



The effect of different slaughter weights on some meat quality traits of *musculus longissimus dorsi thoracis* of male Anatolian buffaloes

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Abstract

This research was performed to examine the effects of different slaughter weights (SWs) on some meat quality traits of Anatolian Buffaloes ($n = 20$). Weaned 5-month-old Anatolian Buffalo calves with an average live weight of 100 kg were used as the animal material of the study. Experimental calves were randomly divided into four different slaughter weight groups 200 kg (SW-1: $n = 5$), 250 kg (SW-2: $n = 5$), 300 kg (SW-3: $n = 5$), and 350 kg (SW-4: $n = 5$). Anatolian buffalo calves were fed with 30:70 roughage/concentrate feed ration. Meat quality attributes of *musculus longissimus dorsi thoracis* (LT) muscle of calves slaughtered at target slaughter weight were investigated. The quality traits included 45th minute pH ($\text{pH}_{45\text{min}}$), 24th hour pH ($\text{pH}_{24\text{h}}$), 1st and 24th hour color parameters (L^* (lightness), a^* (redness) and b^* (yellowness), water holding capacity (WHC), drip loss (3rd day (DL-3) and 7th day (DL-7)), freeze-thaw loss (FTL), cooking loss (CL), chemical composition), fatty acid, and cholesterol profiles. The differences in LT muscle $\text{pH}_{24\text{h}}$, 24th hour a^* and b^* color parameters and WHC values of SW groups were not found to be significant ($P > 0.05$). The lowest DL-3 was observed in SW-1 (6.89%) and the greatest in SW-2 (8.96%) groups. Ether extract (EE) ratios increased ($P < 0.01$) and polyunsaturated fatty acid (PUFA)/saturated fatty acid (SFA) proportions decreased ($P > 0.05$) with increasing SWs. The differences in total cholesterol contents of SW groups were not detected to be significant ($P > 0.05$). Among the SW groups of Anatolian Buffaloes, SW-1 was found to be prominent with high WHC, CP, and PUFA/SFA ratio and the least DL-3 ratio.

Keywords Anatolian buffalo · Slaughter weight · Meat quality · Fatty acids · Cholesterol

Introduction

Meat is defined as the skeletal muscle and related mixture of bone tissue, cartilage tissue, nerve tissue, lymph, lymph ducts, blood vessels, blood tissue, ligament, epithelium tissue not able to be separated from skeletal muscle of mammalian species. Meats are quite abundant in essential amino acids, easy-to-produce healthy, appetizing, filling, and palatable foodstuffs with sufficient quantities of vital nutrients. Meats may

easily prevent nutritional disorders and diseases and have an important place in the nutrition of people of all ages. Therefore, quality criteria for such a significant foodstuff play a great role in consumer health (Karaca and Kor 2007; Kandeepan et al. 2013; Lambertz et al. 2014). Thus, the target of livestock fattening operations is not solely to achieve high live weight gains but also to produce healthy and reliable meat along with the changing and developing consumer preferences. Quantity as well as quality has also become a priority in red meat production activities.

According to 2019 data of Turkish Statistics Institute, annual red meat production of Turkey was 1.201.470 tons. The distributions of this production in according to species were as follows: cattle (1.075.479 tons), sheep (109.382 tons), goat (16.536 tons) and buffalo (73 tons) (TurkStat 2020). The Ministry of Agriculture and Forestry provides increasing quantities of supports for buffalo raising. In this sense, a number of buffalo reached to 180.826 by the year 2019 (Şahin et al. 2019).

Anatolian buffalo constituted the animal material of the present study. They are mostly raised in the Samsun, Tokat,

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Sinop, Amasya, Afyon, and Çorum provinces of Turkey (Şahin and Yıldırım 2012). Anatolian Buffalo are suitable for intensive and extensive production, and they can turn cheap and low-quality roughage sources into milk and meat (Akdağ 2004; Şahin and Yıldırım 2012; Kelgökmen and Ünal, 2015). In Turkey, Anatolian buffaloes are mostly raised for milk production, but they are also used for meat production after the yield-age (Akdağ, 2004).

Buffalo milk is mostly used in yoghurt, cheese, and ice cream production and is less used in clotted cream production, and buffalo meat is generally used in fermented sausage production (Kelgökmen and Ünal, 2015; Tekerli et al. 2016).

Buffalo meat can constitute an alternative for red meat production to meet red meat deficit of Turkey and to prevent meat imports. Several researchers indicated that slaughter weights influenced meat quality (Holló et al. 2001; Vieira et al. 2005; Moreno et al. 2008; Nogalski et al. 2014a; Nogalski et al. 2014b; Kul et al. 2020). Similarly, Keane and Allen (1998) reported that meat quality of beef cattle was influenced by slaughter weight. However, the number of studies investigating the meat quality attributes of Anatolian Buffaloes, the number of which is continuously increasing with the supports of the Ministry of Agriculture and Forestry, is quite limited. In this investigation, the effects of slaughter weights on meat quality attributes of Anatolian Buffaloes raised under intensive conditions were investigated.

Material and method

This research was performed in a private farm conditions in Tokat province (located at 40°30'47" north latitude and 36°32'01" east longitude). Winter and summer temperatures of the study region vary between -1.6 and 29.3 °C (Anonymous 2020). Twenty male weaned Anatolian buffalo calves at the age of 5 months with an average live weight of 100 kg were used as the animal material of the study. Anatolian buffalo calves were randomly divided into four slaughter weight (SW) groups: 200 kg (SW-1; $n = 5$), 250 kg (SW-2; $n = 5$), 300 kg (SW-3; $n = 5$), and 350 kg (SW-4; $n = 5$). Calves were initially subjected to adaption feeding for 7 days. Group feeding was practiced in semi-open 20×20 m paddocks. Cattle fattening feed (2696 kcal kg^{-1} metabolic energy (ME), 16.40% crude protein (CP), and dry alfalfa hay (2186 kcal kg^{-1} ME, 18.07% CP) were used as feed material. Clean water and licking stone were provided ad libitum during the experiments. Throughout the fattening period, calves were starved for 12 h and weighted in every 14 days to determine slaughter weights. Slaughters were performed in accordance with the standard slaughter procedures of Turkish Standard Institute in a licensed slaughterhouse 10 km away from the fattening facility (TSI 1987).

Following the slaughter, *longissimus dorsi thoracis* (LT) muscle of slaughtered buffaloes was dissected. Meat pH values were measured at 45th minute ($\text{pH}_{45\text{m}}$), and color parameters were measured at the 1st hour (L^* (lightness = $L^*_{1\text{h}}$), a^* (redness = $a^*_{1\text{h}}$) b^* (yellowness = $b^*_{1\text{h}}$)). Carcasses were kept at $+4$ °C for 24th hours, and then pH ($\text{pH}_{24\text{h}}$), color parameters ($L^*_{24\text{h}}$, $a^*_{24\text{h}}$, $b^*_{24\text{h}}$), and water holding capacity (WHC) were measured at 24th hour; dripping loss (DL) was measured on 3rd (DL-3) and 7th (DL-7) days, and freeze-thaw loss (FTL), cooking loss (CL), fatty acid structure, total cholesterol content, and chemical composition were also determined.

The $\text{pH}_{45\text{m}}$ and $\text{pH}_{24\text{h}}$ values were measured with a penetration-type pH meter (Testo 205, Lenzkirch, Germany) from between the 12th and 13th ribs (Sen et al. 2011; Aksoy et al. 2019). Color parameters (L^* , a^* , and b^*) of LT muscle of Anatolian buffalo calves were also measured from the same anatomic section with a spectrophotometer (Konica Minolta CR-400, Minolta Co., Ltd., Osaka, Japan) (Aksoy and Ulutaş 2016; Kul et al. 2020). Adipose tissue and ligaments were cleaned out to determine WHC of LT muscle and 100 g of remaining LT muscle were ground. Then 5 g sample was taken from ground meat and placed in between two 110 mm Whatman 1 Qualitative filter papers. Glass plates (30×30 cm) were putted above and below the filter papers, and a pressure of 2.250 kg (upper glass plate + weight) was exerted for 5 min (Grau and Hamm 1956; Barton-Gade et al. 1993). At the end of target duration, WHC of LT muscle samples (%) was determined by Aksoy and Ulutaş (2016). Drip loss of LT muscle was determined on the 3rd (DL-3) and 7th (DL-7) days. About 50 g LT meat samples were placed into the vacuum bag and vacuumed and stored at $+4$ °C for 3 and 7 days (Bond and Warner 2007).

At the end of storage duration, LT drip loss was determined with the use of the following equations: $\text{DL-3 and DL-7 (\%)} = (\text{pre-storage weight (g)} - \text{post-storage weight (g)}) / \text{pre-storage weight (g)} \times 100$ (Aksoy and Ulutaş 2016). About 50 g samples were taken from LT muscle to determine CL. Samples were then vacuumed in plastic bags and stored at -80 °C until the time of analysis. On the day of analysis, muscle samples in vacuumed bags were cooked as to have an inner meat temperature of $+80$ °C (for about 60 min). Following the cooking process, muscle samples were cooled as to have inner meat temperature of $+25$ °C (for about 30 min) and dried then (Honikel 1998; Nogalski et al. 2018). Following the cooking and drying, LT muscle samples were re-weighted and CL was calculated with the use of the following equation: $\text{CL (\%)} = (\text{pre-cooking weight (g)} - \text{post-cooking weight (g)}) / \text{pre-cooking weight (g)} \times 100$. About 50 g LT muscle was vacuumed in plastic bags to determine FTL and stored at -20 °C until the time of analysis. At the day of analysis, closed vacuumed bags were kept in 17 °C hot water bath until full thaw (for about 4 h) (Honikel 1997). Following

the thaw and drying, FTL (%) and T (texture (kg cm^{-2})) using texture analyzer (TA.XP Plus - Stable Micro Systems, Godalming, UK) were detected by Aksoy and Ulutaş (2016).

About 150 g meat samples were dissected from LT muscle and ground and stored in a deep freezer at $-20\text{ }^{\circ}\text{C}$ until the time of analysis. On the day of analysis, samples were removed from the deep freezer and homogenized. Then, chemical content (ash (A), crude protein (CP), dry matter (DM)) (AOAC 1990), and ether extract (EE) ratio (Okeudo and Moss 2007) of LT muscle were determined. Triacylglycerides of cold-extracted lipids of LT muscle were switched into fatty acid methyl esters (FAME) with the use of ISO 12966-2:2011 method (ISO 2011). To determine the cholesterol amounts ($\text{mg } 100\text{ g}^{-1}$ meat) of the same muscle, ISO 12228:1999 method was used (ISO 1999; Dag et al. 2015).

Cholesterol and fatty acid content of LT muscle were determined with the use of Perkin Elmer (Auto system GLX, USA) gas chromatography device. Supelco 37 FAME mix (C4-C24) (Bellefonte, USA) was used as the standard for diagnosis of fatty acids.

The fatty acid findings were determined as wt.% (g per 100 g total fatty acid). The all data were analyzed utilized general linear model procedure of SPSS (1999) software. The subgroup means were compared with Duncan test (Düzgüneş et al. 1987).

Results

Mean values for meat quality traits of LT muscles of male Anatolian buffaloes at different slaughter weights are provided in Table 1, chemical properties are provided in Table 2, fatty acid compositions are provided in Table 3, and cholesterol contents are presented in Fig. 1.

Differences in $\text{pH}_{45\text{min}}$ values of SW groups were found to be significant ($P < 0.01$), but the dissimilarities in $\text{pH}_{24\text{h}}$ values were not found to be significant ($P > 0.05$; Table 1). The dissimilarities in color parameters, except for L^* values, measured on LT muscle 24 h after slaughter were not found to be significant ($P > 0.05$). The greatest WHC was observed in SW-1 (28.12%) and the lowest in SW-2 (29.90%) groups. The differences in WHC of SW groups were not found to be significant ($P > 0.05$). FTL values of SW-1, SW-2, SW-3, and SW-4 groups were, respectively, measured as 8.99, 9.36, 7.86, and 8.31%. CL values generally decreased with increasing SWs ($P > 0.05$). The differences in drip loss (DL) of SW groups were found to be significant for DL-7 ($P < 0.05$). The lowest DL-3 was observed in SW-1 (6.89%) and the greatest in SW-2 (8.96%) groups. The differences in EE, T, and CP of SW groups were found to be significant ($P < 0.05$), but the differences in A and DM values of SW groups were not found to be significant ($P > 0.05$).

Table 1 The effects of different slaughter weights on some meat quality traits of *musculus longissimus dorsi thoracis* (LT) of male Anatolian buffaloes

Traits	Slaughter Weight (SW)				SE	Sig.
	SW-1	SW-2	SW-3	SW-4		
pH						
45 min	6.47 ^a	6.26 ^b	6.25 ^b	6.28 ^b	0.036	**
24 h	5.31	5.29	5.35	5.31	0.028	ns
Color						
$L^*_{1\text{h}}$	31.98 ^a	31.94 ^a	30.67 ^b	30.44 ^b	0.284	***
$a^*_{1\text{h}}$	17.52 ^a	13.90 ^b	13.38 ^b	14.00 ^b	0.439	***
$b^*_{1\text{h}}$	4.86 ^a	3.90 ^b	3.47 ^b	3.66 ^b	0.240	**
$L^*_{24\text{h}}$	38.84 ^{ab}	39.81 ^a	38.88 ^{ab}	38.32 ^b	0.384	*
$a^*_{24\text{h}}$	17.64	17.25	17.68	18.33	0.319	ns
$b^*_{24\text{h}}$	7.60	7.25	7.38	7.15	0.243	ns
FTL (%)	8.99	9.36	7.86	8.31	0.736	ns
CL (%)	39.41	40.23	39.70	39.31	0.969	ns
Drip loss (%)						
DL-3	6.89	8.96	6.96	7.93	0.722	ns
DL-7	8.52 ^a	10.14 ^a	7.63 ^b	10.56 ^a	0.710	*
WHC (%)	28.12	29.90	28.81	29.82	0.756	ns
T (kg cm^{-2})	6.35 ^a	7.43 ^b	8.61 ^c	7.01 ^{ab}	0.350	***

a, b: The means indicated with different letters in the same row are significantly different ($P < 0.05$)

Sig.: Significance; ns: $P > 0.05$; *: $P < 0.05$; **: $P < 0.001$; ***: $P < 0.001$

SE: Standard error of mean

SW-1: 200 kg slaughter weight; SW-2:250 kg slaughter weight; SW-3: 300 kg slaughter weight; SW-4: 350 kg slaughter weight

L^* : Lightness; a^* : Redness; b^* : Yellowness; FTL: Freeze-thaw loss; WHC: Water holding capacity; CL: Cooking loss; DL-3: 3rd day drip loss; DL-7: 7th day drip loss; T: Texture

Of polyunsaturated fatty acids (PUFA), α -linolenic acid (C18:3 n-3) contents generally increased with increasing SWs ($P < 0.001$; Table 3). For monounsaturated fatty acids (MUFA), the variations in oleic acid (C18:1) contents of SW groups were found to be significant ($P < 0.05$). Of total fatty acids, the differences only in MUFA of SW groups were found to be significant ($P < 0.05$). PUFA/SFA ratio increased with increasing SWs ($P > 0.05$). Cholesterol contents of SW groups were respectively measured as 68.41, 64.94, 66.07, and 66.22 $\text{mg } 100\text{ g}^{-1}$ meat (Fig. 1). The differences in total cholesterol contents of SW groups were not found to be significant ($P > 0.05$).

Discussion

Meat pH is considered among the most important quality attribute influencing storage, technological, and sensory

Table 2 The effects of different slaughter weights on chemical composition of *musculus longissimus dorsi thoracis* (LT) of male Anatolian Buffalos (%)

Traits	Slaughter weight				SE	Sig.
	SW-1	SW-2	SW-3	SW-4		
DM	25.86	25.71	26.02	25.73	0.196	ns
M	74.11	74.28	73.97	74.26	0.196	ns
A	0.92	0.88	0.96	0.89	0.022	ns
CP	23.13 ^a	22.10 ^b	22.15 ^b	21.89 ^b	0.193	*
EE	1.79 ^b	2.74 ^a	2.92 ^a	3.01 ^a	0.146	**

a, b: The means indicated with different letters in the same row are significantly different ($P < 0.05$)

Sig.: Significance; ns: $P > 0.05$; *: $P < 0.05$; **: $P < 0.01$

SE: Standard error of mean

SW-1: 200 kg slaughter weight; SW-2: 250 kg slaughter weight; SW-3: 300 kg slaughter weight; SW-4: 350 kg slaughter weight

DM: Dry matter; M: Moisture; CA: Ash; CP: Crude protein; EE: Ether Extract

characteristics (Kandeepan et al. 2013; Lambertz et al. 2014; Uğurlu et al. 2017). In the present study, meat pH_{24h} values of different SW groups varied between 5.29 and 5.35. In previous studies on buffaloes, meat pH_{24h} values were reported as between 5.40–5.70 (Naveena et al. 2004; Kandeepan and Biswas 2007a, Kandeepan and Biswas 2007b; Kandeepan et al., 2009, 2013). Holló et al. (2013) reported *longissimus dorsi* (LD) meat pH_{24h} of milk-fed and grazed buffalo calves (at 196 kg slaughter weight) as 5.77. In a study on swamp buffaloes (slaughtered at about 250 kg live weight), LT muscle pH_{24h} values were reported as between 5.70 and 5.80.

Meat color is considered among the most significant factors influencing visual assessment and consumer appreciation (Aksoy and Ulutaş 2016). Dark color meats are generally hard to market and find buyers from low prices (Soysal 2012). In the present study, L* values of low SW groups were more significant as compared with other groups. Meat color darkened with increasing SWs. Many researchers report that the amount of red meat pigment increases and the L* value decreases so that the meat color darkens with slaughter weight increase (Sanudo et al. 2007; Karaca 2010). Parallel to present findings, lightened meat colors were reported with decreasing SWs (Aksoy and Ulutaş 2016; Kul et al. 2020).

In a study conducted with swamp buffaloes (slaughtered at a live weight of 250 kg), L*, a*, and b* values of LD muscle were, respectively, reported as 35.20, 16.80, and 7.10 (Wanapat et al. 2011). As compared with the literature, LD muscle 1st and 24th hour L*, a*, and b* values reported by Yılmaz et al. (2011) for male and female Anatolian Buffalo were lower than the present values. Masucci et al. (2016) investigated the effects of different silage supplementation ratios into rations on meat quality traits of Italian buffaloes

Table 3 The effects of different slaughter weights on fatty acid composition of *musculus longissimus dorsi thoracis* (LT) of male Anatolian Buffalos (wt.%)

Traits	Slaughter weight				SE	Sig.
	SW-1	SW-2	SW-3	SW-4		
C10:0	0.020	0.018	0.012	0.028	0.005	ns
C12:0	0.028	0.020	0.023	0.028	0.006	ns
C14:0	1.508	1.386	1.600	1.508	0.138	ns
C14:1	0.057	0.054	0.075	0.074	0.012	ns
C15:0	0.400	0.314	0.337	0.206	0.058	ns
C16:0	22.197	23.034	23.703	21.622	1.109	ns
C16:1	1.293	1.440	1.338	1.312	0.104	ns
C17:0	1.280	0.968	1.018	0.990	0.189	ns
C18:0	22.395	23.644	23.958	22.116	1.708	ns
C18:1	32.345 ^b	36.574 ^{ab}	35.870 ^{ab}	40.220 ^a	1.592	*
C18:2 n-6	9.108	4.074	3.685	5.044	1.770	ns
C18:3 n-3	0.450 ^a	0.310 ^b	0.283 ^b	0.278 ^b	0.330	***
C18:3 n-6	0.007	0.012	0.007	0.010	0.003	ns
C20:0	0.220	0.160	0.163	0.154	0.023	ns
C20:1	0.058	0.068	0.108	0.104	0.026	ns
C20:2	0.018	0.022	0.020	0.024	0.005	ns
C20:3 n-6	0.085	0.094	0.085	0.088	0.017	ns
C20:4 n-6	0.310	0.272	0.277	0.172	0.082	ns
C22:0	0.095	0.078	0.070	0.050	0.011	ns
C23:0	0.068	0.062	0.050	0.046	0.028	ns
SFA	48.218	49.684	51.093	46.750	2.487	ns
MUFA	33.753 ^b	38.136 ^{ab}	37.390 ^{ab}	41.710 ^a	1.613	*
PUFA	9.978	4.786	4.360	5.618	1.774	ns
PUFA / SFA	0.230	0.097	0.086	0.125	0.046	ns
UFA / SFA	0.959	0.874	0.824	1.019	0.101	ns
n-6 / n-3	21.691	15.346	14.798	18.493	5.531	ns

a, b: The means indicated with different letters in the same row are significantly different ($P < 0.05$)

SW-1: 200 kg slaughter weight; SW-2: 250 kg slaughter weight; SW-3: 300 kg slaughter weight; SW-4: 350 kg slaughter weight

Sig.: Significance; ns: $P > 0.05$; *: $P < 0.05$; ***: $P < 0.001$

SE: Standard error of mean

SFA: Saturated fatty acids; MUFA: Monounsaturated fatty acids; PUFA: Polyunsaturated fatty acids; UFA: Unsaturated fatty acid; n-6: Omega 6; n-3: Omega 3

slaughtered at live weights of 489 and 498 kg. They reported meat L*_{1h}, a*_{1h}, and b*_{1h} values, respectively, as 44.0, 10.8, and 18.3.

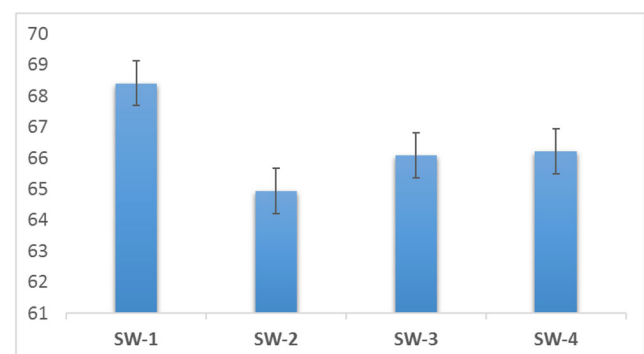


Fig. 1 Cholesterol content of *longissimus dorsi thoracis* (LT) of male Anatolian Buffalos at different slaughter weights. The error bars represent the standard error of the mean. SW-1: 200 kg slaughter weight; SW-2: 250 kg slaughter weight; SW-3: 300 kg slaughter weight; SW-4: 350 kg slaughter weight

FTL generally results from the loss of liquid and formation of residues at the end of freeze-thaw processes (Jama et al. 2008). Present FTL values were lower than the values of Lambertz et al. (2014) reported for buffaloes slaughtered at live weights of 402.5 and 394.4 kg. Increasing CL values generally reduce nutritional values (essential mineral and vitamins) red meats and result in severe economic losses in the meat industry (Jama et al. 2008; Muchenje et al. 2008). In the current research, differences in LT muscle CL values of SW groups were not significant. However, SW-2 group had slightly higher CL values than the other groups. CL values of male and female Anatolian buffaloes were, respectively, reported as 27.40 and 27.93% (Yilmaz et al. 2011). Cifuni et al. (2014) conducted a study with Mediterranean buffaloes of Italy and reported CL values as between 26.94% (alfalfa hay group) and 31.30% (maize silage group). Present CL values of all SW groups were lower than the values of Cifuni et al. (2014) reported for SWs of 393.7 and 394.5 kg.

DL results in the emergence of an undesired appearance during the marketing of meat. It also reduces crispiness and juiciness of meat (Yu et al. 2005; Jama et al. 2008). The lowest DL-3 value was observed in SW-1 and the lowest DL-7 in SW-3 groups. Wanapat et al. (2011) conducted a study with swamp buffaloes slaughtered at a live weight of 250 kg and reported DL of LD muscle as 7.5%.

T value is one of the meat quality traits that determine the acceptability, softness, and juiciness of meat by consumers and increase its value (Miller et al. 2001). In present study, T value determined in all slaughter weight groups was found higher than the T values (3.26–3.18 kg cm⁻²) in LD muscle determined in Anatolian buffaloes by Yilmaz et al. (2011). This result may be due to the difference the SW and method used to determine value. On the other hand, in a study on swamp buffaloes (Wanapat et al. 2011), it was found as 7.50 kg cm⁻² (LD muscle) slaughter at approximately 250 kg live weight. In this study, the hardness value determined in the 250 kg slaughter weight group was found similar to the value detected by Wanapat et al. (2011) for the swamp buffaloes.

LT muscle moisture (M) contents of Anatolian buffaloes with different SWs varied between 73.97 and 74.28%, and M contents of SW groups were not significantly different. Present contents were higher than the values of Fonseca et al. (2005), Juárez et al. (2010), and Dimov et al. (2012) and lower than the values of Infascelli et al. (2005) and Aziz et al. (2012) (71.50%). LT muscle M content of Mediterranean buffaloes raised in Italy was reported as 75.90% (Calabrò et al. 2014). Present M contents of all SW groups were lower than the values reported for Mediterranean buffaloes of Italy (Calabrò et al. 2014). Previous researchers reported M contents of buffalo meat as between 74.04 and 77.75% (Anjaneyulu et al. 1985; Syed Ziauddin et al. 1994; Naveena et al. 2004).

Present A ratios of different SW groups were lower than the values of earlier research (Fonseca et al. 2005; Infascelli et al. 2005; Malek et al. 2009; Juárez et al. 2010; Cifuni et al. 2014) but similar with the values of Holló et al. (2013) reported for buffaloes with 196 kg SW and Aziz et al. (2012) reported for buffaloes of ≤ 2 years of age. LT muscle A content of Mediterranean buffaloes of Italy was reported as 0.76% (Calabrò et al. 2014). EE has significant effects on juiciness, aroma, and crispiness of the meat (Scollan et al. 2006). Present findings on EE of different SW groups were higher than the values of some researchers (Infascelli et al. 2005; Cifuni et al. 2014) but similar with the values of Dimov et al. (2012) reported for buffalo calves (450 kg live weight) with slaughter weights of 580–600 kg.

Present fat content of SW-1 group was similar with the value of Fonseca et al. (2005) reported for LD muscle and Juárez et al. (2010) and Calabrò et al. (2014) reported for LT muscle of buffaloes. Present findings on EE values of all SW groups were greater than the values of Cifuni et al. (2014).

Present CP values of SW-1 group were similar with the values of Dimov et al. (2012) reported for buffalo calves and mature buffaloes and greater than the values of Infascelli et al. (2005) and Cifuni et al. (2014). Present CP values of SW-2, SW-3, and SW-4 groups were higher than the values of Infascelli et al. (2005) and lower than the values of Dimov et al. (2012). Present CP ratios of all SW groups were more significant than the values of Fonseca et al. (2005) and Malek et al. (2009) reported for LD muscle of female Murrah buffaloes and values of Juárez et al. (2010) and Calabrò et al. (2014) reported for LT muscle. Present CP values of SW-2, SW-3, and SW-4 groups were complying with the values of Aziz et al. (2012) reported for buffaloes over the age of 2 years. Present findings on CP ratios were similar with the values of Lambertz et al. (2014) reported for swamp buffaloes. Present CP values of SW-1 group were close to values of Holló et al. (2013) reported for milk-fed buffalo calves (196 kg SW).

Stearic acid (C18:0) and palmitic (C16:0) were reported as the principal saturated fatty acids of red meat of cattle (Fink-Gremmels 1993) and buffaloes (Sharma et al. 1986). Similarly, in the present study, C16:0 and C18:0 amounts were higher in all SW groups than the other fatty acids. The greatest C18:0 and C16:0 levels were observed in SW-3 and the lowest in SW-4 groups. Dimov et al. (2012) reported C16:0 content as 25.75% for male buffaloes with a slaughter weight of 450 kg and as 27.81% for female buffaloes with slaughter weights of 580–600 kg. Present C16:0 contents were lower than the values of Dimov et al. (2012).

Present LT muscle C18:0 contents of all SW groups were greater, and myristic acid (C14:0) contents were similar to the values of Dimov et al. (2012). Monounsaturated fatty acid (MUFA) contents of LT muscle tissue increased with increasing SWs, and the highest value was observed in the SW-4 group. Present values were lower than the values of Sharma

et al. (1986) and Dimov et al. (2012). Palmitic acid (C16:1) contents of SW groups varied between 1.29 and 1.44%, but differences in C16:1 contents of SW groups were not found to be significant. Because of positive impacts on total cholesterol levels, high C16:1 and oleic acid (C18:1) contents are desired in human nutrition (Danke 1994). Present C18:1 contents were similar to the values of Dimov et al. (2012) and C16:1 contents were greater than the values of Dimov et al. (2012).

Differences in SFA levels of SW groups were not found to be significant. The greatest SFA ratio was observed in SW-3 and the lowest in the SW-4 groups. SFA ratios increased with increasing SWs until SW-3 group but got the lowest value in SW-4 group (46.75%). Present SFA ratios of all SW groups were higher than the values of De Mendoza et al. (2015) reported for buffaloes sent to slaughter at the age of 19 and 24 months and were similar with the values of Cifuni et al. (2014) reported for Mediterranean buffaloes of Italy and Dimov et al. (2012) reported for Murrah buffaloes of Bulgaria and lower than the value of Juárez et al. (2010) reported for buffaloes with a slaughter weight of 380 kg. Present SFA values of Anatolian buffaloes were lower than the values reported for Kundi and Murrah buffaloes (Talpur et al. 2007; Rebak et al. 2010).

MUFA ratio was measured as 42.79% for buffaloes fed with compound feed and slaughtered at 450 kg and 41.33% for buffaloes with slaughter weights of 580–600 kg (Dimov et al. 2012). Infascelli et al. (2005) reported total MUFA ratio of buffaloes as 37.30%. Present MUFA ratios of SW-1, SW-2, and SW-3 groups were similar with the conclusions of De Mendoza et al. (2015) and Juárez et al. (2010), lower than the values of Dimov et al. (2012). On the other hand, MUFA ratios of SW-4 group were higher than the values of Juárez et al. (2010) and De Mendoza et al. (2015) and similar with the values of Dimov et al. (2012).

The UFA/SFA ratios of SW groups varied between 0.09 and 0.125. The UFA/SFA ratio was reported as between 0.26 and 0.36 for buffaloes fed with compound feed (Juárez et al. 2010; De Mendoza et al. 2015). Present UFA/SFA ratios of Anatolian buffaloes were lower than the values of the researches conducted in Venezuela (De Mendoza et al. 2015) and Bulgaria (Dimov et al. 2012). Still, they were similar with the values of the research conducted in Italy (Juárez et al. 2010).

It was reported in previous studies that Omega 3 (n-3) and Omega 6 (n-6) PUFAs reduced low-density lipoprotein (LDL) and triglyceride amounts and increased high-density lipoprotein (HDL) amounts (Özkan and Koca, 2006; Yakan and Ünal, 2010; Öztürk 2014; Özdağ 2019). Therefore, in a balanced diet, the n-6/n-3 PUFA ratio should be approximately 3:1 to 1:1, and PUFA/SFA ratio should be greater than 0.4 (Kim et al. 2007; Ekiz et al. 2014; Ibrahim et al. 2018). In the present study, PUFA/SFA ratios of Anatolian buffaloes decreased with increasing from SW1 to SW3 in SW groups, but differences in PUFA/SFA ratios of SW groups were not

found to be significant. The highest n-6/n-3 proportion was seen in SW-1 (21.69) and the lowest in SW-3 (14.96) groups. The more significant total cholesterol level was observed in SW-1 and the lowest in SW-2 groups.

Present total cholesterol levels of all SWs were higher than the values of De Mendoza et al. (2015) reported for 19-year-old buffaloes; Calabrò et al. (2014) reported for Mediterranean buffaloes with a slaughter weight of 350 kg, and Fonseca et al. (2005) reported for Murrah buffaloes. Lapitan et al. (2007) reported a total cholesterol level of crossbreed buffaloes with a slaughter weight of 468 kg as 55.86 mg 100 g⁻¹ meat. In this study, the values of total cholesterol levels, SFA, MUFA, and UFA/SFA ratios of LT muscle in male Anatolian buffaloes were not similar than the earlier investigations due to dissimilarities in fattening methods, breed, slaughter age, and weight.

Conclusions

In the present study, LT muscle WHC and CL values of Anatolian buffaloes decreased and DL-3 values increased with increasing SWs. Among the LT muscle fatty acids, only the differences in C18:1 and C18:3 n-3 fatty acids of SW groups were found to be significant. In general, decreasing PUFA/SFA ratios were observed with increasing SWs. Among the SW groups, SW-1 was found to be prominent with high WHC, CP, and PUFA/SFA ratio and the least DL-3 ratio.

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Compliance with ethical standards

Conflict of interest The authors of this manuscript declared that they have no conflict of interest.

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