.710
∑*n-6*	3.27±0.192	3.23±0.193	0.888
∑*n-3*	0.78±0.050	0.58±0.044	0.010
∑*n-6*/∑*n-3*	4.23±0.234	6.02±0.514	0.004
Nutritive value	4.12±0.299	3.57±0.199	0.141
Atherogenic index	0.35±0.024	0.37±0.021	0.457
Thrombogenic index	1.01±0.083	1.05±0.063	0.709
ΣDFA	79.96±1.196	77.96±0.914	0.201

Nutritive value = (C18:0 + C18:1)/C16:0.
Atherogenic index = ((4*C14:0) + C16:0)/ΣUFA.
Thrombogenic index = (C14:0 + C16:0 + C18:0)/ (0.5*ΣMUFA) + (0.5*Σ*n-6*) + (3*Σ*n-3*) + (Σ*n-3*/Σ*n-6*).
DFA = Desirable fatty acids (C18:0 + ΣMUFA + ΣPUFA).
SFA = Saturated fatty acid.
MUFA = Monounsaturated fatty acid.
PUFA = Polyunsaturated fatty acid.
UFA = Unsaturated fatty acid.

Discussion

Carcass quality

In the current study, certain carcass and meat quality characteristics of male and female Anatolian water buffaloes, which had mean carcass weights of 325.4 kg and 288.2 kg were investigated. As warm carcass weight was higher in male buffaloes than in females, leg length was greater in male buffalo carcasses. However, such a superiority of male buffalo carcasses was not observed for the other carcass conformation characteristics. Supporting these results, Akdağ and Çelik (2006) found no significant sex influence on chest depth and rump width of Anatolian water buffaloes. Variation between male and female animals in terms of back fat thickness and subjective fatness scores in the current study was not significant. Based on these results, it may be assumed that male Anatolian water buffalo carcasses were not fattier than their female counterparts, although carcasses obtained from male animals were heavier. In the majority of previous studies (Węglarz, 2010; Daza et al., 2014), which compared the carcass fatness of male and female farm animals that were slaughtered at similar ages, carcasses of female animals have been reported to have higher fatness than male animals. Lack of such a superiority of female Anatolian water buffaloes for carcass fatness in the current study might be explained by neutralization of the gender influence on carcass fatness by the effect of the presence of the difference in carcass weight between male and female buffaloes. Limited number of studies on carcass quality of Anatolian water buffaloes is available; and buffaloes were raised on pasture in the most of these studies. Akdağ (2004) reported 217 and 249 kg warm carcass weight in buffaloes aged 4 and 5–9 years old, respectively. Akdağ and Çelik (2006) found 235 and 236 kg warm carcass weight for male and female buffaloes at 4 years of age. In the above mentioned studies, which were conducted at extensive conditions, the slaughter age was higher, and warm carcass weight was lower than the current results which indicates that meat production from Anatolian water buffaloes might be increased by intensive fattening programme.

Carcasses having dark yellow fat are not generally preferred by the consumers and such carcasses are sold with lower price in markets (Yilmaz et al., 2009). In the current study, difference between male and female carcasses in terms of yellowness value of subcutaneous fat was not significant. Dunne et al. (2004) noted that subcutaneous fat yellowness values about 5 to 6 might be considered as exceptionally 'white' or 'pale' carcasses, and values about 23 to 24 might be considered as 'yellow' or 'amber' which indicates that subcutaneous fat colour of Anatolian water buffalo carcasses obtained from both gender groups might be accepted in compliance with consumer preference.

Instrumental meat quality and sensory evaluation

pH measurement is an important tool to give a reasonably good indication of the meat quality at the commercial level (Miller, 2002), as instrumental and sensory meat quality characteristics (such as colour, shear force value, water holding capacity and sensory tenderness) are influenced by meat pH_u. Kandeepan et al. (2009) noted that normal values for pH_u of buffalo meat ranges between 5.4 and 5.6 which indicates that pH_u values of male and female Anatolian water buffaloes measured in the current study seem to be within the acceptable range. Supporting the current result also Kandeepan et al. (2009) reported significantly lower meat pH_u for female buffaloes compared with male buffaloes, and the authors explained this result by the difference between male and female buffaloes in terms of response to transport stress. Similarly, Florek et al. (2007) found higher pH of the *longissimus lumborum* muscle in young bulls compared to the heifers.

Gender did not significantly influence expressed juice and cooking loss, which are related to tenderness and juiciness of meat (Miller, 2002). Panellists also gave similar scores to meat from male and female water buffaloes in terms of sensory juiciness. Previous studies (Huff-Lonergan and Lonergan, 2005; Ekiz et al., 2012 a) have indicated that low pH_u might cause the development of low water holding capacity (more expressed juice and higher cooking loss). Although LT muscle of female carcasses had lower pH_u value than that of male carcasses, such a gender influence was not observed in terms of water holding capacity. This is also supported by Pearson's correlation results which is low and not significant between pH_u and expressed juice (r=0.068, P=0.679) and between pH_u and cooking loss (r=–0.142, P=0.383). The lack of an association between meat pH_u and water holding capacity in the current study might be explained by the absence of excessive pH_u differences between meat from male and female water buffaloes and by the fact that pH values observed for individuals were not higher than 5.54 for males and 5.48 for female water buffaloes. Then no differences in WHC between males and females could be expected. Expressed juice and cooking loss values obtained in the current study were similar to results reported by Teke et al. (2014), who used same muscle and methodology with the current study for measuring the amount of expressed juice and cooking loss. The non-significant gender influence was also reported by Liotta et al. (2011) in cooking loss for Cinisara cattle and by Li et al. (2014) in water holding capacity and cooking loss for Angus × Chinese Xiangxi yellow (F_1) cattle. Supporting the current results, also Appa Rao et al. (2009) and Kandeepan et al. (2009) found non-significant differences between male and female buffaloes in terms of sensory juiciness.

Tenderness of cooked meat is one of the most important factors affecting consumer approval and therefore a choice. In the present study WBSF means of LT samples from male and female buffaloes were similar at both 7 and 21 days. Moreover, similar scores were given to meat from male and female animals in terms of sensory tenderness by panellists. Supporting these results, Li et al. (2014) also reported equal WBSF values for male and female cattle. Shackelford et al. (1991) noted that WBSF value of 4.6 kg might be used as the midpoint for tenderness, and meat samples having WBSF values exceeding 5.5 kg would be evaluated as tough by consumers and by a trained sensory panel. This indicates that meat of the Anatolian water buffaloes in the present study might be accepted as very tender meat, because WBSF values in meat samples of male and female Anatolian water buffaloes (3.26 vs. 3.18 kg) were lower than these threshold values.

Meat colour is an important criterion in the acceptance of meat by consumers at the point of purchase at market in Turkey (Ekiz et al., 2012 a). According to the results of colour measurements from LT muscle at 1 h and 24 h after cutting, female water buffaloes had darker meat colour than male water buffaloes with lower L* and higher a* values in females than males. Supporting the current study, Fiems et al. (2003) reported darker meat colour for cows compared with bulls, and they explained this result by the fact that pigment content is increasing more rapidly in females than in males. Numerous authors (Priolo et al., 2001; Ekiz et al., 2012 a) noted that higher pH meats tend to have a lower L* value. Results of the present study seem to be contradictory with lower pH_u and L* values in females than males. This could be due to differences in the time of measurements, because pH_u was measured at 24 h post slaughter whereas meat colour was measured 7 days and 21 days after ageing. Khliji et al. (2010) reported that meat L* and a* values, which are equal to or exceeding 34 and 9.5 respectively are considered acceptable by consumers. According to the reports of these authors, meat L* and a* values of Anatolian water buffaloes obtained in the current study might indicate acceptable colour by consumers.

Although the effect of ageing time on meat quality characteristics in cattle has been documented in numerous studies (Cho et al., 2016), there are limited number of researches conducted in water buffaloes on this subject (Neath et al., 2007). In the current study, ageing time had a significant effect on water holding capacity, WBSF value and L* values of LT muscle at 1 h and 24 h after cutting. Expressed juice, cooking loss and WBSF values of meat samples aged for 21 days were lower than those of meat samples aged for 7 days. Moreover, L* values measured at 1 h and 24 h after cutting increased with the prolonged ageing. These results were in agreement with reports by Hou et al. (2014), who found increased L* and a* values and decreased WBSF value with increasing ageing time in Qinchuan × Angus cattle. Similar results were also reported by Cho et al. (2016), who found a decrease in WBSF value and an increase in L* value and water holding capacity for most muscles as the aging time increased in Hanwoo beef bulls. In the beef studies, mechanism of changes in meat quality characteristics during ageing is widely described. The substantial decrease in WBSF value with the increase in ageing time was mostly attributed to the myofibrillar protein degradation by endogenous enzymes (Koohmaraie, 1996; Mungure et al., 2016). Mungure et al. (2016) observed significantly higher L* value in samples aged for 14 and 21 days compared with samples aged 3 and 7 days, and the authors explained this difference by protein structure modification resulting in higher light reflection in longer ageing times.

Meat fatty acids

In the present study oleic acid (C18:1), palmitic acid (C16:0) and stearic acid (C18:0) displayed about 90% of the total fatty acid content of LT muscle. The most abundant fatty acid in Anatolian water buffalo meat was oleic acid in both male (57.14%) and female (57.26%) animals. Percentages of palmitic acid (18.13 and 20.20% in males and females, respectively) and stearic acid (14.83 and 13.44%) followed oleic acid. Same presence order of fatty acids in *longissimus dorsi* muscle was also observed in previous studies conducted with buffaloes (Cutrignelli et al., 2013) and with beef cattle (Realini et al., 2004; Pesonen et al., 2013).

Gender had no significant influence on proportions of other individual fatty acids. Similarly as in the present study, Zhang et al. (2010) observed a higher proportion of myristic acid in male than female Qinchuan cattle. Many studies explained higher levels of individual polyunsaturated fatty acids (PUFA) and/or ∑PUFA in males than females at a similar slaughter age by less intramuscular fat content in males. Hoffman et al. (2005) observed higher proportions in terms of numerous individual PUFAs in males than females, and the authors attributed this result to lower levels of intramuscular fat and therefore fewer triglycerides in males. Holló et al. (2001) reported that PUFAs were present in higher concentrations in male animals than females, with the exception of C20:3 *n-6,* while amount of individual saturated fatty acids (SFA) was similar in both genders. In the last mentioned study, significant medium correlation between intramuscular fat content and amount of PUFA ($r=-0.45$) was also obtained, and significant gender influence on concentrations of PUFAs were attributed to the fact that females deposit adipose tissues earlier and to a greater extent than males, which may be due to variation in terms of hormonal factors. According to Zhang et al. (2010) variation in unsaturated fatty acid (UFA) content between intact male and female cattle might be due to higher capability of females in terms of intramuscular fat deposition, which may be associated with hormonal differences and their possible influence on enzymatic systems, as lipid metabolism in the adipose tissue can be affected by sex hormones. Also, Węglarz (2010) obtained significantly higher proportions of individual PUFAs in fat from the muscle of bulls compared to fat from heifers. The proportions of individual MUFAs and PUFAs obtained in the current study are comparable with previous report by Lambertz et al. (2014) for male buffaloes fed with guinea grass and concentrate at amounts of 1.5% and 2.0% of body weight.

It is observed that SFAs cause a rise in quantity of low density lipoproteins that may be responsible for coronary artery disease as they are easily deposited on the walls of the arteries (Garaffo et al., 2011). In the current study, gender had no significant influence on proportion of ∑SFA in intramuscular fat of Anatolian water buffaloes. The lack of significant differences between male and female animals in terms of ∑SFA was previously observed in cattle from Avileña-Negra Ibérica breed slaughtered at mean weight of 478 kg (Daza et al., 2014) and for cattle from Holstein-Friesian breed slaughtered between 400 and 600 kg (Holló et al., 2001). On the other hand, adequate intake of *n-3* PUFA is important for the maintenance of health and could reduce the risk of chronic and inflammatory diseases (Welch et al., 2010). In the present study, proportion of ∑*n-3* PUFA was higher in intramuscular fat samples from male Anatolian water buffaloes than their female counterparts. Similarly, Węglarz (2010) for Black-and-White Polish Holstein-Friesian cattle and Holló et al. (2001) for Holstein-Friesian cattle obtained significantly higher proportions of ∑*n-3* PUFA in intramuscular fat of bulls compared with those of heifers.

When human nutrition is concerned, PUFA/SFA and *n-6/n-3* PUFA ratios are important criteria that are commonly used to judge the nutritional value of meat (Holló et al., 2001; Ekiz et al., 2014). In the current study, the effect of gender on ∑PUFA/∑SFA ratio was not significant, while intramuscular fat of male buffaloes showed lower ∑*n*-6/∑*n*-3 ratio than that of female buffaloes, which might be explained by higher ∑*n-3* PUFA proportion in males. The recommendation for optimal ratio of *n*-6/*n*-3 PUFA ratio for the human diet is less than 4.00 (Ekiz et al., 2014). This indicates that *n*-6/*n*-3 PUFA ratio of intramuscular fat from male water buffaloes (4.23) seem to be close to the ideal values. However, *n-6/n-3* PUFA ratio of female water buffaloes (6.02) might be considered as unfavourable from the nutritional point of view. On the other hand, recent epidemiologic studies showed that not all SFAs have the same influence on total cholesterol and LDL levels, since lauric, myristic and palmitic acids have a cholesterol-rising influence, but stearic acid has a neutral effect (Daley et al., 2010) due to rapid conversion of stearic acid to oleic acid *in vivo* (Reddy and Katan, 2004). Rhee (1992) noted that stearic acid and all the UFA might be regarded as desirable fatty acids (DFA). Hoffman et al. (2005) found that total amount of DFA amounted to about 82% and 79% of the total fatty acids for male and female impalas, respectively, and concluded that these levels would indicate healthy food commodity because of its potential to lower plasma cholesterol levels. In the current study, proportions of ∑DFA in intramuscular fat of male (79.96%) and female (77.96%) Anatolian water buffaloes were similar, and these levels might also be considered as acceptable from the nutritional point of view.

Conclusion

Male and female Anatolian water buffalo carcasses displayed similar conformation and fatness levels under the conditions of the present study. No significant gender effect was observed in terms of meat tenderness, juiciness and sensory characteristics. However, female water buffaloes had darker meat colour than male water buffaloes with lower L* and higher a* values in females. Instrumental meat quality characteristics, such as meat juiciness, tenderness and lightness were improved with the prolonged ageing, which indicates that longer ageing period might be considered to produce better quality water buffalo meat. Intramuscular fat of male water buffaloes had higher proportion of ∑*n*-3 PUFA and lower ∑*n*-6/∑*n*-3 ratio compared with females, which might indicate better fatty acid profile in meat from male buffaloes. The results of the present study indicate that high quality buffalo meat might be produced by intensive fattening programme. Further investigations might be required in order to describe the quality characteristics of Anatolian water buffalo meat in different feeding/production systems.

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