Chevon production and quality of Kalahari Red goats fed increasing levels of hempseed cake substituted for soybean meal

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Highlights

- Growth performance of goats did not differ with inclusion of hempseed cake (HSC).
- Dietary inclusion of HSC had no effect on goat carcass attributes.
- Physical meat quality traits were not influenced by addition of HSC in goat diets.
- Intramuscular fat linearly increased with the inclusion of HSC in goat diets.

Abstract

A 42-d study was conducted to evaluate the effects of replacing soybean meal with increasing levels of hempseed cake (HSC) in goat finishing diets on growth performance, carcass and chevon quality attributes. Thirty-five, 3-month-old Kalahari Red wethers (25 ± 1.5 kg initial body weight) were randomly allocated to one of five dietary treatments with seven animals per treatment. Wethers were fed maize-lucerne based finishing diets with inclusions of 0 (control), 25, 50, 75 and 100 g/kg DM of HSC replacing soybean meal as the main protein source. Diet had no effect ($P > 0.05$) on daily feed intake, average daily gain, final body weight and income-over-feed costs. Carcass and meat quality attributes were not influenced ($P > 0.05$) by HSC, except intramuscular fat, which increased linearly ($P \leq 0.05$) with HSC inclusion levels. It was concluded that HSC could completely replace soybean meal in goat finishing diets without affecting chevon production and quality.

Keywords: Animal performance; *Cannabis sativa L.* Kalahari Red goats; Meat quality

1. Introduction

Globally, scarcity of protein and energy feeds often limits chevon production (Goetsch, Merkel, & Gipson, 2011). Soybean meal (SBM) is the major protein feed ingredient for livestock diets (Tona, 2018). However, the ever-growing food-feed-fuel demand for soybean has increased its cost on the global market (Klir, Novoselec, & Antunović, 2019; Tona, 2018). The inclusion of soybean in livestock diets, therefore, makes production less profitable (Tona, 2018). To this end, it is important to find alternative cost-effective protein feed resources that can either maintain or improve chevon production and quality compared to SBM. Hempseed cake (HSC), a by-product of the fast-growing hemp (*C. sativa L.*) industry, is one of the potential protein sources. Currently, there is a booming interest in cultivation of hemp due to its fiber, food,

medicinal and feed benefits (House, Neufeld, & Leson, 2010; Pojić et al., 2014; Rupasinghe, Zheljazkov, Davis, Kumar, & Murray, 2020).

Hemp seed cake (HSC) is a by-product of cold-pressed oil processing, which has high crude protein (CP) content (341 ± 50.4 g/kg dry matter; DM) with relatively balanced amino acid composition (House et al., 2010; Pojić et al., 2014). The contents of ether extract (EE; 116 ± 15.5 g/kg DM) and neutral detergent fiber (NDF; 395 ± 40.7 g/kg DM) in HSC are three times higher than that of SBM (40 ± 15.9; 125 ± 17.6 g/kg DM, respectively) (Karlsson, Finell, & Martinsson, 2010; Paula et al., 2018). The HSC also contains 65–80% polyunsaturated fatty acids (PUFA) with linoleic (18:2 n-6; 60–80%) as the dominant fatty acid followed by α-linolenic acid (18:3 n-3, 18–22%) and oleic acid (C18:1 n-9 16–20%) in that order (Pojić et al., 2014; Siano et al., 2019). It also has plant secondary metabolites including α-tocopherol (29.7 ± 2.76 mg/kg DM), γ-tocopherol (358 ± 28.9 mg/kg DM), total phenolic compounds (1225 ± 485 mg/kg DM) and cannabidiol (10.2 ± 0.21 mg/kg DM) (Pojić et al., 2014; Siano et al., 2019; Teterycz, Sobota, Przygodzka, & Lysakowska, 2021), which possess antioxidant and antimicrobial activities (Leizer, Ribnicky, Poulev, Slavik, & Raskin, 2015).

The nutritional attributes of HSC make it a potential candidate to replace SBM partially or totally in goat diets as a protein, energy and PUFA source. Hempseed cake has been fed to sheep (Karlsson & Martinsson, 2011; Mustafa, McKinnon, & Christensen, 1999; Turner et al., 2012) and cattle (Gibb, Shah, Mir, & McAllister, 2005; Hessle, Eriksson, Nadeau, Turner, & Johansson, 2008; Turner, Hessle, Lundström, & Pickova, 2008) with either neutral or positive effects on feed intake, nutrient utilization, growth performance, carcass and meat quality attributes. However, there are no studies that have investigated the effects of feeding HSC on chevon production and quality. Given that goats have superior fiber digestion efficiency (Domingue, Dellow, & Barry, 1991; Gihad, El-Bedawy, & Mehrez, 1980) and are better able to cope with plant secondary metabolites than sheep and cattle (Estell, 2010; Salem, Salem, El-Adawy, & Robinson, 2006), they could better utilize HSC, which has higher contents of fiber and plant secondary metabolites than SMB. In this regard, it was hypothesized that complete substitution of HSC for soybean meal in goat finisher diets could improve animal performance and meat quality. The objective of the current research was, therefore, to evaluate the effects of substituting soybean meal with increasing inclusion levels of HSC in goat finisher diets on growth performance, carcass attributes, and chevon quality.

2. Materials and methods

Authorization to conduct research activities was obtained from Research Ethics Committee: Animal Care and Use (REC: ACU) of Stellenbosch University prior to the commencement (ACU-2020-11,247). The experiment was conducted between October and November 2020 at Mariendahl Experimental Farm, Elsenburg, South Africa (GPS: 33°51′00”S 18°49′15″E).

2.1. Experimental diets, animal management and design

Cold-pressed HSC was provided by a commercial hempseed oil processing company in Cape Town, South Africa. The seed cake was milled to pass through a 1.5 mm sieve then used to formulate goat finishing diets. Five maize-lucerne based goat finishing diets were formulated to meet nutritional requirements for growing goats (NRC, 2007) with HSC replacing SMB as the main protein source at 0 (control), 25, 50, 75 and 100% (Table 1). All the experimental diets were produced as pellets by a registered commercial feed manufacturer in Cape Town, South Africa. A total of 35 Kalahari Red wether goats of 3–4 months with an average weight

of 25 ± 1.5 kg were sourced from a commercial goat farm. On arrival, the goats were vaccinated against pulpy kidney, tetanus and pasteurellosis using 2 mL of Multivax-P® subcutaneous injection on the upper inner thigh. They were drenched with 20 mL of Ivomec® for internal parasites and dosed with 5 mL of multivitamin (Embavit™). The goats were individually housed on concrete floor pens covered with straw which was changed daily. Each dietary treatment was fed to seven goats (n = 7) in a completely randomized design.

Table 1. Feed ingredient proportions of experimental diets (g/kg DM).

	Hempseed cake inclusion level (%) in the diet				
Ingredients (g/kg DM)	**0**	**2.5**	**5**	**7.5**	**10**
Soybean meal	100	75	50	25	0
Hempseed cake	0	25	50	75	100
Maize white fine	400	400	400	400	400
Lucerne hay	200	200	200	200	200
Chop STD 8.9	93.51	93.51	93.51	93.51	93.51
Molasses syrup	70	70	70	70	70
Wheat straw	50	50	50	50	50
Wheat bran	48.99	48.99	48.99	48.99	48.99
Soybean hulls	10.63	10.63	10.63	10.63	10.63
Savannah Lime	7	7	7	7	7
Vitamin-mineral premix∗	7	7	7	7	7
Ammonium sulphate	5	5	5	5	5
Coarse salt	4.87	4.87	4.87	4.87	4.87
Urea	3	3	3	3	3

∗The composition of the vitamin/premix was not included because of a non-disclosure agreement with the feed manufacturer.

2.2. Feed chemical analysis

The contents of DM, ash and EE were analyzed according to methods 934.01, 942.05 and 920.39, respectively of the AOAC (2002) procedure. Using the Dumas method of AOAC (2002), the total nitrogen content was evaluated with a macro-Nitrogen analyzer (LECO® FP828, LECO Corporation, Miami, USA). The CP content was obtained by multiplying the total nitrogen content in the sample by the 6.25 factor. The procedure described by Hall (2009) was used to estimate the total starch content of the samples with glucose and/or maltodextrins using a commercial starch assay (Total Starch Megazyme kit KTSTA, Megazyme International Ireland Ltd., Wicklow, Ireland). The protocol by Mertens et al. (2002) with sodium sulfite and a heat-stable alpha-amylase was used to measure the neutral detergent fiber (aNDFom). The AOAC (2002) was used to measure acid detergent fiber (ADFom). Lignin (sa.) was analyzed using the procedure described by Raffrenato and Van Amburgh (2011). The aNDFom, ADFom and lignin (sa.) were calculated without ash. The Folin-Ciocalteu colorimetric method described by Makkar (2003) was used to determine the total phenols and tannins. The results were reported as gram gallic acid equivalents per kg DM of feed. All the chemical analyses were performed in duplicate with five replicates.

2.3. Growth performance

The growth performance trial commenced after 14 days of adaptation and lasted for 42 days. At the start and end of the trial, animals were starved for 16 h then weighed to obtain the initial and final shrunk weights. Feed was offered once every day at 8:00 h. Feed and fresh clean water were provided ad libitum, with feed being offered at 10% extra of the previous day's

consumption. Daily feed offered and refusals were weighed for voluntary DM intake (DMI) determination. Weekly, animal full-body weights were determined before feeding and composite samples of feed offered were collected, then stored (−20 °C) for chemical analysis. Average daily gain (ADG) and feed efficiency were calculated.

2.4. Slaughter procedures

At the end of the feeding trial, goats were weighed 16 h before transportation to a commercial abattoir 64 km from the experimental site for slaughter. At the abattoir, goats were rested in the lairage for 16 h and provided with fresh clean water ad libitum, but without feed. The goats were slaughtered according to the procedure of the South African Meat Safety Act (No. 40 of 2000) and stunning was done using 220 V and 1.4 amp for 3 s.

2.5. Carcass measurements

Using the South African Meat Industry Company (SAMIC) classification system (SAMIC, 2006), the carcasses were classed based on age, fatness, conformation and damage after dressing by qualified personnel. The warm carcass weights were determined immediately. Cold carcass weights were determined at 3% shrink loss of the warm carcass weights. The carcass pH and temperature were determined 45 min and 24 h post-mortem in the right *longissimus thoracis et lumborum* (LTL) muscle (between the 12th and 13th ribs) using a portable pH meter (Crison PH25 meter, Lasec, South Africa) in the cold room at 5 °C. The dressing percentage was calculated. The right LTL was excised 24 h post-mortem for meat quality analyses.

2.6. Meat sampling

The whole LTL of the right side was removed and amounts for meat quality analyses sampled from the 9th to 13th rib sliced into five 8 cm × 5 cm × 2 cm rectangular prisms. The prisms were sliced starting from the 9th rib and allocated to color and drip loss (2 prisms), cooking loss and shear force (2 prisms), and proximate (1 prism) analyses in that order.

2.6.1. Meat color and drip loss

A Spectro-guide 45/0 gloss colorimeter (BYK-Gardner GmbH, Germany) was standardized to D65/10° observer settings against white and black tiles, set to sample mode and 11 mm aperture size before determination of meat color. The LTL samples used for color were bloomed for 30 min before measuring lightness (L*), redness (a*) and yellowness (b*) according to AMSA (2012) and CIE (2007) with four readings per sample. The hue angle (h_{ab})(°) and Chroma values (C*) were estimated using the procedure described by AMSA (2012). The drip loss was determined after 24 h storage (4 °C) using a known weight of the LTL meat samples (~80 g each) according to Honikel (1998).

2.6.2. Meat proximate composition

The chemical analyses were performed on homogenized (FOSS Knifetec™ 1095, Höganäs, Sweden) meat samples. The meat samples were trimmed of all visible subcutaneous fat, homogenized, vacuum-packed and stored (−20 °C) for chemical analysis. Moisture and ash were measured using methods 934.01 and 942.05 of the AOAC (2002). The 2/1 (*v*/v) chloroform/ methanol method of Lee, Trevino, and Chaiyawat (1996) was used to determine the total fat of the homogenized meat samples. The Dumas combustion method (AOAC, 2002)

(LECO® FP8288, LECO Corporation, Miami, USA) was used to measure the total nitrogen with the defatted dry meat samples.

2.6.3. Cooking loss and shear force

Cooking loss and tenderness (i.e., Warner-Bratzler Shear Force; WBSF) were determined by the method described by AMSA (2015) and Honikel (1998). The LTL meat samples for cooking loss and shear force (~100 g each) were cooked to an internal temperature of 75 °C in plastic bags immersed in a water bath (80 °C). The WBSF test was used to test for instrumental shear force (kg). A Warner-Bratzler fitting with a V-shaped cutting blade (1 mm thick) at a speed of 3.33 mm/s attached to an electric scale (masskot SCALE CAS 212001, Germiston, South Africa) to compute the maximum weight (force, kg) required to shear through the sample. A sharp stainless double blade scalpel was used to obtain at least six 1 cm × 1 cm × 4 cm square prisms in the direction of the muscle fibers per replicate. The WBSF was reported in Newton.

2.7. Financial analysis

The income-over-feed cost (IOFC) was calculated based on total feed costs and total income after selling carcasses using the following formulae by Buza, Holden, White, and Ishler (2014): IOFC = Total income (TI) − Total feed costs (TFC), where, TI = income generated after selling cold carcasses and, TFC = feed costs per diet × dry matter intake. The carcasses were valued at United State Dollars ($) 3.40/kg at the abattoir. Hempseed cake and soybean meal were valued at $0.22/kg and $0.30/kg, respectively (Agricultural Utilization Research Institute, 2019).

2.8. Statistical analysis

All the data were analyzed using the GLIMMIX procedure of SAS (version 9.4; SAS Institute Inc. Cary, NC, USA). The statistical model incorporated diet as a fixed factor and animal as a random factor. Initial weight was considered as a covariate with day as a repeated measure for feed intake and ADG data. Animal was considered as an experimental unit. The linear and quadratic effects of inclusion levels of the treatment diets on response variables were tested using a response surface regression (PROC RSREG) procedure of SAS Institute Inc (2012). Least square means were considered significantly different at $P \leq 0.05$ using Tukey's test.

3. Results

3.1. Dietary ingredients and chemical composition

The HSC had higher DM, ash, EE, NDF, ADF, lignin, tannins and total phenols, and lower CP, starch, ME and NFC than SBM (Table 2). The substitution of HSC for SBM in goat finisher diets resulted in a linear increase ($P \leq 0.05$) in DM, ash, EE, NDF, ADF, lignin, total phenol and tannin contents (Table 3). Crude protein, starch, ME and NFC declined linearly ($P \leq 0.05$) with increasing levels of HSC in the diets (Table 3).

Table 2. Chemical composition of the experimental feed ingredients (g/kg DM) (n = 5).

Chemical Composition (g/kg)	Hempseed cake	Soybean meal	SEM[g]	*P*-value
Dry matter (DM)	926	899	3.52	<0.0001
Ash	155	83.7	5.76	<0.0001
Crude protein (CP)	246	369	3.17	<0.0001
Starch	76.5	91.5	4.69	0.0365
Ether extract (EE)	80.6	6.87	0.27	<0.0001
Ash-free neutral detergent fiber (aNDFom)[a]	374	67.2	3.34	<0.0001
Ash-free acid detergent fiber (ADFom)[b]	255	51.8	2.88	<0.0001
Lignin (sa.)[c]	91.3	10.3	1.48	<0.0001
Metabolizable energy (ME; MJ/kg)[d]	10.2	11.4	0.10	<0.0001
Non-fibrous carbohydrates (NFC)[e]	145	473	6.05	<0.0001
Total phenols (g GAE/kg DM)[f]	0.36	0.16	0.02	<0.0001
Tannins (g GAE/kg DM)[f]	0.25	0.07	0.02	<0.0001

All chemical analyses were analyzed in triplicate with five replicates per sample.

[a]aNDFom: Neutral detergent fiber analyzed with a heat-stable amylase and reported without ash.

[b]ADFom: Acid detergent fiber reported without ash.

[c]Lignin (sa.): Lignin analyzed by solubilization of cellulose with sulfuric acid.

[d]Calculated according to Freer et al. (2007).

[e]Non-fibrous carbohydrates: calculated as: 1000 – (aNDFom + CP + EE + ash; g/kg).

[f]GAE: Gallic acid equivalent.

[g]SEM: Standard error of means.

Table 3. Chemical composition of experimental diets (g/kg DM) (n = 5).

	Hempseed cake inclusion level in the diet					Empty Cell	P-value		
Chemical Composition (g/kg)	**0**	**2.5**	**5**	**7.5**	**10**	**SEM[g]**	**Diet**	**Linear**	**Quadratic**
Dry matter (DM)	877	888	888	888	890	3.51	0.083	0.023	0.160
Ash	59.2[c]	67.6[b]	68.1[b]	73.7[ab]	78.1[a]	4.32	<0.0001	<0.0001	0.716
Crude protein (CP)	135[a]	135[a]	134[a]	130[b]	125[c]	0.89	<0.0001	<0.0001	0.170
Starch	409[a]	363[b]	322[b]	258[c]	228[c]	10.12	<0.0001	<0.0001	0.885
Ether extract (EE)	25.4[d]	27.4[c]	29.3[b]	31.6[a]	32.2[a]	0.38	<0.0001	<0.0001	0.105
Neutral detergent fiber (aNDFom)[a]	172[c]	180[b]	183[b]	186[ab]	191[a]	1.73	<0.0001	<0.0001	0.362
Acid detergent fiber (ADFom)[b]	93.8[d]	104[c]	106[bc]	108[b]	116[a]	1.16	<0.0001	<0.0001	0.450
Lignin (sa)[c]	18.8[c]	22.6[bc]	23.4[bc]	25.0[ab]	29.2[a]	1.40	<0.0001	<0.0001	0.762
Metabolisable energy (MJ/kg)[d]	11.9[a]	11.7[ab]	11.6[bc]	11.5[cd]	11.3[d]	0.05	<0.0001	<0.0001	0.730
Non-fibrous carbohydrates (NFC)[e]	609[a]	594[ab]	584[bc]	579[c]	576[c]	3.77	<0.0001	<0.0001	0.063
Total phenols (g GAE/kg DM)[f]	0.37[b]	0.39[ab]	0.40 [a]	0.41[a]	0.41[a]	0.008	<0.001	0.020	0.857
Tannins (g GAE/kg DM)[f]	0.231[b]	0.240[ab]	0.255[ab]	0.257[ab]	0.263[a]	0.001	0.036	0.002	0.487

All chemical analyses were analyzed in triplicate with five replicates per sample.

Least square means with different superscript within a row are significantly different ($P \leq 0.05$).

[a]aNDFom: Neutral detergent fiber analyzed with a heat-stable amylase and reported without ash.

[b]ADFom: Acid detergent fiber reported without ash.

[c]Lignin (sa.): Lignin analyzed by solubilization of cellulose with sulfuric acid.

[d]Calculated according to Freer et al. (2007).

[e]Non-fibrous carbohydrates: calculated as: 1000 – (aNDFom + Crude protein + ether extract + ash; g/kg).

[f]GAE: Gallic acid equivalent.

[g]SEM: Standard error of means.

3.2. Growth performance and carcass attributes

The growth and carcass characteristics of Kalahari Red goats fed increasing levels of HSC are shown in Table 4. The DMI, final live weights, ADG and feed efficiency of goats did not differ ($P > 0.05$) with addition of HSC to the diet. The feed costs linearly decreased ($P \leq 0.05$) with HSC inclusion in the diets. Income-over-feed costs were, however, similar ($P > 0.05$) across diets. All the goat carcasses were classed as young (i.e., age class 1) and lean (i.e., fat class 2)

with medium conformation (i.e., class 3). Diet had no effect (P > 0.05) on hot and cold carcass weights, dressing percentage, pH and temperature at 45 min and 24 h.

Table 4. Effects of feeding increasing levels hempseed cake on growth performance and carcass attributes of Kalahari Red wether goats (*n* = 7).

	Hempseed cake inclusion level (%) in the diet						**P-value**		
Growth performance parameters	**0**	**2.5**	**5**	**7.5**	**10**	**SEM**	**Diet**	**Linear**	**Quadratic**
Growth traits									
Final live weight, kg	35.3	35.7	35.7	36.0	36.1	1.410	0.996	0.694	0.966
Average daily gain, kg	0.25	0.24	0.25	0.24	0.25	0.017	0.974	0.897	0.693
Dry matter intake, kg/d	1.21	1.17	1.17	1.16	1.20	0.062	0.970	0.929	0.481
Dry matter intake, g/kg $BW^{0.75}$	87.7	85.6	85.1	86.0	87.5	3.615	0.980	0.100	0.515
Feed efficiency	0.005	0.005	0.005	0.005	0.005	0.0002	0.650	0.944	0.718
Income and feed costs ($)									
Total income	60.1	60.8	61.4	60.1	62.1	2.525	0.976	0.678	0.691
Total feed cost	1.64^{a}	1.43^{ab}	1.37^{ab}	1.29^{b}	1.21^{b}	0.072	0.003	0.001	0.359
Income-over-feed cost	37.5	39.5	39.5	37.7	39.4	1.824	0.861	0.714	0.730
Carcass attributes									
Hot weight, kg	18.2	18.4	18.6	18.2	18.8	0.766	0.973	0.666	0.945
Cold weight, kg	17.7	17.9	18.1	17.7	18.3	0.743	0.976	0.678	0.931
Dressing %	50.0	50.0	50.7	49.3	50.6	0.870	0.812	0.863	0.830
pH (45 min)	6.48	6.45	6.80	6.51	6.66	0.106	0.123	0.219	0.479
pH (24 h)	6.00	5.95	6.03	6.01	6.09	0.070	0.717	0.293	0.530
Temperature (45 min)	33.5	32.8	32.9	32.1	32.5	0.488	0.310	0.071	0.440
Temperature (24 h)	3.58	3.39	3.41	3.19	3.24	0.127	0.230	0.064	0.655

Least square means with different superscript within a row are significantly different (P ≤ 0.05).

$BW^{0.75}$: Metabolic body weight.

SEM: Standard error of means.

3.3. Meat quality characteristics

Most meat physicochemical traits (i.e., moisture, crude protein, drip loss color parameters, cooking loss and WBSF) of LTL meat from Kalahari Red goats did not differ (P > 0.05) across diets, except for intramuscular fat (IMF) and ash (P ≤ 0.05; Table 5). The IMF linearly increased (P ≤ 0.05) while ash linearly decreased (P ≤ 0.05) with the inclusion level of HSC in the diets. Drip loss tended to increase (*P* = 0.065) with the inclusion of HSC in the diets.

Table 5. Effects of feeding increasing of hempseed cake on physiochemical traits of *Longissimus thoracis et lumborum* muscle of Kalahari Red wether goats (n = 7).

	Hempseed cake inclusion level (%) in the diet					Empty Cell	**P-value**		
	0	**2.5**	**5**	**7.5**	**10**	**SEM[1]**	**Diet**	**Linear**	**Quadratic**
Moisture, %	74.5	74.9	73.9	73.5	74.2	0.479	0.321	0.204	0.537
Ash, %	2.07[a]	1.81[ab]	1.57[ab]	1.14[c]	0.79[d]	0.074	<0.001	<0.001	0.186
Crude protein, %	20.0	20.6	20.0	20.4	20.2	0.397	0.228	0.094	0.404
Intramuscular fat, %	4.07[b]	4.19[b]	5.25[a]	5.29[a]	5.45[a]	0.388	0.035	0.003	0.522
L*	36.8	37.4	37.5	37.9	37.9	0.655	0.774	0.202	0.781
a*	11.4	11.9	11.7	11.9	11.9	0.427	0.899	0.459	0.623
b*	9.54	9.84	9.03	9.52	9.23	0.377	0.601	0.432	0.924
Hue angle (H°)	39.9	39.6	37.5	38.7	37.9	0.985	0.356	0.128	0.543
Chroma (C)	14.9	15.4	14.8	15.3	15.1	0.506	0.902	0.916	0.793
Drip loss, %	1.23	1.54	1.56	1.66	2.19	0.479	0.271	0.065	0.361
Cooking Loss, %	36.2	37.1	36.2	35.8	34.4	1.614	0.809	0.335	0.482
WBSF[2], N	50.4	51.5	52.8	54.2	49.5	2.498	0.691	0.919	0.225

Least square means with different superscript within a row are significantly different ($P \leq 0.05$).

[1]SEM: Standard error of means.

[2]WBSF: Warner-Bratzler Shear Force.

4. Discussion

To the authors knowledge, this is the first documented study to evaluate the effects of feeding HSC to goats, thus comparisons will be made to sheep and cattle where necessary. The similarity in DM intake (DMI) of goats fed increasing levels of HSC up to 10% suggest that the reported dietary differences in contents of tannins, lipids, rapidly and slowly fermentable carbohydrates were not large enough to significantly influence palatability and digestibility of the diets. The NDF, tannin and EE contents of the diets were respectively below 340, 110 and 30 g/kg DM, the values above which DMI of goats is negatively affected (Avondo, Biondi, Pagano, Bonanno, & Lutri, 2008; Teh et al., 1994; Yisehak, Kibreab, Taye, Ribeiro Alves Lourenço, & Janssens, 2016). In addition, all diets met CP (120 g/kg DM) and ME (11.0 MJ/kg DM) requirements for growing goats (Avondo et al., 2008; Freer, Dove, & Nolan, 2007; Goetsch et al., 2011). Overall, current findings indicate that addition of HSC to goat finishing diets up to 10% does not depress DMI.

The linear decrease in total feed cost was related to the inclusion of HSC in the diets which was valued at $0.22/kg versus SBM at $0.30/kg (Agricultural Utilization Research Institute, 2019). The neutral effects observed when goats are fed graded levels of HSC on goat production traits in the current study are related to similar DMI observed across diets, which may have resulted in similar ADG, final live weights and carcass attributes. Neutral growth performance and carcass attributes were also reported when feeding sheep HSC compared to canola meal, peas or rape seed meal (Karlsson & Martinsson, 2011; Mustafa et al., 1999), and when feeding cattle HSC versus soybean (Hessle et al., 2008; Turner et al., 2008).

The neutral diet effect on pH (45 min and 24 h) and temperature (45 min and 24 h) might be ascribed to the similar growth rates and carcass weights, which respectively influence muscle fiber composition (Młynek & Guliński, 2007) and carcass cooling rates (Jacob & Hopkins,

2014; Zhang, Mao, Li, Luo, & Hopkins, 2019). The ultimate pH (pH_u) of goat carcasses in the current study was higher than the normal range for red meat (5.5–5.8; Warner, 2015), but within acceptable range for goat meat (5.8–6.2; Webb, 2014; Webb, Casey, & Simela, 2005). Goats easily succumb to pre-slaughter stress due to their excitable nature, hence depleting their muscle glycogen concentration below 60 mmol/g of tissue required to achieve the normal red meat pH_u (Pophiwa, Webb, & Frylinck, 2017, Warner, 2015, Webb, 2014). The temperatures of carcasses in the present study were below 7 °C, the recommended temperature required before carcasses are fabricated into primal cuts (Zhang et al., 2019).

The lack of difference in the meat physical and chemical attributes in the current study was previously reported in sheep (Turner et al., 2012) and cattle (Turner et al., 2008) when feeding HSC as opposed to SMB. The meat moisture and CP contents in the current study are within the ranges reported in other goat studies (Silva et al., 2021; Webb, 2014). The linear increase in chevon IMF in this study might be attributed to a similar trend in the dietary EE with increasing HSC inclusion. Contrary to previous studies, the increase in dietary EE with dietary addition of HSC has been reported to have no effect on IMF of lamb (Turner et al., 2012) and beef (Turner et al., 2008). The increase in IMF with HSC addition observed in the present study could probably influence chevon flavor, and this warrant investigation. The linear decrease in the ash content of goat meat was expected since there is a strong negative correlation between meat ash and IMF (Keeton, Llerbeck, & de González, 2014). Muscle is the main contributor to ash content and the percentage of muscle decline with an increase in IMF.

Despite disparities in IMF, the similarity of the color indexes are coherent to the pH_u values which were similar across diets (Joseph, Nair, & Suman, 2015; Neethling, Suman, Sigge, Hoffman, & Hunt, 2017). The color indexes in the current study are similar to those reported for Boer goats (Abhijith et al., 2021) and Australian goats (Dieters, Meale, Quigley, & Hoffman, 2021). The lack of difference in the WBSF observed in the current study despite the changes in the IMF could imply that muscle fiber size and connective tissue content were similar across diets. According to Joo, Kim, Hwang, and Ryu (2013) meat shear force is largely determined by fiber diameter, amount of connective and IMF content. Similarly, no tenderness differences were observed in steers fed HSC versus SBM (Turner et al., 2008). The observed WBSF values are within the acceptable range (58.4–74.6) for goats (Webb et al., 2005).

5. Conclusions

Complete substitution of HSC for soybean meal in goat finishing diets had neutral effects on growth performance, carcass and meat attributes of Kalahari Red goats. So, HSC could replace up to 100% of SBM in goat finishing diets without negatively affecting chevon production and quality. This feed alternative is timeous given that most countries worldwide are legalizing cultivation of hemp for fiber and oil production. Further research should focus on evaluating the transfer of HSC active ingredients such as vitamin E, cannabidiol and PUFA into meat and their effect on shelf life, fatty acid profile and sensory attributes of goat meat.

Declaration of Competing Interest

No conflict of interest to declare by the authors.

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