Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition)
ISSN：1671-5497
E-Publication Online Open Access
Vol: 41 Issue: 10-2022
DOI 10.17605/OSF.IO/CJWXG

EFFECT OF BREED AND SLAUGHTER WEIGHTS ON MEAT QUALITY OF MALE LAMBS

[1]REYZAN A. HAMO, [2]REDEER K. SAADULLAH, [3]TAHER M. TAHER and [4]FATAH M. KHALAF

[1,2,3,4]Animal Production Department, College of Agricultural Engineering Science, University of Duhok, Kurdistan Region-Iraq.

ABSTRACT

The aim of the present study was to compare meat quality traits of Karadi and Awassi male lambs at different slaughter weights raised intensively. Fifteen male lambs from either Awassi or Karadi were randomly blocked by live weight into three slaughter weights (30 kg, 40 kg and 50 kg), all lambs were fed on iso energetic and nitrogenous concentrated diet ad libitum. lambs were slaughtered once they reached a target weight. Proximate results showed moisture and fat percentage were affected by weight with the highest moisture % and lowest fat % for lambs slaughtered at 30 kg compared to those slaughtered at 50 kg. Crude protein, ash, and myoglobin were not affected by either breed or slaughter weight. Drip loss and cooking loss were not influenced by either breed or slaughter weight. Free fatty acid % in meat increased significantly by slaughter weight from 0.67% to 0.87% for 30 kg and 50 kg, respectively, during storage period. Similarly, free fatty acid % was increased significantly by storage period from 0.70% at day 1 to 0.88% at day 7 of storage period. TBARS values in meat was not affected by breed and slaughter weight, whereas during the storage period TBARS values increased from 0.65 mg MDA/kg meat at day 1 to 2.7 mg MDA/kg meat at day 7. Neither breed nor slaughter weight had an adverse effect on meat quality characteristics.

KEY WORDS: Breed; slaughter weight; proximate; lipid oxidation; free fatty acid

Introduction

The consumption of ovine meat has steadily declined probably due to low eating quality and unsuitable price (Ellies-Oury et al., 2019). Several factors affect ovine meat quality (Prache et al., 2021) and one of the marketing problems for the consumer is the variability in the quality of meat, which causes the consumer to demand a consistent product at purchase. the carcass weight is considered an effective factor effect on meat quality and price (Sañudo et al., 2006; Cloete et al., 2012). Consumers of southern Europe countries usually prefer meat from the light animals as it is considered meat from that animals are more tender than from heavier animals. Most studies analyze age and weight of animals at slaughter together. it is well known animals from the same genetic base have a greater weight at slaughter implies a greater age unless feed is restricted (Doreau and Chilliard, 1997; Polidori et al., 2017; Budimir et al., 2018). Age and weight of animals at slaughter effect on the consumer acceptability in many countries (Font i Furnols et al., 2006). As a result, during the study of meat quality a special attention is required. The physical and chemical characteristics of sheep meat are influenced by the age and slaughter weight which coinciding with growth and development (Santos-Silva et al., 2002; Polidori et al., 2017).

Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition)
ISSN：1671-5497
E-Publication Online Open Access
Vol: 41 Issue: 10-2022
DOI 10.17605/OSF.IO/CJWXG

Generally, sheep genotype could have a significant influence on performance, carcass characteristics and meat quality of lamb (Sañudo et al., 1998; Santos-Silva et al., 2002; Hoffman et al., 2003; De Lima Jùnior et al., 2016).

The Karadi and Awassi sheep is not primarily a milk and wool producer; but main product is meat, which compromise almost 20 and 60%, respectively of the total sheep population in Iraq (Alkass and Juma, 2005). Comparative studies of Karadi and Awassi have been carried out and differences in parameters such as growth performance and carcass characteristics (Alkass and Hassan, 2014; Oramari et al., 2014). However, there is little data on meat quality characteristics. The objective of this study is to compare meat quality traits of Karadi and Awassi male lambs at different slaughter weight raised intensively.

Materials and Methods

Animals and experimental design:

A total of 30 weaned entire male lambs (15 Awassi male lambs and 15 Karadi male lambs) were used in this study (the initial live weights was around 25kg). Lambs from each breed were randomly blocked designed and distributed in to three treatments according to the slaughter weight as follows:

- Treatment 1, five lambs from each Awassi and Karadi breeds were slaughtered at 30 kg live body weight.
- Treatment 2, five lambs from each Awassi and Karadi breeds were slaughtered at 40kg live body weight.
- Treatment 3, five lambs from each Awassi and Karadi breeds were slaughtered at 50 kg live body weight.

All lambs were fed on concentrate diet and raised in individual pens (1.30m x 1.50 m) at the Animal Farm Project, Department of Animal Production, College of Agricultural engineering sciences, University of Duhok. For further information, which related to the diet composition, feeding regime and experimental protocol see a published paper (Khalaf and Oray, 2021)

Slaughtering and sample preparation

Animals were slaughtered when each lamb reached their target body weight of approximately 30 kg (T1), 40 kg (T2) and 50 kg (T3). The feed was withheld overnight with free access to water and animals were weighted then slaughtered according to Muslim way at the College of Agricultural engineering sciences abattoir. After lamb being slaughtered and chilled at 2-4 oC for 24 hrs, the carcasses were processed according to Cross, (1977). Approximately 80 gm of The Longissimus dorsi (LD) muscle was dissected out from the right side of each carcass, trimmed off from fat and packed and stored at -20°C for proximate analysis and myoglobin. The remaining of the Longissimus dorsi were used for drip loss (50 gm) and cooking loss (50 gm).

Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition)
ISSN：1671-5497
E-Publication Online Open Access
Vol: 41 Issue: 10-2022
DOI 10.17605/OSF.IO/CJWXG

Approximately 100 gm of the LD muscle from the left side was minced, stored in polyethylene bag and conditioned for 1, 3 and 7 days at 2-4 C for measuring lipid oxidation (TBARS), free fatty acid value % at each point.

Proximate analysis

All the samples for the proximate analysis were analyzed in duplicate according to the method of Association of Official Analytical Chemist (AOAC, 2019). Dry matter content of meat sample was measured according to the procedure 930. 15 (AOAC, 2019). Meat sample was accurately weighted and oven dried at 60 °C for 6 days until a constant weight obtained. Subsequently, dried sample was grinded and frozen at -20 °C for further proximate analysis. Crude protein in meat sample was measured according to method 968. 06 (AOAC, 2019) using Kjeldahl analyzer and a conversion factor 6.25 of nitrogen/ gram of protein. Total fat content of meat sample was measured according to the method 948. 22 (AOAC, 2019) using Soxhlet extraction. Ash content of dried meat sample was determined according to the method 942. 05 (AOAC, 2019) using muffle furnace after sample being ashed at 550 °C for 4 hrs.

Myoglobin

Myoglobin (Mb) concentration was measured according to the method described by Krzywicki (1982). After meat sample being minced, 5 grams was placed in test tube, then 25 ml of ice-cold phosphate buffer (pH 6-8) was added, the mixture was homogenized for 2 two minutes and cooled at 4 C for one hour. Meat sample centrifuged at 5000 rpm for 10 minutes, then the supernatant was filtered by using whatman no. 1 filter paper and the absorbance was measured at 700 nm and 525 nm using spectrophotometer (Jenway, UK). Myoglobin concentration was determined by using the following equation: myoglobin (mg/gm meat) = (A525-A700) X 2.303 X dilution factor/ weight of sample (gm).

Drip loss

Drip loss was determined according to the method of Honikel, (1998). Approximately 50 gm of meat sample was weighted and suspended inside a plastic container after being putted into a netted bag at 4 °C for 24 hrs. meat sample was then removed and dried by using paper towel and reweighted. Subsequently, the drip loss was calculated using the following equation: Drip loss % = [(Initial weight of sample (gm) – Final weight of sample (gm)/ Initial weight of sample (gm))] X 100.

Cooking loss

Cooking loss was determined according to the method of Sazili et al., (2013). Meat sample was removed from freezer (- 20 °C) and thawed at 2-4 °C for 24 hrs. Approximately, 50 gm of thawed meat weighted and recorded as initial weight. Sample was then vacuum packed and cooked at 70 °C for 1 h in a water bath. Cooked meat sample was then cooled down by using running tap water for 30 minutes, dried with paper towel and reweighted as a weight of cooked meat using the following equation: [

Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition)
ISSN：1671-5497
E-Publication Online Open Access
Vol: 41 Issue: 10-2022
DOI 10.17605/OSF.IO/CJWXG

(Cooking loss % = Initial weight of meat (gm) – Weight of cooked meat (gm) / Initial weight of meat (gm))] X 100.

Thiobarbituric Acid Reactive Substances (TBARS)

Lipid oxidation of meat sample was measured using TBARS assay a according to the method of Buege and Aust, (1978). Approximately 0.5 gm of minced meat sample was weighted in a 15 ml of test tube to which 2.5 ml of TBARS stock solution (1 liter of 150 gm of trichloroacetic acid and 3.75 thiobabituric acid in 0.25 N HCL) was added. Sample was then vortexed for 15 seconds and heated in a water bath at 95 °C for 15 minutes until pink color appeared. The tubes was then rapidly cooled and centrifuged at 3000 g for 10 minutes. The supernatant was then transferred into a 1 ml cuvette and the absorbance was measured at 532 nm using spectrophotometer (Jenway, UK) against blank (0.5 ml of deionized water and 2.5 ml of stock solution). The concentration of TBARS in meat sample was determined as mg of malondialdehyde/ kg of meat by using an appropriate malondialdehyde standard curve.

Free fatty acid value (FFV)

Free fatty acid value was measured according to the method described by Rukunudin et al, (1998). Approximately 2.5 gm of meat sample was mixed with 15 ml of chloroform, homogenized for 1 minute and filtered by using Whatman number-1 filter paper. Five drops of an indicator phenolphthalein were added to 10 ml of filtrated sample then titrated with 0.01N KOH solution. Free fatty acid value was determined using the following equation: Free fatty acid value % = [(Titration (ml) X normality of KOH X 28.2) / Initial weight of meat sample (gm)] X 100.

Statistical Analysis

Data were analyzed as factorial 2 x 3 (breed and slaughter weight) using a general leaner model GenStat 13th (Lawes Agricultural Trust, VSN International Ltd, Oxford, UK), free fatty acid and TBARS values were analyzed by repeated measure ANOVA as randomized block design with the main effect of treatment and time. To determine a significant difference between treatment a Tukey's multiple range (α =0.05) was used and $P< 0.10$ being identified as a trend.

Proximate composition of muscle

The results for muscle chemical composition as percentage are presented in Table 1. The moisture, crude protein, fat and ash of LD muscle were unaffected ($P >0.05$) by neither breed (Awassi vs Karadi) nor their interaction with slaughter weight. However, muscle moisture content as a percentage was affected ($P <0.001$) by the slaughter weight with lambs slaughtered at 30 kg had the highest moisture percentage compared to those slaughtered at 40 kg and 50 kg (76.05 vs 74.74 vs 73.22). There was non-significant effect of breed on muscle fat content of either Awassi or Karadi (4.02% vs 3.71%). In contrast, the muscles fat percentage from lambs slaughtered at 50 kg had the highest muscle fat content compared to those slaughtered at 40 kg and 30 kg (4.96 vs 4.13 vs 2.51). Similar results have been reported by Das et al. (2008), Polidori et al.

Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition)
ISSN：1671-5497
E-Publication Online Open Access
Vol: 41 Issue: 10-2022
DOI 10.17605/OSF.IO/CJWXG

(2017) and Khalaf and Oray (2021), who found as the muscle moisture content significantly decreases and fat content significantly increases as the animal grow up toward the heaver weight (McPhee et al., 2008 ; Junkuszew et al., 2020). No significant difference was recorded in LD muscle from lambs of either breed or slaughter weight on muscle myoglobin content. However, the slaughter weight tended (P=0.08) to increase the muscle myoglobin content from 0.88 to 1.14 for 30 kg and 50 kg respectively. One of the most noticeable of meat physical characteristics is colour as it has a main effect on meat appearance and consumer acceptability. Meat colour is affected mainly by the myoglobin content. Juárez et al. (2009) argued breed has an effect on muscle myoglobin content and showed for Merino breed ; 4.01 mg/g for growing phase, while for Churra breed showed a value 2.79 mg/g for the same stage. In this study no differences were found could be due to that all lambs were from the same growing productive stage.

Table 1: Effect of breed and slaughter weight on proximate (%) and myoglobin of lamb's longissimus dorsi muscle.

	Awassi			Karadi				P-value		
	30 kg	40 kg	50 kg	30 kg	40 kg	50 kg	SED	breed	weight	breed.weight
Moisture	75.64^{bc}	74.65^{abc}	73.02^{a}	76.46^{c}	74.83^{abc}	73.41^{ab}	0.809	0.33	<.001	0.858
CP[1]	20.36	20.52	20.67	19.6	20.2	20.02	0.734	0.188	0.71	0.908
Fat	2.47^{a}	4.36b^{c}	5.22^{c}	2.54^{a}	3.9 ^{b}	4.7b^{c}	0.35	0.146	<.001	0.436
Ash	1.46	1.58	1.51	1.65	1.46	1.28	0.211	0.673	0.518	0.366
Mb[2]	0.94	1.04	1.08	0.82	0.97	1.2	0.155	0.806	0.081	0.527

$^{a, b, c}$ Means in a row with the same superscript are not different (P>0.05)

[1]Crude protein

[2]Myoglobin mg/gm muscle

Drip loss and Cooking loss

The drip and cooking loss percentage of the LD muscle of Awassi and Karadi lambs slaughtered at different weight are presented in Table 2. There was no effect of breed and slaughter weight on either drip loss or cooking loss. However, there was a trend (P=0.09) for the effect of breed on the drip loss after 24 hrs to be higher for Awassi LD muscle compared to Karadi LD muscle (1.46% vs 1.20%). Drip loss defines as water losing from the muscle during storage time (shelf life) or following cooking process. This is mainly depending on the capability of myofibrillar protein to maintain or retain water inside the muscle (Warner, 2017). Protein of meat undergo oxidation process by exposing meat to oxygen during storage, the oxidation weakness the bind between myofibrillar and water that leads to increase water loss. Hence, a post mortem degradation of muscle protein and fat content have an effect on muscle water retain (Amdadul Haque et al., 2016 and Warner, 2017); the higher the fat content of meat could have the lower drip loss as reported by Cam et al. (2021) when a drip loss of meat from two breeds compared. Similarly, Suliman et al. (2021) found that there are no

Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition)
ISSN：1671-5497
E-Publication Online Open Access
Vol: 41 Issue: 10-2022
DOI 10.17605/OSF.IO/CJWXG

significant differences in drip loss of SM from three different breeds (Awassi, Harri and Najdi). No significant differences were seen in cooking loss of meat from either different breed or different slaughter weight as previously reported by Albikim et al. (2016) and Suliman et al. (2021).

Table 2: Effect of breed and slaughter weight on drip loss and cooking loss (%) of lamb's longissimus dorsi muscle.

	Awassi			Karadi				P-value		
	30 kg	40 kg	50 kg	30 kg	40 kg	50 kg	SED	breed	weight	breed.weight
Drip loss	1.699	1.269	1.405	1.366	1.225	1.022	0.2492	0.096	0.169	0.592
Cooking loss	31.98	34.47	31.08	30.44	32.29	31.84	2.304	0.469	0.366	0.645

Stability of lipid in meat during shelf life

There was an effect (P <0.001) of storage period on percentage of free fatty acid in LD muscle in Table 3. Free fatty acid % was increased from 0.70% at day one to 0.79% at day 4 then to 0.88% at day 7 of storage period. Similar results have been reported by Wang (2001); Aksu and Kaya (2005) when free fatty acid measured during storage period, as a continuous of lipolytic enzyme activity to hydrolyze lipids and phospholipids that results to increase free fatty acid in meat during storage period. In contrast, Free fatty acid % of meat during storage period was not effected (P >0.05) by breed with values of 0.79% and 0.78% for Awassi and Karadi lambs, respectively, Figure 1. Slaughter weight had an effect (P <0.001) on free fatty acid % in meat during storage period having high free fatty acid % in meat from lamb slaughtered at 50 kg compared to those slaughtered at 30 kg (0.68% vs 0.87%). As the animal grow up toward a heaver weight the muscle content of fat increases significantly (McPhee et al., 2008 ; Junkuszew et al., 2020). This can be also confirmed from the above data of fat percentage in meat of those lambs slaughtered at heaver weight had higher fat percentage which are considered a main precursor of free fatty acids in meat (Galanakis, 2019). There was no breed X weight and time X breed X weight interaction on meat free fatty acid % during storage period.

Table 3: Effect of breed and slaughter weight on free fatty acid % of LD muscle during storage period.

	Awassi			Karadi				P-value		
	30 kg	40 kg	50 kg	30 kg	40 kg	50 kg	SED	Breed	Weight	Breed X Weight
Day 1	0.53	0.72	0.83	0.63	0.74	0.73	0.066	0.864	<0.001	0.109
Day 4	0.64	0.80	0.90	0.70	0.83	0.83	0.054	0.87	<0.001	0.201
Day 7	0.80	0.88	0.99	0.75	0.89	0.95	0.072	0.507	0.004	0.776

SED values: Time=0.022, Breed=0.003, Weight=0.033, TxB=0.038, TxW=0.05, BxW=0.064, TxBxW=0.065.

P values: Time=<0.001, Breed=0.841, Weight=<0.001, TxB=0.57, TxW=0.89, BxW=0.204, TxBxW=0.401.

Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition)
ISSN：1671-5497
E-Publication Online Open Access
Vol: 41 Issue: 10-2022
DOI 10.17605/OSF.IO/CJWXG

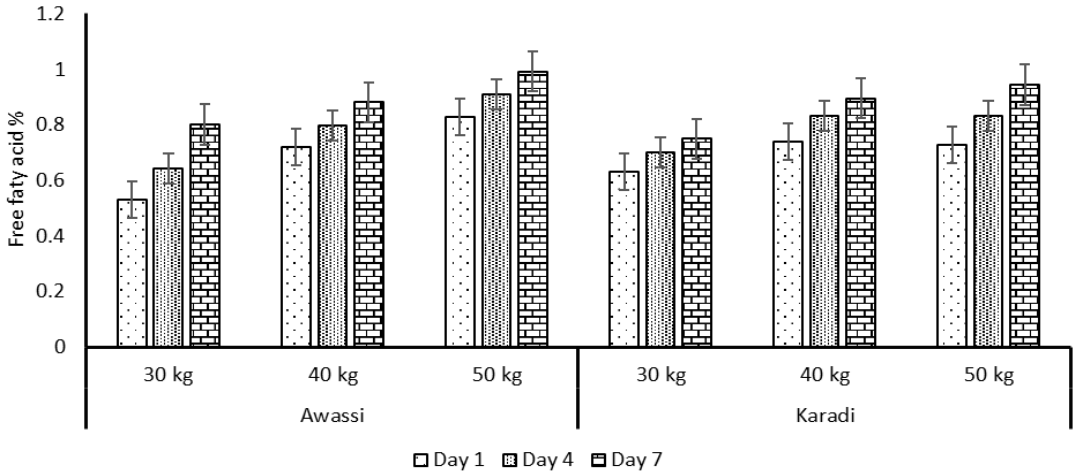

Figure 1: Effect of breed and slaughter weight on free fatty acid during storage period.

Lipid stability (TBARS)

The lipid stability or lipid oxidation in LD muscle of lambs from Awassi and Karadi lambs slaughtered at different weight is presented in Table 4. There was an effect (P <0.001) of time on lipid oxidation of meat during storage period. TBARS values increased from 0.65 mg MDA/kg meat at day 1 to 1.8 mg MDA/kg meat at day 4, then increased to 2.7 mg MDA/kg meat at day 7, Figure 2. It has been reported that storage period has an effect on oxidation process (Domínguez et al., 2019). There is a possibility that lipid oxidation increase with the time due to the increasing radical production that damage lipids (Gonzales-Barron et al., 2021). TBARS is considered a good indicator for the oxidation status as reported a secondary by products of lipid oxidation. An elevation value of TBARS is associated with off-flavor and odors which have a negative effect on sensory properties, nutritional value and shelf life of meat (Gonzales-Barron et al., 2021). There was no effect (P >0.05) of breed and time or interaction of breed X time on TBARS values of meat during storage period. Similar result has been reported by Demirel (2019) that there was no significant difference in TBARS values between two breeds (Suffolk x Lleyn and Scottish Blackfac). It has reported that the production system has a clear effect on TBARS value of meat during storage period (Fernandes et al., 2012). This is possibly related to the fat content and fatty acid composition of meat with unsaturated fat being more susceptible to oxidation during shelf life (Domínguez et al. (2019).

Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition)
ISSN：1671-5497
E-Publication Online Open Access
Vol: 41 Issue: 10-2022
DOI 10.17605/OSF.IO/CJWXG

Table 4: Effect of breed and slaughter weight on TBARS value mg/kg meat of LD muscle during storage period.

	Awassi			Karadi				P-value		
	30 kg	40 kg	50 kg	30 kg	40 kg	50 kg	SED	breed	weight	breed.weight
day 1	0.64	0.50	0.53	0.79	0.85	0.50	0.153	0.175	0.111	0.429
day 4	1.51	1.90	2.36	1.55	1.76	1.72	0.397	0.289	0.218	0.474
day 7	2.28	2.81	3.18	2.41	2.65	2.89	0.528	0.726	0.206	0.849

SED values: Time=0.106, Breed=0.196, Weight=0.235, TxB=0.228, TxW=0.278, BxW=0.339, TxBxW=0.393.

P values: Time=<0.001, Breed=0.731, Weight=0.376, TxB=0.173, TxW=0.037, BxW=0.638, TxBxW=0.741.

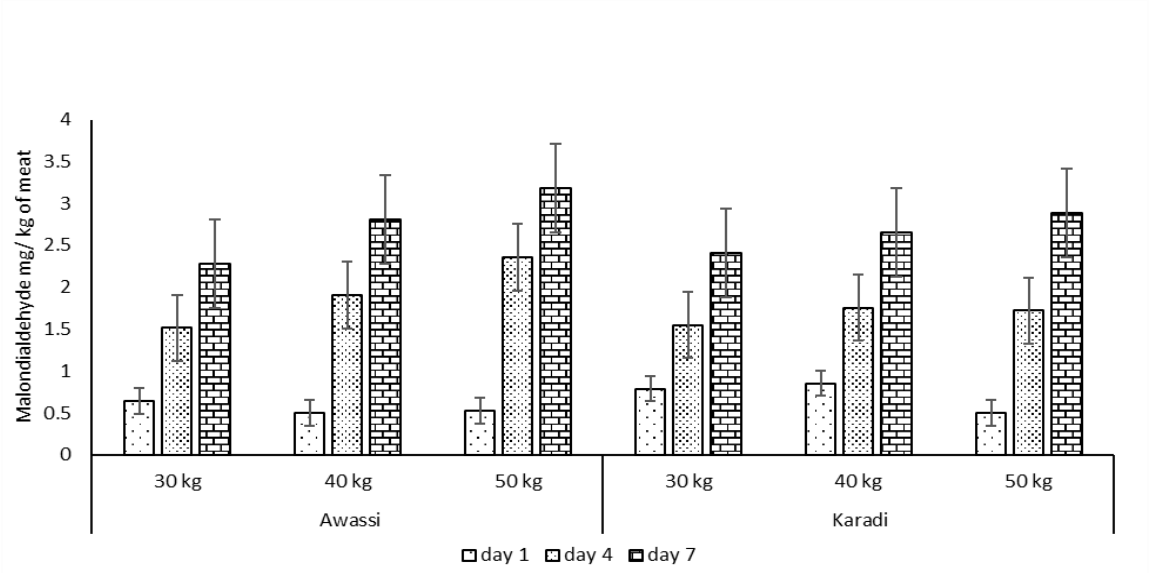

Figure 2: Effect of breed and slaughter weight on TBARS value mg/kg meat during storage period.

Conclusion

It can be concluded that neither breed nor slaughter weight had a negative effect on the studies meat quality parameters. Therefore, meat from either breed or slaughter weight is suitable for consumption after taken into account the growth performance and cost of gain.

References

Ablikim, B., Liu, Y., Kerim, A., Shen, P., Abdurerim, P., & Zhou, G. H. (2016). Effects of breed, muscle type, and frozen storage on physico-chemical characteristics of lamb meat and its relationship with tenderness. *CyTA-Journal of Food*, *14(1), 109-116.*

ISSN：1671-5497
E-Publication Online Open Access
Vol: 41 Issue: 10-2022
DOI 10.17605/OSF.IO/CJWXG

Aksu, M. I., Kaya, M., & Ockerman, H. W. (2005). Effect of modified atmosphere packaging and temperature on the shelf life of sliced pastirma produced from frozen/thawed meat. *Journal of Muscle foods*, *16(3), 192-206.*

Alkass, J. E., & Hassan, C. S. (2014). Growth performance and carcass composition of Karadi and their crossbred raised under two feeding levels. *Adv. J. Anim. Res, 2, 123-130.*

Alkass, J. E., & Juma, K. H. (2005). Small ruminant breeds of Iraq. In characterization of small ruminant breeds in west Asia and north Africa. *Small Ruminant Research*.

AOAC 2019. Official methods of analysis. Association of Official Analytical Chemists, Arlington, VA.

Arsenos, G., Banos, G., Fortomaris, P., Katsaounis, N., Stamataris, C., Tsaras, L., & Zygoyiannis, D. (2002). Eating quality of lamb meat: effects of breed, sex, degree of maturity and nutritional management. *Meat Science, 60(4), 379-387.*

Budimir, K., Trombetta, M.F., Francioni M, Toderi, M. and D'Ottavio, P. (2018). Slaughter performance and carcass and meat quality of Bergamasca light lambs according to slaughter age. *Small Ruminant Research 164, 1–7.*

Buege, J. A., & Aust, S. D. (1978). Microsomal lipid peroxidation. *In Methods in enzymology (Vol. 52, pp. 302-310). Academic press*.

Cloete, J. J. E., Hoffman, L. C., & Cloete, S. W. P. (2012). A comparison between slaughter traits and meat quality of various sheep breeds: Wool, dual-purpose and mutton. *Meat science, 91(3), 318-324.*

Cross HR 1977. Lamb slaughtering , cutting , preserving , and cooking on the farm. Department of Agriculture, Agricultural Research Service.

Das, A. K., Anjaneyulu, A. S. R., Gadekar, Y. P., Singh, R. P., & Pragati, H. (2008). Effect of full-fat soy paste and textured soy granules on quality and shelf-life of goat meat nuggets in frozen storage. *Meat science*, *80(3), 607-614.*

De Lima Jùnior, D., de Carvalho, F., Da Silva, F., do N. Rangel, A., Novaes, L. & Difante, G. (2016). Intrinsic factors affecting sheep meat quality: a review. *Revista Colombiana de Ciencias Pecuarias 29, 3–15.*

Demirel, G. (2019). Effects of dietary fat source, breed and vitamin E level on lipid oxidation of muscles from sheep. *Journal of Istanbul Veterinary Sciences*, *3(1), 1-5.*

Domínguez, R., Pateiro, M., Gagaoua, M., Barba, F. J., Zhang, W., & Lorenzo, J. M. (2019). A comprehensive review on lipid oxidation in meat and meat products. *Antioxidants*, *8(10), 429*.

Doreau, M. and Chilliard Y, (1997). Digestion and metabolism of dietary fat in farm animals. *The British journal of nutrition 78 Suppl 1, S15–S35.*

Ellies-Oury, M. P., Lee, A., Jacob, H., & Hocquette, J. F. (2019). Meat consumption–what French consumers feel about the quality of beef?. *Italian Journal of Animal Science.*

Fernandes, S., Lúcia, A., Monteiro, G., Dittrich, R., Salgado, J., José, C., Gabriela, M., Beltrame, O., Henrique, P. and Pinto, N. (2012). Early weaning and concentrate supplementation on the performance and metabolic profile of grazing lambs. *Revista Brasileira de Zootecnia 41, 1292–1300.*

Galanakis, C. M. (Ed.). (2019). *Lipids and Edible Oils: Properties, processing and applications*. Academic Press.

Gonzales-Barron, U., Santos-Rodrigues, G., Piedra, R. B., Coelho-Fernandes, S., Osoro, K., Celaya, R., ... & Cadavez, V. A. (2021). Quality attributes of lamb meat from European breeds: Effects of intrinsic properties and storage. *Small Ruminant Research*, *198*, *106354.*

ISSN：1671-5497
E-Publication Online Open Access
Vol: 41 Issue: 10-2022
DOI 10.17605/OSF.IO/CJWXG

Haque, M. A., Timilsena, Y. P., & Adhikari, B. (2016). Food proteins, structure, and function.

Hoffman, L. C., Muller, M., Cloete, S. W. P., & Schmidt, D. (2003). Comparison of six crossbred lamb types: sensory, physical and nutritional meat quality characteristics. *Meat Science*, *65*(4), 1265-1274.

Honikel, K. O. (1998). Reference methods for the assessment of physical characteristics of meat. *Meat science*, *49(4), 447-457.*

Hui, Y., Ed.; CRC Press; Taylor & Francis: Boca Raton, FL, USA, (2006); pp. 8(1)–8(21). ISBN 0849398487.

Juárez, M., Horcada, A., Alcalde, M.J., Valera, M., Polvillo, O. and Molina, A. (2009). Meat and fat quality of unweaned lambs as affected by slaughter weight and breed. *Meat Science 83, 308–313.*

Junkuszew, A., Nazar, P., Milerski, M., Margetin, M., Brodzki, P., & Bazewicz, K. (2020). Chemical composition and fatty acid content in lamb and adult sheep meat. *Archives Animal Breeding*, *63*(2), 261-268.

Khalaf, F. M., & Oray, K. A. (2021). Growth performance, carcass characterestics and cost of gain of Awassi and Karadi lambs slaughtered at different weight. *Journal of Duhok University*, *24*(2), 134-145.

Krzywicki, K. (1982). The determination of haem pigments in meat. *Meat Science*, *7*(1), 29-36.

McPhee, M. J., Hopkins, D. L., & Pethick, D. W. (2008). Intramuscular fat levels in sheep muscle during growth. *Australian Journal of Experimental Agriculture*, *48*(7*), 904-909.*

Oramari, R. A., Alkass, J. E., & Mahmud, K. I. (2014). A comparative study on growth, carcass traits and tissue distribution of Awassi and Hamdani lambs. *J. Biol. Agri. And Heal*, *4, 36-43.*

Polidori P, Pucciarelli S, Cammertoni N, Polzonetti V and Vincenzetti S 2017. The effects of slaughter age on carcass and meat quality of Fabrianese lambs. *Small Ruminant Research 155, 12–15.*

Prache, S., Schreurs, N., & Guillier, L. (2021). Factors affecting sheep carcass and meat quality attributes. *animal, 100330.*

Richards, M.P. Lipid chemistry and biochemistry. In Handbook of Food Science, Technology, and Engineering;

Rukunudin, I. H., White, P. J., Bern, C. J., & Bailey, T. B. (1998). A modified method for determining free fatty acids from small soybean oil sample sizes. *Journal of the American Oil Chemists' Society*, *75*(5), *563-568.*

Santos-Silva, J., Bessa, R.J.B. & Santos-Silva, F. (2002). Effect of genotype, feeding system and slaughter weight on the quality of light lambs. II. Fatty acid composition of meat. *Livestock Production Science 77, 187–194.*

Sañudo, C., San Julian, R., Campo, M., Olleta, J.L., Font i Furnols, M., Oliver, M.A., Guerrero, L., Álvarez, I., Cañeque, V., Branscheid, W., Nute, G. & Montossi, F. (2006). Sensory evaluation of lamb produced under different production systems from Uruguay and Europe. *2nd Seminar of the Scientific-Professional Network on Mediterranean Livestock Farming 78, 325–331*.

Sañudo, C., Sanchez, A. and Alfonso, M. (1998). Small ruminant production systems and factors affecting lamb meat quality. *Meat Science 49, S29–S64*.

Sazili, A. Q., Norbaiyah, B., Zulkifli, I., Goh, Y. M., Lotfi, M., & Small, A. H. (2013). Quality assessment of longissimus and semitendinosus muscles from beef cattle subjected to non-penetrative and penetrative percussive stunning methods. *Asian-Australasian journal of animal sciences*, *26*(5), 723.

Suliman, G. M., Al-Owaimer, A. N., El-Waziry, A. M., Hussein, E. O. S., Abuelfatah, K., & Swelum, A. A. (2021). A comparative study of sheep breeds: fattening performance, carcass characteristics, meat

ISSN：1671-5497
E-Publication Online Open Access
Vol: 41 Issue: 10-2022
DOI 10.17605/OSF.IO/CJWXG

chemical composition and quality attributes. *Frontiers in Veterinary Science*, *8*, 647192.

Wang, F. S. (2001). Lipolytic and proteolytic properties of dry-cured boneless hams ripened in modified atmospheres. *Meat science*, *59*(1), 15-22.

Warner, R. D. (2017). The eating quality of meat—IV water-holding capacity and juiciness. In *Lawrie´ s meat science* (pp. 419-459). Wood head Publishing.