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Feed Utilization and Growth Performance Responses to Incremental Dietary Levels of Tomato Pomace Powder in Finishing Sheep

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ABSTRACT

Agro-processing by-products such as tomato pomace (TP) contain high levels of protein, fat and bioactive compounds such as phenolics, lycopene, and beta-carotene. Accordingly, the inclusion of TP in lamb diets has the potential to improve the feed utilization, and growth performance in finishing lambs. This study was, therefore, designed to investigate the maximum tolerance level of TP in finishing lambs using nutrient utilization and growth performance as indicators. A feeding trial was conducted using 35, five months old ram lambs (22.8 ± 5.6 kg) to evaluate changes in feed intake, weight gain, and feed conversion ratio (FCR) in response to incremental levels of TP. The lambs were randomly assigned to five diets which were formulated including milled tomato pomace in the conventional lamb finisher diet at 0 (TP0), 15 (TP15), 30 (TP30), 45 (TP45), and 60% (TP60) on a dry matter basis. Overall, TP45 had the highest (679.36 kg) total feed intake while TP60 had the least (510.22 kg) total feed intake. Tomato pomace inclusion had a significant effect ($P < 0.05$) on weight gain in weeks 1 – 4 but not ($P > 0.05$) in weeks 5 – 9. Lambs fed TP containing diets had the highest overall weight gain (OWG) and a lower overall FCR when compared to the control diet (TP0). Based on the improved weight gain, feed intake and FCR, it was concluded that TP inclusion in lamb diets enhances feed utilization and growth performance of lambs and the optimum TP inclusion is 33%.

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Introduction

The cost of feed in small ruminant enterprises is of great concern as it affects the profitability of such enterprises. It is estimated that feed accounts for 64% of the total production cost in small ruminant enterprises. Therefore, for sustainable food security, the use of cheaper alternatives that will improve feed efficiency and animal production in feed formulations must be explored. Agro-processing by-products have the potential of being a solution to the animal nutrition problem (Ajila *et al*., 2012). Furthermore, they have proven to be an essential source of protein for livestock (Sindhu *et al*., 2002). Tomato pomace is the by-product remaining after the processing of tomato into juice, paste and sauce (Nobakht & Safamehr, 2007). Tomato pomace contains valuable nutritional compounds, such as fibre (59.0%), protein (19.3%), sugars (25.7%), pectins (7.6%), fat (5.9%), minerals (3.9%) and antioxidants (e.g., lycopene) (Del Valle *et al*.,2006). Therefore, it is a promising source of bioactive compounds with antioxidant and antimicrobial potential. Tomato pomace has a high fibre content and dietary fibre influences nutrient utilisation of a diet (Noblet & Senach, 2005). Lambs require a minimum amount of fibre to ensure rumen functioning (Jeon *et al.,* 2019). Fiber can act as an antinutritional factor as it often encapsulates nutrients in cell walls of plant-based feed ingredients. Furthermore, fibre (neutral detergent fibre) has a direct influence on dry matter intake and consequently the energy intake (Tedeschi *et al.,* 2019).

Feed intake, weight gain and feed conversion ratio are important economic traits that determine the profitability of meat sheep production enterprises (Talebi, 2012). Voluntary feed intake (VFI) in growing animals provides the animal with the nutrients needed for tissue growth and development according to its genetic potential. Animal weight gain is dependent on the amount of feed that the lamb consumes but intake varies with the physical size of the animal and along with changes in maintenance requirements during growth (Finlayson *et al.,* 1995). Supplementation of barley-based diets with tomato pomace at a rate of 200 g/kg ration had similar nitrogen retentions and growth performance parameters to soybean protein in young lambs up to the body weight of 28 kg (Fondevilla *et al*., 1994). The inclusion of 20% tomato pomace in ewe diets improved their milk fat and essential fatty acid contents (Romano *et al*.,2010). Furthermore, tomato pomace can be included in adult goats at a level of 100 g without causing digestive disturbances (Ventura *et al*.,2009). It is of vital importance to determine the maximum tolerance level of tomato pomace in finishing lamb diets due the variable factors such as fibre. Therefore, this research study, was designed to determine the feed utilization and growth performance of finishing lambs fed diets containing incremental levels of tomato pomace.

Materials and Methods

Study site and source of ingredients

The research study was conducted at Grootfontein Agricultural Development Institute, located in the Greater Karoo regions of the Eastern Cape province of South Africa. The geographical coordinates are 31° 47′ South, 25° 02′ East. Annual temperatures range from -4°C to 42°C, while annual rainfall ranges between 169 and 347mm. Fresh tomato pomace (TP) containing the peel, seed and pulp of the whole tomato fruit was collected from Tiger Brands tomato processing plant (Musina, Limpopo) whose geographical coordinates are 22° 21′ South 30˚ 1′ East. The tomato pomace was sun-dried by being spread on a plastic sheet. Samples for proximate analysis were taken after sun-drying.

Experimental design and diet formulation

Thirty-five (35) ram lambs (5 months old) were sourced from a farm in Stutterheim (Eastern Cape, South Africa) and used in this study. The lambs were randomly assigned to five diets in a completely randomized design such that each diet had 7 replications, with the lambs housed as experimental groups resulting into five groups of animals. The diets were formulated by a commercial feed manufacturing company, Simple Grow Agricultural Services in Pretoria (Gauteng, South Africa). A conventional lamb finisher diet was used as the control diet. Treatment diets were formulated by substituting protein source in the conventional finisher diet with dried tomato pomace at 15%, 30%, 45%, and 60% on a dry matter basis. The diets were formulated to meet the nutritional requirements of growing fattening lambs (NRC, 2007) and were iso-caloric and iso-nitrogenous. The lambs were adapted to their respective diets for a period of 10 days and measurements commenced on day 11- 73. The nutritional composition of tomato pomace is shown in Table 1.1. The iso-nitrogenous and iso-energetic experimental diets were formulated to contain graded levels of TP as follows: TP0 = Commercial lamb diet without TP; TP15 = Commercial lamb diet containing 15% TP; TP30 = Commercial lamb diet containing 30% TP; TP45 = Commercial lamb diet containing 45% TP; and TP60 = Commercial lamb diet containing 60% TP as shown in Table 1.2.

Table 1. Nutritional composition of tomato pomace

[1]Parameters (%)	Tomato pomace
Dry matter	90.41
CP	21.55
Crude fat	11.57
NDF	49.48
ADF	38.59
ADL	19.65
Organic matter	4.22
Calcium	0.55
Phosphorus	0.51
Potassium	0.96
Sodium	0.10

[1]Parameters: CP = crude protein; NDF = neutral detergent fibre; ADF = acid detergent fibre

Feeding and sheep management

Fresh water was provided *ad libitum* throughout the experimental period. Dietary treatments were provided twice daily at 0800h and 1400h. The feed offered was weighed before feeding and the refusals were collected every morning and weighed. Average group feed intake was measured daily, and live weights were measured weekly before feeding. All the lambs were weighed at the beginning of the trial (initial body weight) and subsequently weighed weekly (Tal-Tec LS4, 0.1 kg readability (one decimal place) supplied by Tal-Tec SA, Brits, SA).

Proximate analysis

The dry matter (DM), crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (ADL), metabolizable energy (ME), organic matter (OM) and mineral content of tomato pomace and the diet samples were determined in the Animal Science laboratory of the North-West University. For laboratory DM determination, approximately 1 g of each treatment sample was placed into pre-weighed crucibles and oven-dried at 105°C for 12 hours. After 12 h, the crucibles were taken from the oven and placed into the desiccator to cool and then weighed. The loss in weight was measured as moisture content and DM was calculated as the difference between the initial sample and moisture content. Organic matter content was determined by ashing the dried samples in a muffle furnace set at 600°C for 6 h. After 6 h, the crucibles were removed from the furnace and placed into a desiccator to cool and thereafter weighed. The loss in weight was measured as OM content and the residue was measured as ash. Total nitrogen content was determined using the standard macro-Kjeldahl method (AOAC. 2005; method no. 984.15) and converted to crude protein (CP) by multiplying the percentage N content by a factor of 6.25. Neutral detergent fibre and ADF were determined by refluxing 0.45 - 0.5 g of samples weighed in ANKOM F57 filter bags with neutral detergent and acid detergent solutions for 60 min and 75 min, respectively, using the ANKOM^{2000} Fibre Analyser (ANKOM Technology, New York) according to van Soest *et al*. (1991) and α-amylase was added during NDF determination. Acid detergent lignin was determined by treating the ADF residue in ANKOM F57 filter bags with 72% sulphuric acid to dissolve the cellulose and estimated after drying in an oven set at 105°C for a period of 12 h. The energy content was determined using a bomb calorimeter and measured as kilocalories (kcal).

Table 2. Ingredient composition (kg/ton as-fed) of tomato pomace-containing diets

[1]**Dietary treatments**					
Ingredients	**TP0**	**TP15**	**TP30**	**TP45**	**TP60**
Yellow maize 8.0%	392.50	350.81	336.05	321.30	306.71
Wheat bran 15%	178.07	120.08	94.74	69.39	43.37
Molasses syrup	80.00	80.00	80.00	80.00	80.00
Soya O/C 47%	100.00	60.00	45.00	30.00	15.00
Tomato pomace	0	142.00	197.43	252.86	308.70
Eragrostis hay	100.00	100.00	100.00	100.00	100.00
Lucerne meal	100.00	100.00	100.00	100.00	100.00
Acid buffer	6.00	6.00	6.00	6.00	6.00
Ammonium chloride	10.00	10.00	10.00	10.00	10.00
Ammonium sulphate	3.00	3.00	3.00	3.00	3.00
Kynofos 21 elite (MDCP 21%)					0.20
Limestone	24.15	21.06	20.42	19.77	19.03
Magnesium oxide 51%	0.74	1.51	1.82	2.13	2.44
Salt course	5.00	5.00	5.00	5.00	5.00
Summer lick premix	0.33	0.33	0.33	0.33	0.33
Salinomycin 12%	0.16	0.16	0.16	0.16	0.16
Stafac 500 (Virginiamycin)	0.05	0.05	0.05	0.05	0.05

[1]Dietary treatments: TP0= Commercial lamb diet without TP; TP15 = Commercial lamb diet containing 15% TP; TP30 = Commercial lamb diet containing 30% TP; TP45 = Commercial lamb diet containing 45% TP; and TP60 = Commercial lamb diet containing 60% TP

Mineral content was analysed by using the dry ashing macro and trace minerals methods. following the guidelines provided by the Agri-Laboratory Association of Southern Africa (Agri-LASA, 1998). Samples that were used to determine the DM were further incinerated in a muffle furnace for 12 h. The ash was weighed and digested with 1 mL of 55% nitric acid and 10 mL of 32% hydrochloric acid using a Microwave Reaction

System Model 3000. Samples were digested for 45 minutes, cooled, and transferred into respective volumetric flasks (100 mL). which were eventually topped-up with distilled water and left standing for 24 h to allow the sediment to settle down. After 24 h, samples were slowly transferred to McCartney bottles without disturbing the sediment. The concentrations of Ca, P, K, Na and Fe were then determined using an ICP Mass Spectrometer (Perkin-Elmer. 1982. NexION 300Q).

Feed intake

Feed intake per group was measured weekly by subtracting the weight of feed leftovers from that of the feed offered per week. The weekly group feed intake was calculated as:

$$Feed\ intake\ (DM) = \frac{Feed\ offered\ - Feed\ offered}{Number\ of\ days}$$

Average daily weight gain

The initial live weight of the lambs was recorded at the start of the experiment. Thereafter weekly weights were measured in the morning before feeding at 0800h throughout the feeding period. The average daily weight gain (ADWG) was calculated as:

$$\boldsymbol{A}DWG\ = \frac{W(T) - \mathrm{W}(t_0)}{T - t_0}$$

Feed conversion ratio

Feed conversion ratio (FCR) per group of animals per period was calculated as:

$$\mathrm{FCR} = \frac{\text{Feed intake}}{\text{Weight gain}}$$

Statistical analysis

The NORMAL option in the Proc univariate statement was used to test for normality of the measure parameters. Weight gain and overall weigh gain data was analyzed using the general linear model procedure of SAS (2010). The linear statistical model employed was as follows:

$Y_{ik} = \mu + D_i + E_{ij}$

Where, Y_{ik} = dependent variable; μ = population mean, D_i = effect of diets and E_{ik} = random error associated with observation *ik* assumed to be normally and independently distributed.
The weight gain and overall weight gain data was evaluated for linear and quadratic effects using polynomial contrasts. Response surface regression analysis (Proc RSREG; SAS 2010) was applied to determine the optimum TP inclusion level according to the following quadratic model:
$y = c + bx + ax^2$

Where, *y* = response variable; *a* and *b* are the coefficients of the quadratic equation; *c* is the intercept; *x* is the TP inclusion level and $-b/2a$ is the *x* value for optimal response. For all statistical tests, significance was declared at $P < 0.05$.

Results

Table 3 shows that the diet containing 60 % tomato pomace had the highest NDF (253.95 g/kg DM) and ADF (171.29 g/kg DM) content. The diet containing 0% tomato pomace had the highest calcium content (12.48 g/kg DM) while the same calcium content was observed across all the remaining dietary treatments.

Table 1. Chemical composition (g/kg DM unless otherwise stated) of tomato pomace-containing diets

	[2]Dietary treatments				
[1]Parameters	TP0	TP15	TP30	TP45	TP60
Dry matter	874.46	880.99	879.78	878.58	877.38
ME (MJ/kg)	10.50	10.50	10.50	10.50	10.50
CP	150.0	150.0	150.0	150.0	150.0
Fat	24.90	51.55	46.75	41.98	37.22
NDF	168.06	208.74	223.82	238.90	253.95
ADF	77.08	120.86	137.65	154.44	171.29
Calcium	12.48	12.0	12.0	12.0	12.0
Phosphorus	3.48	3.30	3.31	3.35	3.76
Iron (mg/kg)	101.73	59.31	76.13	74.86	82.58

[1]Parameters: ME = metabolizable energy; CP = crude protein; NDF = neutral detergent fibre; ADF = acid detergent fibre.
[2]Dietary treatments: TP0 = diet containing 0% tomato pomace; TP15 = diet containing 15% tomato pomace; TP30 = diet containing 30% tomato pomace; TP45 = diet containing 45% tomato pomace; TP60 = diet containing 60% tomato pomace.

Table 4 shows the average group feed intakes of lamb diets containing graded levels of tomato pomace. TP15 had the highest feed intake on week 1 (55.27 kg), week 2 (80.77 kg) and week 4 (87.01 kg) when compared to other TP diets. Overall, TP45 had the highest (679.36 kg) total feed intake, followed by TP15 (675.74 kg), TP30 (615.48 kg), TP0 (574.98 kg) and TP60 (510.22 kg) which had the least total feed intake.

Table 4. Effect of tomato pomace containing diets on average group feed intake (kg)

	[1]Dietary treatments				
Week	TP0	TP15	TP30	TP45	TP60
1	51.49	55.27	52.42	46.65	34.12
2	64.5	80.77	61.68	70.45	58.91
3	70.93	83.94	76.46	93.28	65.53
4	70.72	87.01	71.70	76.41	56.30
5	64.65	78.55	83.38	89.56	63.62
6	68.48	83.83	65.22	88.86	62.88
7	61.63	69.15	71.55	78.22	55.79
8	65.39	74.23	70.01	75.75	57.72
9	57.19	62.99	63.06	60.18	55.35
Total feed intake	574.98	675.74	615.48	679.36	510.22

[1]Dietary treatments: TP0 = diet containing 0% tomato pomace; TP15 = diet containing 15% tomato pomace; TP30 = diet containing 30% tomato pomace; TP45 = diet containing 45% tomato pomace; TP60 = diet containing 60% tomato pomace

Table 5 and 6 shows that TP inclusion had significant (P < 0.05) differences on weight gain (WG) from week 1 to week 4. There was no effect (P > 0.05) on WG from week 5 to 9 and on the overall weight gain. TP30 had the highest WG in week 1 (4.07 kg), 7 (2.53 kg) and 9 (2.09 kg). In week 1, TP60 was significantly different (P < 0.05) to TP15, TP30 and TP45 which were similar (P > 0.05) and similar (P > 0.05) to TP0, which was also similar (P > 0.05) to TP60. In week 2, TP30 was significantly different (P < 0.05) to TP15 and TP60, which were similar (P > 0.05) and both similar (P > 0.05) toTP0 and TP45, which were similar (P > 0.05) and similar (P > 0.05) to TP30. In week 3, TP15 had the least (0.56 kg) WG but significantly different (P < 0.05) from all the other TP levels, which were similar (P > 0.05). However, in week 4, TP15 had the highest WG (3.08kg) and was again significantly different (P < 0.05) from all the other TP levels, which were similar (P > 0.05).

Table 5. Level of significance of effects on weight gain of lambs fed diets containing TP

Week	[1]Parameters
	Weight gain
1	**
2	**
3	**
4	***
5	NS
6	NS
7	NS
8	NS
9	NS
Overall weight gain	NS

[1]Parameters: NS = P > 0.05; * = P < 0.05; ** = P < 0.01; *** = P < 0.001

Table 6. Weight gain (kg) of lambs fed diets containing tomato pomace

Week	[1]Dietary treatments					[2]SEM
	TP0	**TP15**	**TP30**	**TP45**	**TP60**	
1	2.78^{ab}	3.51^{b}	4.07^{b}	3.24^{b}	1.15^{a}	0.47
2	1.23^{ab}	2.87^{b}	0.78^{a}	2.56^{ab}	3.17^{b}	0.50
3	2.85^{b}	0.56^{a}	2.46^{b}	2.50^{b}	3.17^{b}	0.43
4	0.77^{a}	3.08^{b}	1.87^{a}	0.77^{a}	0.87^{a}	0.34
5	0.63	0.39	0.67	1.76	0.79	0.39
6	1.60	1.42	1.55	1.82	1.52	0.29
7	2.15	2.19	2.53	2.37	2.35	0.39
8	1.59	1.11	2.01	2.12	2.14	0.39
9	1.90	1.66	2.09	1.64	1.03	0.34
Overall WG	15.47	16.84	18.03	18.79	16.18	1.43

[1]Dietary treatments: TP0 = diet containing 0% tomato pomace; TP15 = diet containing 15% tomato pomace; TP30 = diet containing 30% tomato pomace; TP45 = diet containing 45% tomato pomace; TP60 = diet containing 60% tomato pomace
[2]SEM = Standard error of mean
[a.b.c] Means in a row with different lowercase superscripts denote significant differences (P < 0.05)

Table 7 and 8 show that there were significant linear and quadratic effects on weight gain in week 1 [$y = 2.628\ (\pm 0.46) + 0.112x(\pm 0.04) - 0.002(\pm 0.00)x^2$; R^2 = 0.31; *P* =0.0004] in response to TP inclusion in diets. There were no linear and quadratic effects (*P* > 0.05) on weight gain in week 2 and week 5 – 7 in response to TP inclusion in diets. Furthermore, there were no linear and quadratic effects (*P* > 0.05) on overall weight gain in response to TP inclusion in diets. There were significant quadratic effects on weight gain in week 3 [$y = 2.295\ (\pm 0.49) - 0.056x(\pm 0.04) + 0.001(\pm 0.00)x^2$; R^2 = 0.11; *P* =0.049] and week 4 [$y = 1.343\ (\pm 0.43) + 0.066x(\pm 0.03) - 0.001(\pm 0.00)x^2$; R^2 = 0.17; *P* =0.015] in response to TP inclusion in diets. However, no linear effects (*P* > 0.05) were observed.

Table 7. Response of weight gain on lambs fed diets containing tomato pomace

	Weight gain	
	[1]Significance	
Week	**Linear**	**Quadratic**
1	*	***
2	NS	NS
3	NS	*
4	NS	**
5	NS	NS
6	NS	NS
7	NS	NS
8	NS	NS
9	NS	NS
Overall WG	NS	NS

[1]Significance: NS = *P* > 0.05; * = *P* < 0.05; ** = *P* < 0.01; *** = *P* < 0.001

Table 8. Regression of weight gain (kg) of lambs fed diets containing tomato pomace

	Weight gain			
Duration	**Quadratic equation**	**R^2**	***P* value**	**X Min/Max**
Week 1	$y = 2.628\ (\pm 0.46) + 0.112x(\pm 0.04) - 0.002(\pm 0.00)x^2$	0.31	0.0004	1.4
Week 3	$y = 2.295\ (\pm 0.49) - 0.056x(\pm 0.04) + 0.001(\pm 0.00)x^2$	0.11	0.049	25
Week 4	$y = 1.343\ (\pm 0.43) + 0.066x(\pm 0.03) - 0.001(\pm 0.00)x^2$	0.17	0.015	33

Table 9 shows the feed conversion ratio (FCR) of lambs fed diets containing graded levels of tomato pomace. Lambs fed TP0 had the highest FCR in week 4 (15.37) and the least in week 1 (3.10). TP15 had the highest FCR in week 3 (20.99), week 5 (26.18), week 6 (9.01) and week 8 (9.28), whilst the least FCR was observed in week 4 (4.03). TP30 had the highest FCR at week 2 (11.21), week 6 (6.04) and the least FCR at week 1 (1.84). TP45 had the highest FCR in week 5 (7.28). TP60 had the highest FCR at week 5 (13.54) and the least FCR at week 2 (3.10), week 3 (3.45), week 7 (3.96) and week 8 (4.51).

Table 9. Feed conversion ratio of lambs fed diets containing tomato pomace

	[1]Dietary treatments				
Week	**TP0**	**TP15**	**TP30**	**TP45**	**TP60**
1	3.10	2.24	1.84	2.06	4.94
2	8.96	3.98	11.21	3.94	3.10
3	4.17	20.99	4.49	5.33	3.45
4	15.37	4.03	5.47	4.15	10.83
5	17.96	26.18	17.53	7.28	13.54
6	6.77	9.01	6.04	6.94	6.83
7	4.78	4.49	4.04	4.71	3.96
8	6.96	9.28	4.97	5.12	4.51
9	5.02	5.43	4.32	5.23	8.93
Overall FCR	6.40	5.73	4.87	5.17	5.25

[1]Feed conversion ratio: TP0 = diet containing 0% tomato pomace; TP15 = diet containing 15% tomato pomace; TP30 = diet containing 30% tomato pomace; TP45 = diet containing 45% tomato pomace; TP60 = diet containing 60% tomato pomace

Table 10 shows the effect of tomato pomace diets on the overall WG and FCR. The overall WG and FCR of the lambs ranged from 15.46 -18.78 kg and 4.87 - 6.20, respectively. Lambs fed TP45 had the highest overall WG (18.78 kg) whilst lambs fed TP0 had the least overall WG (15.46 kg). Lambs fed the control diet (TP0) had the highest overall FCR (6.20) whilst those fed TP30 had the least overall FCR (4.87).

Table 10. Effect of tomato pomace containing diets on overall FCR and weight gain

	[1]Dietary treatments				
	TP0	**TP15**	**TP30**	**TP45**	**TP60**
[2]Overall WG (kg)	15.46	16.84	18.03	18.78	16.18
[3]Overall FCR	6.40	5.73	4.87	5.17	5.25

[1]TP inclusion: 0 = diet containing 0% tomato pomace; 15 = diet containing 15% tomato pomace; 30 = diet containing 30% tomato pomace; 45 = diet containing 45% tomato pomace; 60 = diet containing 60% tomato pomace, [2]Overall WG = overall weight gain, [3]Overall FCR = overall feed conversion ratio

Discussion

The determination of growth performance of lambs fed tomato pomace diets is of vital importance to determine the efficiency of this agro-processing by-product in small ruminant diets. Tomato pomace has a high nutritional value as it contains about 16% crude protein and has a high concentration of bioactive compounds such as vitamins, polyphenols, minerals, flavonoids, carotenoids, vitamin C and E (Azabou *et al*., 2020; Toor and Savage, 2005). The highest percentage of carotenoids found in tomato pomace include lycopene, α-carotene, β-carotene, lutein, zeaxanthin and β-cryptoxanthin (Dorais *et al*., 2008). However, the major challenge with using TP as an ingredient in lamb diets is that it is very fibrous and has poor digestibility due to the presence of lignin (Cepeda & Collado, 2014). Therefore, it is crucial to determine the optimum inclusion level of tomato pomace in small ruminant diets to not negatively affect their growth performance and health status.

Dry matter intake of fibrous biomass depends on factors such as palatability, rate of digestion and NDF concentration (Decruyenaere *et al.,* 2009; Tedeschi *et al.,* 2019). In this study, lambs fed TP45 (679.36 kg) had the highest overall intake followed by TP15 (675.73 kg), TP30 (614.49 kg), TP 0 (574.92 kg) and TP60 (510.22 kg), which had the least intake. These results agree with Mizael *et al.* (2020), who concluded that inclusion of 60% TP in diets resulted to a decrease in nutrient uptake by lactating ewes. The low intake of TP60 could be attributed to its high fibre component. Feed stuff with low digestibility have a low dry matter intake due the distension of the rumen-reticulum (Oliveira *et al*., 2020).

The results of this study showed a quadratic response on weight gain in week 4 and the optimum weight gain was calculated to be 33kg.This suggest that feeding beyond 4 weeks has no positive impact on the weight gain of the lambs. Indeed, according to Valenti *et al*. (2018), there was no differences in the final weight between lambs fed commercial concentrates and those that were also supplemented with dried tomato pomace after a 36-day trial period. High weight gains in early stages of lamb feedlots are due to compensatory growth (Addah *et al*., 2017). The intake of higher quality feed, increased feed intake, lower maintenance requirements and more efficient use of available nutrients, are all factors that can be associated with compensatory growth, leading to higher growth rates early in the feeding period (Atti & Ben Salem, 2008). Lambs fed the control diet (TP0) had the least overall weight gain when compared to those fed the tomato pomace containing diets. Indeed, dried tomato pomace supplementation in lamb diets showed the potential to replace commercial concentrate diets without negatively affecting performance and meat quality (Valenti *et al*.,2018). Lambs fed TP45 (18.79 kg) had the highest overall weight gain followed by TP30 (18.03 kg), TP15 (16.84 kg), TP60 (16.18 kg) and TP0 (15.47 kg) which had the lowest overall weight gain. This agreed with the findings of other research that incremental levels of 5%. 10% and 15% tomato pomace supplementation in lamb diets improved the average daily weight gain and total body weight gains as supplementation levels increased (Omer and Abdel-Magid, 2015).

The results of this study indicate that lambs fed the highest TP diet (TP60), had the least overall WG when compared to those fed the TP containing diets. Indeed, Mizael *et al*. (2020) concluded that feeding lactating ewe's 60% TP diets reduced the body weight of the ewes. This could be attributed to the high fibre content that was observed in the TP which resulted into low dry matter digestibility of the offered diet. Indeed, Benaouda *et al*. (2023) showed that incremental levels of fibre in cattle diets results to reduced dry matter and fibre digestibility. Nutrient digestibility of growing goats increased when the physical effective neutral detergent fibre (peNDF) was reduced from 32.97% to 28.14% (Zhou *et al*., 2022).

From week 2 to 6, high FCR values were observed from TP0 (17.96), TP15 (26.18), TP30 (17.53), TP45 (7.28) and TP60 (13.53). The high FCR values observed could be caused by complications with the lambs adapting to their respective diets. Indeed, Brand *et al*. (2017), observed high FCR values (10.3) due to feed adaptation challenges after 21 days of feeding feedlot diets to lambs. Tomato pomace containing diets had a lower overall FCR when compared to the control diet (TP0). Indeed, TP containing diets improve the overall FCR of growing lambs (Omer & Abdel-Magid, 2015). A low FCR indicates a high efficiency of a feed (Van der Westhuizen *et al*., 2004). Furthermore, it has a huge impact on farming enterprises in relation to optimising feed costs (Davison *et al.,* 2023). Based on the lowest overall FCR, TP30 (4.87), is the most efficient diet when compared to the rest of the diets.

Conclusion

The inclusion of tomato pomace in lamb diets as a protein source improved the nutritional value of the diet by improving the feed intake, weight gain, feed conversion ratio, overall weight gain and overall feed conversion ratio. A maximum amount of 33% tomato pomace must be observed as more incremental amounts caused decreases in feed intake and subsequent weight gain. This could be attributed to the high fibre level found in the tomato pomace. It can thus be concluded that tomato pomace can be a sustainable lamb protein source for resource-poor farmers.

Competing Interest

The authors declare that they have no competing interests.

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References

1. Addah W, A Ayantunde and EK Okine, 2017. Effects of restricted feeding and re-alimentation of dietary protein or energy on compensatory growth of sheep. South African Journal of Animal Science, 47(3): 389-398.
2. Agri-Lasa. 1998. Feed and plant analysis methods. Agri laboratory association of Southern Africa. Pretoria. South Africa.
3. Ajila CM, SK Brar, M Verma, RD Tyagi, S Godbout and JR Valéro, 2012: Bio-processing of agro-byproducts to animal feed. Critical Reviews of Biotechnology, 32(4): 1-9.
4. AOAC, 2005. In official methods of analysis of AOAC International. 18th ed. Association of official analytical chemists, Arlington, VA, USA.
5. Atti N and H Ben Salem, 2008. Compensatory growth and carcass composition of Barbarine lambs receiving different levels of feeding with partial replacement of the concentrate with feed blocks. Animal Feed Science and Technology, 147: 265 – 277.
6. Azabou S, H Sebii, FB Taheur, Y Abid, M Jridi and M Nasri, 2020. Phytochemical profile and antioxidant properties of tomato by-products as affected by extraction solvents and potential application in refined olive oils. Food Bioscience, 36.
7. Benaouda M, G Manuel, F Avilés-Nova, MF Vázquez-Carrillo and M Castelan-Ortega, 2023. Effect of fiber digestibility on methane emission, milk production and quality in dairy cattle. ALPA, 31: 213-220.
8. Brand TS, EJ van der Westhuizen, DA van der Merwe and LC Hoffman, 2017. Effect of days in feedlot on growth performance and carcass characteristics of Merino, South African Mutton Merino and Dorper lambs. South African Journal of Animal Science, 47(1): 26-33.

9. Cepeda E and I Collado, 2014. Rheology of tomato and wheat dietary fibers in water and in suspensions of pimento purée. Journal of Food Engineering, 134: 67-73.
10. Davison C, C Michie, C Tachtatzis, I Andonovic, J Bowen and CA Duthie, 2023. Feed conversion ratio (FCR) and performance group estimation based on predicted feed intake for the optimisation of beef production. Sensors, 23: 4621.
11. Decruyenaere V, A Buldgen and D Stilmant, 2009: Factors affecting intake by grazing ruminants and related quantification methods: a review. Biotechnology Agronomy Society Environment, 13(4): 559-573.
12. Del Valle M, M Cámara and ME Torija, 2006. Chemical characterization of tomato pomace. Journal of the Science Food and Agriculture, 86: 1232-1236.
13. Dorais M, DL Ehret and AP Papadopoulos, 2008. Tomato (Solanum lycopersicum) health components: from the seed to the consumer. Phytochemistry Review,7(2): 231-250.
14. Finlayson JD, OJ Cacho and AC Bywater, 1995. A simulation model of grazing sheep: I. Animal growth and intake. Agricaltural Systems, 48: 1-25.
15. Fondevilla M, JA Guada, J Gasa and C Castrillo, 1994. Tomato pomace as a protein supplement for growing lambs. Small Ruminants Research, 13: 117-126.
16. Jeon S, S Jeong, M Lee, J Seo, DK Kam, JH Kim, J Park and S Seo, 2019. Effects of reducing inclusion rate of roughages by changing roughage sources and concentrate types on intake. growth. rumen fermentation characteristics. and blood parameters of Hanwoo growing cattle *(Bos taurus coreanae).* Asian- Australas Journal of Animal Science, 32(11): 1705-1714.
17. Mizael WC, RG Costa, BCG Rodrigo, CFF Ramos, NL Ribeiro, A Lima, R Domínguez and JM Lorenzo, 2020: Effect of the use of tomato pomace on feeding and performance of lactating goats. Animals, 10: 1574.
18. Nobakht A ans AR Safamehr, 2007. The effect of inclusion different levels of dried tomato pomace in laying hens' diets on performance and plasma and egg yolk cholesterol content. Journal of Animal and Veterinary Advances, 6: 1101-1106.
19. Noblet J and IU Senach, 2006. Energy evaluation of feeds for pigs: consequences on diet formulation and environment protection. Lohmann Information, 41: 38-50.
20. NRC (National Research Council), 2007: Nutrient Requirements of Small Ruminants: Sheep. Goats. Cervids. and New World Camelids. National Academy Press. Washington DC. USA.
21. Oliveira APD, CS Cunha, ES Pereira, S Biffani, AND Medeiros and AMDA Silva, 2020. Meta-analysis of dry matter intake and neutral detergent fiber intake of hair sheep raised in tropical areas. Plos One, 15(12): 244.
22. Omer H and SS Abdel-Magid, 2015. Incorporation of dried tomato pomace in growing sheep rations. Global Veterinaria, 14: 1-16.
23. Romano R, F Masucci, A Giordano, SS Musso, D Naviglio and A Santini, 2010. Effect of tomato by-products in the diet of Comisana sheep on composition and conjugated linoleic acid content of milk fat. International Dairy Journal, 20: 858-862.
24. Supplementing diets of Awassi ewes with olive cake and tomato pomace: on-farm recovery of effects on yield. composition and fatty acid profile of the milk. Website: https://www.researchgate.net/publication/267043635_Supplementing_diets_of_Awassi_ewes_with_olive_cake_and_tomato_pomace_onfarm_recovery_of_effects_on_yield_composition_and_fatty_acid_profile_of_the_milk (Accessed 31 July 2024).

25. Sindhu, AA, MA Khan, U Un-nisa and M Sarwar, 2002. Agro-industrial by-products as a potential source of livestock feed. International Journal of Agriculture and Biology, 12: 307-310.
26. Talebi MA, 2012. Feed intake, feed efficiency, growth and their relationship with Kleiber ratio in Lori-Bakhtiari lambs. Archiva Zootechnica, 15(4): 33-39.
27. Tedeschi, LO, G Molle, HM Menendez, A Cannas and MA Fonseca, 2019. The assessment of supplementation requirements of grazing ruminants using nutrition models. Translational Animal Science, 3: 812-828.
28. The Effect of Feeding Dried Tomato Pomace and Concentrate Feed on Body Weight Change. Carcass Parameter and Economic Feasibility on Hararghe Highland Sheep. Eastern Ethiopia. Website: https://www.researchgate.net/publication/276916364_The_Effect_of_Feeding_Dried_Tomato_Pomace_and_Concentrate_Feed_on_Body_Weight_Change_Carcass_Parameter_and_Economic_Feasibility_on_Hararghe_Highland_Sheep_Eastern_Ethiopia (Accessed 25 July 2024).
29. Tedeschi L. O, G Molle, HM Menendez, A Cannas and MA Fonseca, 2019. The assessment of supplementation requirements of grazing ruminants using nutrition models. Translational Animal Science, 3: 812-828.
30. Toor, RK and GP Savage, 2005. Antioxidant activity in different fractions of tomatoes. Food Research International Journal, 38(5): 487-494.
31. Valenti B, G Luciano, M Pauselli, S Mattioli, L Biondi, A Riolo, A Natalello, L Morbidini and M Lanza, 2018. Dried tomato pomace supplementation to reduce lamb concentrate intake: Effects on growth performance and meat quality. Meat Science, 145: 63-70.
32. Van der Westhuizen RR, J Van der Westhuizen and SJ Schoeman, 2004. Genetic variance components for residual feed intake and feed conversion ratio and their correlations with other production traits in beef bulls. South African Journal of Animal Science, 34(4): 257.
33. Van Soest, PJ, JB Robertson and BA Lewis, 1991. Methods for dietary fibre. neutral detergent fibre. and non-starch poly-saccharides in relation to animal nutrition. Journal of Dairy Science, 74: 3583-3597.
34. Ventura MR, MC Pieltain and JIR Castanon, 2009. Evaluation of tomato crop by-products as feed for goats. Animal Feed Science Technology,154: 271-275.
35. Zhou J, B Xue, A Hu, S Yue, M Wu, Q Hong, Y Wu, Z Wang, L Wang, Q Peng and B Xue, 2022. Effect of dietary peNDF levels on digestibility and rumen fermentation. and microbial community in growing goats. Frontiers in Microbiology, 13.