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Effect of dietary Marula (*Sclerocarya birrea caffra*) nut meal on the growth performance, carcass traits and meat quality of Dorper lambs

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ABSTRACT

Use of Marula nut meal (MNM) to replace Soyabean meal (SBM) as a dietary protein source in lamb fattening diets by determining effects on growth performance, carcass yield and meat quality was evaluated. MNM replaced SBM on a crude protein (CP) basis, in five diets, at 0%, 25%, 50%, 75% and 100%, respectively. Forty 112-day old entire male Dorper lambs (average body weight: 22.1 ± 3.3 kg) were randomly allocated to the diets and fed *ad libitum* for 63 days. Weekly and final body weight (FBW), body weight gain (BWG), average daily gain (ADG), daily feed intake (FI) and feed conversion ratio (FCR), warm and cold carcass weight, dressing percentage, meat (physical and chemical attributes) quality were determined. Dietary MNM caused no significant difference in FBW, BWG, ADG, FI, FCR, carcass weight and the meat's physical attributes compared to SBM. At 25% and 100% dietary substitution of SBM (CP basis), MNM significantly ($P < 0.05$) reduced meat protein content. Feeding MNM-based diets produced meat with higher fat content compared to the control SBM diet ($P < 0.05$). The meat's total monounsaturated fatty acid content, dominated by oleic acid, increased with increasing dietary MNM. At 100% substitution of SBM, dietary MNM produced meat with the highest ($P < 0.05$) oleic acid content. The results obtained in the study showed that MNM can replace SBM in lamb fattening diets without compromising growth performance, feed utilisation efficiency, carcass yield and physical attributes of meat. MNM can potentially be utilised to improve lamb quality by increasing its oleic acid content.

1. Introduction

Animal products are an essential agricultural commodity for global food security since they provide 31% of global protein consumption (FAOSTAT, 2020). There is a population and income-mediated increase in the demand for animal products globally (Mazinani and Rude, 2020). Alexandratos and Bruinsma (2012) projected the demand for animal products to increase from 48% to 57% between 2005 and 2050. Consumption of meat is projected to grow by 30%, 12%, 18%, 9% and 0.4% in Africa, Latin America, Asia and Pacific region, North America and Europe, respectively (OECD-FAO Agricultural Outlook 2021–2025). In sub-Saharan Africa's least developed countries, the rapidly growing demand for meat is deemed a "livestock revolution" (Wright et al., 2012). Compared to the stagnant supply for meat in developed countries, the 17% decline in meat supply projected for sub-Saharan Africa (SSA) countries by 2050 is due to a decline in animal productivity caused by reduced feed supply (Godde et al., 2021) resulting in a mismatch between demand and supply of meat for human consumption. In SSA demand for mutton and lamb outweighs regional supply (Enahoro et al., 2019) and countries supplement local production with imports (OECD-FAO, 2016).

Nutritionally balanced feeds are a necessity to leverage intensive livestock production. Dietary protein and energy are key feed ingredients necessary to enhance intensive livestock production (Cortese et al., 2019). Soyabean meal (SBM) is a major source of protein and energy used in intensive livestock production (Engelbrecht et al., 2020). It has high protein and essential amino acid content and high digestibility. Utilisation of SBM is however, restricted by its availability and costly price (Grain, 2020).

Recent research characterised indigenous tree seeds to determine their potential as alternative sources of nutrients in feeds (Hagan et al., 2016). Such characterisation work has demonstrated Marula nut meal (MNM) to be a potential source of protein in feeds (Malebana et al., 2018). Currently SBM costs USD450 per metric tonne on the world commodities market (Index Mundi, 2022) while MNM, a by-product of Marula nut oil extraction, is freely available; so there is no direct cost

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attributed its production. Marula fruit yield ranges from a few kg per tree to 2860 kg in young and older trees, respectively (Botelle et al., 2002). Yield records from Botswana show Marula trees bearing up to 6000 kg fruit per season (Botelle et al., 2002). There is also an active drive to capacitate smallholder and rural communities to cultivate the tree mainly for its fruit which have multiple nutraceutical and industrial uses. Therefore, there is this large biomass of "freely available" MNM which could be used as a feed resource.

Mechanically defatted Marula kernel meal from the South African *Sclerocarya birrea caffra* provenance contains 33–39% crude protein (Malebana et al., 2018) and that from the Nigerian provenance is reported to contain 36.7% crude protein (Mariod and Abdelwahab, 2012). Solvent extracted Marula nut meal was shown to have a higher crude protein content than SBM (Mazizi et al., 2019). Since dietary fatty acid profile is largely mirrored in animal products (Butler et al., 2019), MNM in addition to potentially reducing dependency on SBM, can be exploited to improve the fatty acid profile of meat due to high oleic acid content in its residual oil. The replacement of SBM with MNM in lamb fattening was evaluated in this study, determining effects on growth performance, feed utilisation efficiency, meat yield and quality.

2. Material and methods

2.1. Feed ingredients and diets formulation

The Agricultural Research Council (ARC) of South Africa's Vegetable and Ornamental Plant Institute supplied *Eragrostis curvula* (Weeping love grass) and Lucerne (*Medicago sativa*) hay. Sugarcane molasses, feed grade limestone, hexane-extracted SBM, salt and wheat bran were procured from Greenbridge Group (PTY) LTD, Pretoria, South Africa. Canola oil was purchased from Energy Oil, Johannesburg, South Africa and Home of Phadima Marula Oil (Phalaborwa, South Africa), supplied mechanically extracted MNM. The experimental diets, formulated to meet nutrient requirements of growing lambs as per the National Research Council NRC (2007), were iso-energetic and iso-proteic (Table 1).

Table 1
Ingredients and chemical composition of the experimental diets (n = 3).

	Diet				
	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
Ingredients (%)					
Weeping love grass	8.00	8.00	8.00	8.00	8.00
Lucerne hay	10.00	10.00	10.00	10.00	10.00
Maize	47.00	47.00	47.00	47.00	47.00
Wheat bran	11.00	11.00	11.00	11.00	11.00
Molasses	5.00	5.00	5.00	5.00	5.00
Marula nut meal	0.00	4.73	9.49	14.22	18.95
Soybean meal	15.00	11.25	7.50	3.75	0.00
Canola oil	7.00	5.25	3.50	1.750	0.00
Salt	0.50	0.50	0.50	0.50	0.00
Limestone	1.50	1.50	1.50	1.50	1.50
Chemical composition					
Proximate (%)					
Dry matter	92.66	92.06	92.18	92.43	92.30
Organic matter	87.15	85.97	86.36	87.17	86.51
Crude protein[1]	14.70	14.43	14.40	14.98	15.07
Ether extract	11.54	11.50	11.98	13.62	13.29
Energy (MJ/kg DM)					
Gross energy	19.67	20.12	19.78	20.49	19.98
Fibre fraction (%)					
Acid detergent fibre	14.10	14.24	14.01	15.73	16.00
Neutral detergent fibre	33.11	31.38	32.14	32.66	32.79

Diet 1 = 100% SBM as protein source; Diet 2 = 75% SBM + 25% MNM as protein source; Diet 3 = 50% SBM +50% MNM as protein source; Diet 4 = 75% SBM +25% MNM as protein source; Diet 5 = 100% MNM as protein source; 1Total nitrogen x 6.25.

2.2. Ethical clearance, study site, animals, diets and experimental design

The study was approved by the University of the Witwatersrand Animal Ethics Screening Committee (clearance number: AESC 2014/50/B) and the ARC-API Ethics Committee (clearance number: APIEC 14/019). The experiment was done at Irene's ARC's Animal Production Institute (ARC-API) Research Station. In compliance with veterinary regulations, the lambs were transported (permit number: 57/1959 ART/SEC 6/8) from Farm Number 156 Mamogalies Kraal, North West, South Africa, to the ARC-API. Each lamb was ear-tagged, topically treated for ectoparasites with 1% Flumethrin and drenched with Albendazole against internal parasites.

Metabolism crates (1.2 m length x 0.74 m width x 0.92 m height); each with slatted floors and equipped with a feeding trough and nipple drinker housed each lamb and were kept in a ventilated animal house. Forty 112-day old entire male Dorper lambs (mean induction body weight 22.1 ± 3.3 kg) were randomly allocated and fed test diets (each replicated 8 times) for a 21-day adaptation period prior to data collection. In the test diets MNM replaced SBM on a CP basis at 0%, 25%, 50%, 75% and 100% for diets 1–5, respectively. During the data collection period, the lambs were fed for 63 days with *ad libitum* access to feed and drinking water.

2.3. Measurements: growth performance, carcass traits and meat quality

Each lamb's initial and weekly body weight were measured. Feed intake (FI) was determined daily. At the end of the feeding trial the lambs' terminal body weights (TBW) were measured after a 15-hour fast period and thereafter each lamb was electrically stunned, exsanguinated and dressed. Warm carcass weight (WCW) was measured using an overhead digital scale (DIGI DS160 Industrial Scale, Toronto, Canada) and carcass-dressing percent was calculated from TBW and WCW data.

Initial pH (pH_i) and warm carcass temperature were measured on the left *Musculus longissimus lumborum* (*M. LL*) muscle using a Cyberscan pH 300 digital pH meter fitted with an electrode (Eutech Instruments, Thermo Fisher Scientific, Vernon Hills, USA). Cold carcass weight, ultimate pH (pH_u) and cold carcass temperature were determined after carcass chilling at 4ºC for 24 h. The *M. LL* muscle from each carcass was then dissected from the 12/13 region bilaterally. Twenty-five millimetre long samples were cut from each left side *M. LL* muscle and allowed to bloom for 1 h at 4ºC and then meat colour determined using a Minolta meter (Chroma Meter CR-200, Minolta Co., Ltd., Osaka, Japan) according to the CIE L* , a* and b* system. The meat's myoglobin redox forms were determined from its (meat) reflectance using the Minolta CM-2002 spectrophotometer according to the American Meat Science Association (American Meat Science Association AMSA, 1995). Approximately 50 g of the *M. LL* muscle from the left side of each carcass was sliced to 10 × 10 × 20 mm strips to determine drip loss. The initial weight of each strip was determined following which it was then put inside a 200 ml sample bottle and stored at 4ºC for 72 h. Thereafter the strip was reweighed to determine final weight. Drip loss was calculated by subtracting the final weight from the initial.

Four meat samples, two of them 30 mm long and the other two each weighing 50 g were collected from each carcass's right-side *M.LL* muscle and vacuum packed in shrink bags. One of each of the 30 mm and 50 g samples were aged for 1 day and the remainder were aged for 7 days at 2ºC. Immediately after aging each sample was frozen stored for 7 days at −20ºC and thereafter weighed to determine the initial weight. Following the determination of the initial weight, each sample was then thawed for 24 h at 4ºC and then re-weighed to determine the final weight. Thaw loss (TL) was computed. Following the determination of TL, a Mielé electric oven (Model H217, Mielé & Cie, Gütersloh, Germany) was pre-heated to 260ºC. The thawed 30 mm samples were then broiled in the oven to a sample core temperature of 70ºC. Sample total cooking loss (TCL) was computed as the difference between the thawed sample weight and its broiled weight. Cooking drip loss (CDL) and cooking evaporation loss

(CEL) of the sample were computed as described by Jama et al. (2008).

Cooled (to room temperature) broiled samples were used to evaluate meat tenderness by determining the sample Warner Bratzler shear force using an Instron Universal Testing Machine (Model 4301, Instron Ltd, Buckinghamshire, England). Each thawed 50 g sample was cut into 3 g sub-samples to determine the meat's myofibrillar fragmentation length (MFL) using an Olympus BX40 system microscope at 400 x magnification and computed as the average length of 100 single myofibril fragments per sub-sample.

2.4. Chemical analysis

The dry matter, ash, crude protein and ether extract content of the feed and meat were determined as described by Association of Analytical Chemists (Association of Official Analytical Chemists AOAC, 2006: method numbers 930.15, 942.05, 990.03, and 920.39, respectively). Dietary gross energy (GE) content was analysed using an MC-1000 Modular Calorimeter (Energy Instrumentation, Centurion, South Africa) equipped with a PC and MC1000 software and dietary fibre (aNDF, ADF and ADL) content were determined as outlined by Van Soest et al. (1991).

The meat's fatty acid profile was determined from fat extracted from 0.5 g meat samples using a Soxhlet apparatus as described by Association of Official Analytical Chemists AOAC (2006). Following methylation of fatty acids in the fat, the fat methyl esters were extracted using heptane. The fatty acid profile was then determined as described by Christopherson and Glass (1969) using gas chromatography. Nonadecanoic acid was used as an internal standard.

2.5. Statistical analysis

Data were analysed using the Statistical Analysis System (SAS) software, version number 9.3 (Statisitcal Analysis System SAS, 2011). The General Linear Model procedure was used to analyse the fixed effects of treatments on nutrient intake, growth performance, and carcass yield and meat quality. Polynomial contrasts were used to determine linear and quadratic responses to increased dietary inclusion of MNM. A P-value < 0.05 was declared significant. The regression equation was adjusted when significant differences ($P < 0.05$) were detected and tests were performed using PROC MIXED of SAS.

3. Results

3.1. Experimental diets: fatty acid content

Table 2 shows the fatty acid profile of the experimental diets. Generally, the total saturated and total monounsaturated fatty acid proportion of the diets increased with increasing dietary MNM but diet 3 had the highest total saturated fatty acid proportion and diet 5 had the highest total monounsaturated fatty acid, cis fatty acids proportions and

Table 2
Fatty acid profile of the experimental diets (n = 3).

Fatty acid (%)	Diet					SEM	P-value		
	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5		Treatment	Linear	Quadratic
Saturated fatty acids									
C10:0 (Capric acid)	0.05^{b}	0.06^{a}	0.04^{b}	0.03^{c}	0.05^{b}	0.003	< 0.001	< 0.001	< 0.001
C12:0 (Lauric acid)	0.08^{ab}	0.08^{a}	0.05^{bc}	0.01^{c}	0.08^{ab}	0.012	0.009	0.062	0.019
C14:0 (Myristic acid)	0.03^{d}	0.03^{d}	0.20^{a}	0.15^{b}	0.10^{c}	0.008	< 0.001	< 0.001	< 0.001
C16:0 (Palmitic acid)	0.83^{d}	0.85^{d}	1.84^{a}	1.34^{c}	1.63^{b}	0.027	< 0.001	< 0.001	< 0.001
C17:0 (Margaric acid)	0.02^{d}	0.02^{e}	0.06^{a}	0.04^{b}	0.04^{c}	0.001	< 0.001	< 0.001	< 0.001
C18:0 (Stearic acid)	0.31^{d}	0.31^{d}	1.40^{a}	1.06^{b}	0.93^{c}	0.011	< 0.001	< 0.001	< 0.001
C20:0 (Arachidic acid)	0.05^{c}	0.07^{b}	0.04^{c}	0.10^{a}	0.04^{c}	0.005	< 0.001	0.953	0.005
C21:0 (Heneicosylic acid)	0.03^{a}	0.00^{a}	0.02^{a}	0.02^{a}	0.01^{a}	0.009	0.413	0.765	0.519
C22:0 (Behenic acid)	0.13^{a}	0.15^{a}	0.01^{c}	0.11^{b}	0.16^{c}	0.006	< 0.001	< 0.001	0.826
C24:0 (Lignoceric acid)	0.01^{b}	0.00^{b}	0.02^{b}	0.01^{b}	0.02^{b}	0.005	0.197	0.183	0.909
Total saturated fatty acids	**1.56^{c}**	**1.59^{c}**	**3.77^{a}**	**2.88^{b}**	**2.98^{b}**	0.037	< 0.001	< 0.001	< 0.001
Monounsaturated fatty acids									
C14:1 (Myristoleic acid)	0.01^{a}	0.00^{b}	0.01^{a}	0.01^{a}	0.01^{a}	0.001	< 0.001	0.020	0.914
C16:1 (Palmitoleic acid)	0.02	0.02	0.00	0.00	0.02	0.006	0.091	0.179	0.038
C20:1 (Paullinic acid)	0.11^{b}	0.11^{b}	0.10^{c}	0.17^{a}	0.08^{bc}	0.008	< 0.001	0.884	0.408
C22:1n9 (Erucic acid)	0.00^{b}	0.01^{ab}	0.01^{ab}	0.02^{a}	0.02^{a}	0.003	0.047	0.004	0.621
C18:1 n9c (Oleic acid)	3.57^{b}	3.80^{b}	3.57^{b}	3.08^{c}	5.78^{a}	0.104	< 0.001	< 0.001	< 0.001
C18:1 n9t (Elaidic acid)	0.01^{d}	0.00^{d}	0.15^{a}	0.13^{b}	0.06^{c}	0.010	< 0.001	0.001	0.001
Total monounsaturated fatty acids	**3.71^{bc}**	**3.93^{b}**	**3.68^{c}**	**3.28^{d}**	**5.91^{a}**	0.073	< 0.001	< 0.001	< 0.001
Polyunsaturated fatty acids									
C18:2 n6c (Linoleic acid)	1.76^{a}	1.84^{a}	1.07^{c}	0.78^{d}	1.53^{b}	0.032	< 0.001	< 0.001	< 0.001
C18:2 n6t (Linolelaidic acid	0.01^{bc}	0.00^{c}	0.02^{ab}	0.02^{a}	0.01^{c}	0.003	0.003	0.132	0.026
C18:3 n3 (α-linoleic acid)	0.30^{a}	0.31^{a}	0.16^{b}	0.07^{c}	0.08^{c}	0.007	< 0.001	< 0.001	0.031
C18:3 n6 (γ-linoleic acid)	0.02^{a}	0.01^{b}	0.01^{b}	0.01^{b}	0.01^{b}	0.003	0.012	0.002	0.346
C20:3 n3 (Eicosatrienoic acid)	0.04^{a}	0.01^{b}	0.01^{b}	0.00^{b}	0.00^{b}	0.007	0.007	0.001	0.095
C20:3 n6 (Dihomo-γ-linolenic acid)	0.00	0.05	0.03	0.02	0.00	0.013	0.085	0.403	0.032
C20:4 n6 (Arachidonic acid)	0.00^{b}	0.00^{b}	0.02^{a}	0.02^{a}	0.02^{a}	0.005	0.021	< 0.001	0.416
C20:5 n3 (Eicosapentaenoic acid)	0.03	0.01	0.02	0.03	0.02	0.006	0.062	0.789	0.352
C22:6 n3 (Docosahexaenoic acid)	0.03	0.07	0.03	0.02	0.08	0.040	0.710	0.712	0.556
Total polyunsaturated fatty acids	**2.19^{a}**	**2.30^{a}**	**1.32^{c}**	**0.97^{d}**	**1.74^{b}**	0.078	< 0.001	< 0.001	0.001
Trans fatty acid	0.02^{c}	0.00^{c}	0.17^{a}	0.15^{a}	0.06^{b}	0.008	< 0.001	< 0.001	< 0.001
Cis fatty acid	5.32^{c}	5.63^{b}	4.64^{d}	3.86^{e}	7.31^{a}	0.061	< 0.001	< 0.001	< 0.001
n-3 (Omega-3)	0.41^{a}	0.40^{a}	0.21^{b}	0.12^{b}	0.18^{b}	0.040	0.001	< 0.001	0.171
n-6 (Omega-6)	1.78^{b}	1.90^{a}	1.12^{d}	0.84^{e}	1.56^{c}	0.033	< 0.001	< 0.001	< 0.001
n-9 (Omega-9)	3.58^{c}	3.80^{b}	3.73^{bc}	3.22^{d}	5.85^{a}	0.072	< 0.001	< 0.001	< 0.001
n-6/n-3	0.24^{a}	0.24^{a}	0.18^{a}	0.14^{a}	0.14^{a}	0.05	0.174	0.027	0.805
PUFA/SFA	1.40^{a}	1.45^{a}	0.35^{c}	0.34^{c}	0.58^{b}	0.035	< 0.001	< 0.001	< 0.001

^{abcde} Within row means with different superscripts denote significant difference ($P < 0.05$). Diet 1 = 100% SBM as protein source; Diet 2 = 75% SBM +25% MNM as protein source; Diet 3 = 50% SBM +50% MNM as protein source; Diet 4 = 75% SBM +25% MNM as protein source; Diet 5 = 100% MNM as protein source; PUFA/SFA = polyunsaturated fatty acid to saturated fatty acid ratio; SEM= standard error of means; P-value = Probability value.

highest omega-6 to omega-3 ratio ($P < 0.05$). The proportion of dietary total polyunsaturated fatty acids decreased with increasing dietary MNM and were highest in diets 1 and 2 ($P < 0.05$). Palmitic acid, which increased with dietary MNM inclusion, was the dominant dietary saturated fatty acid and its proportion was highest ($P < 0.05$) in diet 3. Oleic acid whose proportion was highest ($P < 0.05$) in diet 5 was the dominant dietary monounsaturated fatty acid. Linoleic acid, the dominant polyunsaturated fatty acid, followed a similar trend to the TPUFAs.

3.2. Growth performance

Table 3 shows the effect of dietary MNM on the terminal body weight (TBW), average daily gain (ADG), body weight gain (BWG), feed intake (FI) and feed conversion ratio (FCR) of the lambs. Dietary MNM resulted in no significant difference on FBW, BWG, ADG, FI and FCR compared to SBM.

3.3. Carcass and meat traits

Dietary MNM resulted in no significant difference in carcass weight, meat temperature and pHi and pHu compared to SBM. At 25% substitution of the SBM's CP contribution to the diet it yield carcasses with greater dressing percentages (linear; $P = 0.05$) compared to the rest (Table 4). The substitution of SBM with MNM had no effect ($P > 0.05$) on meat's colour, myoglobin redox reaction forms, and drip loss (Table 5). Similarly the substitution had no effect ($P > 0.05$) on the meat's TL, TCL, CEL and CDL, tenderness and MFL (Table 6).

MNM at 25% and 100% SBM substitution resulted in meat with higher DM content ($P < 0.05$). The meat's fat content increased with dietary MNM and was highest in meat from lambs fed diet 3 (Table 7). Meat from lambs fed MNM-based diets at 0% and 50% SBM substitution had the highest ash content ($P < 0.05$) and meat from lambs fed diet 5 (100% SBM substitution) had the lowest ($P < 0.05$) protein content. Meat from lambs fed MNM-based diets had similar but higher ($P < 0.05$) total saturated fatty acid content compared to control and stearic acid, the dominant saturated fatty acid (SFA) in the meat, increased with increasing dietary MNM. The total monounsaturated fatty acids content of meat from lambs fed diet 5 (100% substitution of SBM CP) was higher ($P < 0.05$) compared to that of counterparts fed diets 1–4 and oleic acid, the dominant monounsaturated fatty acid in the meat, increased with increasing dietary MNM. Total polyunsaturated fatty acids (TPUFAs) of meat fed the control diet were higher compared to that from lambs fed MNM-based diets ($P < 0.05$) which (meat from lambs fed MNM-based diets) had similar ($P > 0.05$) TPUFAs content. Linoleic acid, the dominant polyunsaturated fatty acid (PUFA) in the meat, generally decreased with increasing dietary MNM. The meat's Omega-6 fatty acid content, n3 to n6 ratio and PUFA to SFA ratios decreased with increasing dietary MNM ($P < 0.05$) but the Omega-9 fatty acid content from lambs fed diets 1–4 which was similar ($P > 0.05$) was lower ($P < 0.05$) than that from lambs fed diet 5. Table 8.

4. Discussion

4.1. Experimental diets: fatty acid profile

Diet 5 wherein MNM replaced 100% of SBM's CP contribution to the diet had the highest oleic acid content mirroring its high content in the MNM. The dominance of oleic acid in the MNM-based diets is in tandem and mirrors the high oleic acid (75 g/DM kg) content of cold pressed MNM (Malebana et al., 2018) used in formulating the experimental diets. The increase in the proportion of TSFAs in the diets with increasing MNM inclusion potentially assists increase the shelf-life of the diets since unsaturated fatty acids undergo lipid peroxidation resulting rancidity, thus the decrease in the TPUFAs content of the diets with increasing MNM inclusion potentially enhances the shelf-life of the feed. While there is a perception that consumption of diets rich in saturated fatty acids compromises consumer health, recent multiple reviews of evidence have come to the conclusion that the recommendation to limit the intake of saturated fats to a maximum of 10% of the total calories requirement is not supported by rigorous scientific research (Astrup et al., 2021).

4.2. Feed intake, growth performance and feed utilisation efficiency

Feed intake, digestion and absorption supplies nutrients for maintenance and productive requirements (Gebreegziabher, 2016). The absorbed nutrients are metabolised to generate energy, the pacesetter of production (Odle et al., 2017). Poor feed palatability results in decreased feed intake (Po et al. 2012) and low feed digestibility (Forbes, 2000). Our findings show similarities in FI across dietary treatments (Table 3). The lambs' FBW, BWG, ADG and FCR were similar across treatments. Similarities in feed and nutrient intake by the lambs across treatments suggests that dietary MNM did not compromise palatability of the feed. Importantly, similarities in growth performance and feed utilisation efficiency show that the efficiency of utilisation of MNM-based diets to supply energy for lamb growth was similar to the SBM-based diet. A decrease in FCR is indicative of efficient feed utilisation (Okunade, Olafadehan, 2019) and an FCR range of 4.00–5.00 for growing fattening lambs is reported (NRC, 2017). Our FCR range of 4.23–4.89 falls within the recommended range suggesting that MNM can replace SBM with similar efficiency to supply energy for use by the lambs.

The feeding trial period (4 months at induction and 6.25 month at termination) spanned the lambs' pubertal growth phase characterised by accelerated growth (Barbosa et al., 2013) and accretion of lean mass. This puberty-mediated accelerated growth depends on adequate nutrient supply for the accretion of lean meat (Cordova-Izquierdo, 2016). Our findings show sustained growth during the feeding trial characterised by consistent body weight gain that suggests that dietary MNM matched the nutrient supply from SBM and met the nutrient requirements of the growing lambs. Dietary MNM therefore replaced SBM without compromising the nutrient-demanding pubertal growth phase of male Dorper lambs.

Table 3
Effect of graded dietary substitution of SBM with MNM on growth performance of male Dorper lambs (n = 8).

Parameter	Diet					SEM	P-value		
	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5		Treatment	Linear	Quadratic
Initial Body Weight (kg)	21.39	21.91	23.92	21.91	21.39	1.20	0.70	0.35	0.41
Terminal Body Weight (kg)	35.48	35.00	37.34	34.84	35.06	1.58	0.79	0.84	0.56
Body Weight Gain (kg)	14.09	13.09	13.61	12.10	12.28	0.95	0.54	0.14	0.93
Average Daily Gain (g/day)	223.60	207.70	216.10	192.10	194.90	15.12	0.54	0.14	0.93
Feed Intake (g DM/day)	931.00	983.00	973.00	896.00	911.00	35.10	0.31	0.27	0.29
Feed Conversion Ratio (g /g)	4.23	4.89	4.67	4.71	4.65	0.37	0.78	0.58	0.40

Diet 1 = 100% SBM as protein source; Diet 2 = 75% SBM +25% MNM as protein source; Diet 3 = 50% SBM +50% MNM as protein source; Diet 4 = 75% SBM +25% MNM as protein source; Diet 5 = 100% MNM as protein source; SEM = standard error of means; P-value = probability value.

Table 4
Effect of graded dietary substitution of soybean meal with Marula nut meal on carcass characteristics, pH and temperature of muscle from Dorper lambs (n = 8).

Parameter	Diet					SEM	P-value		
	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5		Treatment	Linear	Quadratic
Dressing Percentage (%)	46.46^{b}	48.55^{a}	46.29^{b}	46.12^{b}	46.61^{b}	1.10	0.02	0.05	0.18
Warm Carcass Weight (kg)	16.58	17.69	17.31	16.04	15.98	0.66	0.17	0.16	0.70
Warm muscle pH_i	5.93^{ab}	5.01^{b}	5.87^{b}	6.10^{a}	5.88^{b}	0.06	0.73	0.56	0.64
Warm muscle temperature (°C)	33.26^{b}	34.40^{ab}	35.19^{a}	34.12^{a}	34.7^{ab}	0.62	0.35	0.79	0.86
Cold Carcass Weight (kg)	16.00	17.17	16.85	15.58	15.51	0.63	0.63	0.41	0.26
Cold muscle pH_u	5.63^{ab}	5.66^{ab}	5.66^{ab}	5.70^{a}	5.58^{b}	0.04	0.62	0.66	0.18
Cold muscle temperature (°C)	5.38^{a}	4.98^{ab}	3.69^{ab}	4.25^{ab}	2.45^{b}	1.00	0.57	0.10	0.95

^{ab} Within row means with different superscripts denote significant difference ($P < 0.05$).
Diet 1 = 100% SBM as protein source; Diet 2 = 75% SBM +25% MNM as protein source; Diet 3 = 50% SBM +50% MNM as protein source; Diet 4 = 75% SBM +25% MNM as protein source; Diet 5 = 100% MNM as protein source; TRT = Treatment; SEM = standard error of means; P-value = probability value.

Table 5
Effect of graded dietary substitution of soyabean meal with Marula nut meal on the drip loss, colour and myoglobin redox reaction forms of lamb (n = 8).

Parameter	Diet					SEM	P-value		
	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5		Treatment	Linear	Quadratic
Drip loss (%)	1.59	1.56	1.45	1.35	1.54	0.09	0.30	0.24	0.18
Colour									
L* (D_{65})	36.75	36.53	35.35	36.47	36.64	0.78	0.72	0.91	0.30
a* (D_{65})	11.19	11.18	11.47	10.50	11.06	0.49	0.71	0.73	0.66
b* (D_{65})	12.02	12.47	12.06	11.86	12.53	0.38	0.67	0.73	0.66
C* (D_{65})	16.47	16.77	16.65	15.88	16.75	0.51	0.72	0.84	0.80
H* (D_{65})	47.05	48.13	46.47	48.73	48.79	1.20	0.57	0.29	0.68
Myoglobin redox reaction (%)									
Met	18.62	17.08	18.00	17.43	18.12	0.61	0.38	0.77	0.19
Deoxy	4.60	56.00	56.00	58.0	54.80	2.83	0.88	0.60	0.77
Oxy	26.88	26.86	27.20	24.86	26.88	2.37	0.86	0.62	0.98

Diet 1 = 100% SBM as protein source; Diet 2 = 75% SBM + 25% MNM as protein source; Diet 3 = 50% SBM + 50% MNM as protein source; Diet 4 = 75% MNM + 25% SBM as protein source; Diet 5 = 100% MNM as protein source; SEM = standard of error means; P-value = probability value; L* = lightness; a* = redness; b* = yellowness; C* = colour saturation; H* = spectral colour; Met = metmyoglobin; Deoxy = deoxymyoglobin; Oxy = oxymyoglobin.

Table 6
Effect of graded dietary substitution of soyabean meal with Marula nut meal on moisture characteristics, shear force and myofibrillar fragmentation length of lamb (n = 8).

Parameter	Diet					SEM	P-value		
	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5		Treatment	Linear	Quadratic
1-day aged lamb									
Thaw Loss (%)	0.78^{a}	0.47^{ab}	0.62^{ab}	0.72^{a}	0.32^{b}	0.14	0.14	0.14	0.65
Total Cooking Loss (%)	14.08	13.27	12.61	13.07	12.96	0.85	0.80	0.37	0.44
Cooking Drip Loss (%)	2.35	2.38	1.94	2.31	2.16	0.53	0.98	0.79	0.82
Cooking Evaporation Loss (%)	11.73	10.89	10.68	10.77	10.80	0.60	0.72	0.30	0.37
Warner Bratzler Shear Force (kg)	5.79	4.53	5.08	5.33	5.00	0.44	0.37	0.58	0.35
Myofibrillar Fragmentation Length (μm)	40.55	40.97	40.68	42.34	40.20	1.84	0.94	0.91	0.65
7-days aged lamb									
Thaw Loss (%)	0.31	0.23	0.32	0.33	0.35	0.08	0.85	0.50	0.72
Total Cooking Loss (%)	13.65	13.93	14.41	13.73	14.80	0.92	0.89	0.48	0.90
Cooking Drip Loss (%)	2.44	3.34	3.17	2.92	3.50	0.61	0.76	0.38	0.75
Cooking Evaporation Loss (%)	11.21	10.59	11.24	10.81	11.30	0.55	0.86	0.82	0.58
Warner Bratzler Shear Force (kg)	3.36	2.87	3.08	2.93	3.02	0.34	0.87	0.57	0.53
Myofibrillar Fragmentation Length (μm)	25.37	26.62	25.85	23.61	24.65	1.75	0.78	0.43	0.78

^{ab} Within row means with different superscripts denote significant difference ($P < 0.05$).
Diet 1 = 100% SBM as protein source; Diet 2 = 75% SBM + 25% MNM as protein source; Diet 3 = 50% SBM + 50% MNM as protein source; Diet 4 = 75% MNM + 25% SBM as protein source; Diet 5 = 100% MNM as protein source; TRT = Treatment; SEM = standard error of means; P-value = probability value.

4.3. Carcass traits

Slaughter weight is an accurate predictor of carcass weight and meat yield (König et al., 2017). Carcass dressing percentage increases with an increase in slaughter weight (Rosa et al. 2005) pointing to increased meat yield. Our findings showed similarities in slaughter weight (FBW) and carcass warm and cold weight but carcasses from lambs fed diet 2 (25% substitution of SBM CP with MNM CP) had higher dressing percentage compared to the rest. The higher dressing percentage could be a result of better efficiencies generated due to possible positive associative effects at 25% MNM dietary inclusion. However, the similarities in warm and cold carcass weights suggests that dietary MNM can replace SBM in lamb fattening diets with no risk of compromising meat yield.

4.4. Meat physical attributes

The meat's pH_u, colour and water holding capacity influence tenderness, juiciness and flavor which are critical determinants of

Table 7
Effect of graded dietary substitution of soyabean meal with Marula nut meal on the proximate composition of lamb (n = 8).

Parameter	Diet					SEM	P-value		
	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5		Treatment	Linear	Quadratic
Proximate (% DM)									
Dry matter	25.76^{d}	27.82^{a}	26.30^{c}	26.64^{b}	27.94^{a}	0.04	< 0.001	< 0.001	0.07
Ash	3.51^{a}	3.13^{c}	3.50^{a}	3.33^{b}	3.31^{b}	0.04	0.002	0.21	0.26
Crude protein[1]	74.87^{a}	72.99^{a}	74.16^{a}	74.08^{a}	69.78^{b}	0.63	0.003	0.002	0.03
Ether extract	16.41^{c}	22.48^{a}	17.43^{bc}	18.95^{b}	22.57^{a}	0.48	< 0.001	< 0.001	0.37

^{abc} Means within a row with different superscripts differ significantly (P < 0.05).
Diet 1 = 100% SBM as protein source; Diet 2 = 75% SBM + 25% MNM as protein source; Diet 3 = 50% SBM + 50% MNM as protein source; Diet 4 = 75% MNM + 25% SBM as protein source; Diet 5 = 100% MNM as protein source; SEM = standard error of means; P-value = probability value; [1]Total nitrogen x 6.25.

Table 8
Effect of graded dietary substitution of soybean meal with Marula nut meal on the fatty acid profile of meat (n = 8).

Fatty acid	Diet					SEM	P-value		
	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5		TRT	Linear	Quadratic
Saturated fatty acid									
C10:0 (Capric acid)	0.01^{c}	0.12^{b}	0.15^{a}	0.04^{d}	0.00^{e}	0.010	< 0.001	< 0.001	< 0.001
C12:0 (Lauric acid)	0.15^{bc}	0.18^{ab}	0.21^{a}	0.12^{c}	0.11^{c}	0.020	0.004	0.010	0.003
C13:0 (Tridecylic acid)	0.01	0.02	0.02	0.02	0.01	0.006	0.111	1.000	0.013
C14:0 (Myristic acid)	2.49^{b}	2.72^{a}	2.54^{b}	2.20^{c}	2.09^{c}	0.070	< 0.001	< 0.001	0.001
C15:0 (Pentadecylic acid)	0.38^{b}	0.41^{a}	0.37^{bc}	0.36^{bc}	0.35^{c}	0.010	0.001	< 0.001	0.095
C16:0 (Palmitic acid)	19.88^{c}	21.50^{a}	21.76^{a}	20.46^{bc}	20.67^{b}	0.301	0.001	0.468	< 0.001
C17:0 (Margaric acid)	1.07^{a}	0.99^{b}	0.97^{c}	0.93^{d}	0.92^{d}	0.007	< 0.001	< 0.001	< 0.001
C18:0 (Stearic acid)	22.45^{c}	22.68^{c}	22.71^{c}	24.86^{a}	24.11^{b}	0.254	< 0.001	< 0.001	0.818
C20:0 (Arachidic acid)	0.17^{a}	0.16^{a}	0.24^{a}	0.19^{a}	0.19^{a}	0.039	0.355	0.420	0.300
C22:0 (Behenic acid)	0.20^{a}	0.14^{a}	0.52^{a}	0.15^{a}	0.63^{a}	0.303	0.406	0.238	0.691
C23:0 (Tricosylic acid)	0.00	0.02	0.28	0.01	0.01	0.181	0.484	0.096	0.256
Total saturated fatty acids	**46.90^{b}**	**49.01^{a}**	**49.68^{a}**	**49.32^{a}**	**49.09^{a}**	**0.359**	**< 0.001**	**< 0.001**	**< 0.001**
Monounsaturated fatty acids									
C14:1 (Myristoleic acid)	0.08^{abc}	0.09^{a}	0.08^{ab}	0.06^{c}	0.07^{bc}	0.008	0.037	0.025	0.221
C16:1 (Palmitoleic acid	1.16 ^{cd}	1.27^{b}	1.36^{a}	1.13^{d}	1.23^{bc}	0.040	0.003	0.913	0.011
C17:1 (Margaric acid)	0.39^{a}	0.37^{b}	0.34^{c}	0.32^{c}	0.33^{c}	0.008	< 0.001	< 0.001	0.022
C20:1 (Paullinic acid)	0.10^{a}	0.03^{a}	0.01^{a}	0.00^{a}	0.00^{a}	0.630	0.560	0.166	0.402
C24:1 (Nervonic acid)	0.01	0.06	0.09	0.07	0.02	0.022	0.108	0.279	0.026
C22:1 n9 (Erucic acid)	0.00^{c}	0.03^{a}	0.02^{bc}	0.03^{ab}	0.02^{ab}	0.007	0.019	0.051	0.051
C18:1 n9c (Oleic acid)	37.46^{b}	37.56^{b}	38.15^{b}	37.68^{b}	38.88^{a}	0.320	0.012	0.003	0.215
C18:1 n9t (Elaidic acid)	7.29^{a}	7.39^{a}	6.20^{c}	7.01^{b}	7.00^{b}	0.084	< 0.001	< 0.001	< 0.001
Total monounsaturated fatty acids	**39.44^{b}**	**39.64^{b}**	**40.14^{ab}**	**39.45^{b}**	**40.71^{a}**	**0.360**	**0.032**	**0.019**	**0.357**
Polyunsaturated fatty acids									
C18:2 n6c (Linoleic acid)	3.72^{a}	2.86^{b}	2.89^{b}	2.91^{b}	2.30^{c}	0.053	< 0.001	< 0.001	< 0.001
C18:2 n6t (Linolelaidic acid)	0.53	0.37	0.28	0.27	0.24	0.115	0.176	0.031	0.290
C18:3 n3 (α-linoleic acid)	0.46^{a}	0.34^{b}	0.26^{c}	0.22^{c}	0.15^{d}	0.024	< 0.001	< 0.001	< 0.056
C18:3 n6 (γ-linoleic acid)	0.06	0.08	0.04	0.08	0.10	0.038	0.509	0.332	0.481
C20:2 (Eicosadienoic acid)	0.13	0.08	0.09	0.12	0.14	0.032	0.304	0.591	0.074
C20:3 n3 (Eicosatrienoic acid)	0.06	0.01	0.00	0.00	0.00	0.037	0.518	0.176	0.324
C20:3 n6 (Homo-γ-linoleic acid)	0.04^{ab}	0.07^{a}	0.03^{bc}	0.07^{a}	0.00^{c}	0.017	0.015	0.093	0.037
C20:4 n6 (Arachidonic acid)	0.44^{a}	0.22^{c}	0.40^{ab}	0.35^{b}	0.38^{b}	0.028	< 0.001	0.959	0.007
C20:5 n3 (Eicosapentaenoic acid)	0.04	0.04	0.09	0.03	0.02	0.024	0.120	0.266	0.072
Total polyunsaturated fatty acids	**5.91^{a}**	**3.70^{b}**	**3.84^{b}**	**3.78^{b}**	**3.04^{b}**	**0.521**	**0.005**	**0.001**	**0.083**
Trans fatty acids	7.82^{a}	7.76^{a}	6.48^{c}	7.28^{b}	7.24^{b}	0.074	< 0.001	< 0.001	< 0.001
Cis fatty acids	41.19	40.47	41.03	40.60	41.18	0.363	0.239	0.870	0.132
n-3 (Omega-3)	0.56^{a}	0.39^{b}	0.36^{b}	0.25^{bc}	0.17^{c}	0.071	0.005	< 0.001	0.528
n-6 (Omega-6)	4.79^{a}	3.69^{b}	3.63^{b}	3.59^{b}	2.98^{c}	0.060	< 0.001	< 0.001	< 0.001
n-9 (Omega-9)	44.77^{b}	45.03^{ab}	44.36^{b}	44.73^{b}	45.91^{a}	0.389	0.034	0.051	0.024
n-6/n-3	0.12^{a}	0.11^{a}	0.10^{ab}	0.07^{bc}	0.06^{c}	0.015	0.013	0.001	0.693
PUFA/SFA	0.13^{a}	0.08^{b}	0.08^{b}	0.08^{b}	0.06^{b}	0.012	0.002	< 0.001	0.075

^{abcde} Means within a row with different superscripts differ significantly (P < 0.05). Diet 1 = 100% SBM as protein source; Diet 2 = 75% SBM +25% MNM as protein source; Diet 3 = 50% SBM +50% MNM as protein source; Diet 4 = 75% MNM +25% SBM as protein source; Diet 5 = 100% MNM as protein source; SEM = standard error of means; *P*-value = probability value.

meat's eating quality (Maltin et al., 2003). The pH_i plays a critical role in transforming muscle into meat and the pH_u is a major determinant of shelf life. The process of converting muscle to meat initiates toughness mediated by the depletion of energy and the buildup of lactic acid which cause rigor mortis where muscle contract without relaxing (Maltin et al., 2003). The developed muscle toughness is resolved when proteolysis sets in resulting in increases in tenderness with aging. A pH_i range of 5.0–6.0 is ideal for the effective transformation of muscle to meat and a pH_u of 6.0 points to good quality meat Kocak et al. (2016). We show similarities in temperature, pH_i and pH_u of the carcasses across treatments with pH_i and pH_u ranging from 5.01 to 6.10 and 5.58–5.70; respectively suggesting that dietary MNM did not compromise metabolic processes that influence pH but yielded meat of good quality. Additionally and importantly, similarities in the meat's tenderness and myofibrillar fragmentation length across treatments suggest that MNM equally allowed for endogenous proteolytic systems that resolve the rigor-induced toughness as the SBM.

Meat's moisture characteristics affect colour, texture and tenderness

(Bekhit et al., 2019). High drip loss causes reduced tenderness by mediating water loss from myofibrils into the extracellular space (Bertram et al., 2002). Our results show similarities in TL, CDL, TCL and CEL of the lamb across treatment diets thus confirming similarities in meat's colour and tenderness. Importantly, the drip loss range of the meat across dietary treatments fell within the normal drip loss of good quality lamb according to Ingólfsson and Dransfield (1991); suggesting MNM can replace SBM without compromising lamb quality.

Primary determinants of meat colour are content and chemical form of myoglobin, muscle structure morphology and the muscle's ability to scatter and or absorb incident light (Walters, 1975). We observed similarities in the meat's colour profile across diets probably due to the similarities in the content of the myoglobin forms in the meat across dietary treatments. Our findings imply that dietary MNM did not alter the muscle structure of the meat hence its ability to absorb and scatter incident light. We argue that dietary MNM can substitute SBM in lamb fattening diets without compromising the consumer's colour perception of the meat thus will not compromise consumer choice of the product.

4.5. Meat chemical composition and fatty acid content

Increased consumer awareness of the impact poor dietary choices on health affects food choice including the "type" and nutrient profile of meat (Flowers et al., 2019) due to the association between intake of fatty foods and increased risk of developing obesity and associated metabolic diseases (Alfadda et al., 2019). Lean, as opposed to fatty meat, is preferable (Flowers et al., 2019). The type of feed consumed by the animal, in addition to other factors, influences the chemical nutrient content of meat (Romans et al., 1994). Butler et al. (2019) contend that the fatty acid profile of meat, milk and eggs closely mirrors the dietary fatty acid profile. The MNM had higher lipid and oleic acid content compared to SBM (Malebana et al., 2018). Lambs fed 100% MNM-based diet (complete substitution of SBM's CP contribution) yielded meat with lower CP content compared to meat from lambs fed diets consisting of MNM at 0%, 25%, 50% and 75% SBM CP replacement. Meat from lambs fed diet 2 and 5 (25% and 100% SBM substitution) had the highest dry matter (DM) and ether extract contents than that from counterparts fed diets consisting of MNM at 0%, 50% and 75%. The meat from lambs fed diets 3 and 4 (50% and 75% SBM substitution) had high CP and ash contents but low DM and fat comparable to that fed the control diet. These results suggest that dietary MNM inclusion at 50% and 75% to be ideal to mediate the production of lamb with a higher protein but with less fat.

Our findings show that meat from lambs fed MNM-based diets had higher TSFAs content dominated by stearic acid that increased with MNM inclusion; TMUFAs was highest in meat from lambs fed diet 5 (100% substitution of SBM CP) and oleic acid (OA) the dominant MUFA in the meat increased with increasing dietary MNM. Furthermore, meat from lambs fed the control diet had the highest TPUFAs content compared to that from lambs fed-MNM-based diets and linoleic acid, the dominant PUFA, in general decreased with increasing dietary MNM and the meat's Omega-6 fatty acid content, n3 to n6 ratio and PUFA to SFA ratios decreased with increasing dietary MNM. However, the Omega-9 fatty acid content from lambs fed diets 1–4 was lower than that from lambs fed diet 5. Stearic acid, the dominant SFA in the meat from lambs fed MNM-based diets, is cholesterol-neutral and has antioxidant properties (Daley et al., 2010), is a precursor of OA. Human trials have shown that the consumption of high OA red meat increased plasma concentration of HDL-cholesterol, which lowers the risk of CVDs (Smith et al., 2020). Dietary OA has been shown to have protective effects against diet-induced metabolic diseases through decreasing abdominal fat and central obesity (Tutunchi et al., 2020). The increase in the TSFAs dominated by cholesterol-neutral stearic acid and the dominance of OA in the meat's fat, especially meat from lambs fed diet 5 (100% substitution of SBM CP by MNM), has health benefits to consumers as both stearic acid and OA have health beneficial biological activities.

Dietary fatty acid profile significantly affects the fatty acid profile of meat (De Smet and Vossen, 2016). Therefore, feeding diets that possess favourable fatty acids to lambs can be exploited to favourably improve their meat's fatty acid profile. Animal nutritionists seek to produce healthier meat with a high PUFA: SFA ratio and a desirable balance between n-3 and n6 PUFAs in order to combat diet-induced metabolic diseases (Wood et al., 2004). Globally, nutritionists advocate for decreased intake of SFAs, *Trans* fat and cholesterol but promote the intake of n-3 polyunsaturated (Daley et al., 2010). Excessive intake of SFAs, *Trans* fats and cholesterol increases LDL-cholesterol concentration which increases susceptibility to cardiovascular diseases [CVDs); Daley et al., 2010)]. However, recent multiple reviews of evidence have shown that the recommendation to limit intake of saturated fats to 10% of energy requirements is not supported by rigorous scientific research (Astrup et al., 2021). In order to mitigate the potential negative effects on consumer health of the intake of sheep meat with high TSFA, solvent (hexane) extracted and not mechanically extracted MNM with lower residual oil could be used in formulating lamb fattening diets.

A meat n3:n6 ratio less than 4 is desirable; and reduces the risk of CVDs (Scollan et al., 2006). Wood et al. (2007) state the ideal PUFA: SFA ratio for lamb to be 0.1. Our findings show an n3-n6 ratio range of 0.06–0.12 in the meat across treatments which (ratio) is lower than 4 suggesting MNM can replace SBM as a dietary protein source in lamb fattening diets without increased risk of CVDs in consumers. Across dietary treatments the meat's PUFA:SFA ratio ranged from 0.06 to 0.13 with (mean: 0.09) suggesting that MNM-based diets could be used to produce lamb with the desirable PUFA:SFA ratio. Although there was an increase in TSFAs in the meat with dietary MNM it is important to note that stearic acid and OA contributed about 61% of the meat's fat; these fatty acids have been shown to reduce the risk of developing CVDS (Daley et al., 2010; Smith et al., 2020).

5. Conclusion

MNM, as a dietary protein source in lamb fattening diets, can be used with the same efficiency as SBM, to support growth performance, feed utilisation efficiency, meat yield and quality. Additionally, partial replacement of SBM with MNM at 50% and 75% yielded low-fat high-protein lamb and a total replacement of SBM with MNM increased the meat's OA content thus improving its quality.

Declaration of conflict of interest

The authors declare no conflict of interest.

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Corrigendum

Corrigendum to "Effect of dietary Marula (Sclerocarya birrea caffra) nut meal on the growth performance, carcass traits and meat quality of Dorper lambs" [Small Rumin. Res. 219 (2023)]

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The authors regret that in listing the names of the authors there was an error in terms of who should be listed first. Dr. Ingrid M. M. Malebana should be listed first thus the correct order of the authors names should be as follows: **I.M.M. Malebana[a], B.D. Nkosi[a], K.H. Erlwanger[b], E. Chivandi[b]**. This correction is important in recognition of Dr. Malebana's contribution especially in view of the fact that the order of authors in a paper is important for acknowledgement purposes and also for promotion purposes. The authors would like to apologise for any inconvenience caused.

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