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IMPACT OF SESAME HULLS ON GROWTH AND BLOOD PROFILE IN AWASSI LAMBS

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ABSTRACT

The objective of this study was to evaluate the effect of dietary sesame hulls (SH) on the growth and blood profiles of growing lambs. Twenty-four lambs (initial body weight = 21.8 ± 1.35 kg; age = 75 ± 2.5 days) were randomly assigned to 3 diets. Diets with no SH (CON), 75 g/kg SH (SH75), or 150 g/kg SH (SH150), for 120 days, with 10 days adaptation period, followed by 110 days for data collection. The dry matter, crude protein, neutral detergent fiber, acid detergent fiber, and metabolizable energy intake were greater in the SH75 and SH150 diets than in the CON diet. Conversely, the group SH150 exhibited the highest values (P < 0.05) of ether extract intake. Lambs fed diets containing SH showed greater final body weight, total gain, and average daily gain than those fed the CON diet. Notably, the gain cost was lower for the SH75 and SH150 groups than for the CON diet. Blood parameters did not vary in response to the SH supplementation. Sesame hulls could be an alternative nutritional feed ingredient for growing lambs due to their nutritional value and cost-effectiveness.

Key words: Alternative feeds; cost of gain; nitrogen balance; nutrient digestibility;

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INTRODUCTION

Feed availability is a critical determinant in the growth and development of animals because their health, growth rate, and productivity are influenced directly (Allen, 2014; Dougherty et al., 2022). Pasture and commercial feeds, which are conventional feed sources in most areas, are highly limited during off-seasons or in resource-poor areas (Al-Khaza'leh et al., 2020; Boudalia et al., 2024) and are more expensive compared with alternative feeds (Vasta et al., 2005; Andika et al., 2025; Saed et al., 2025) or agro-industrial by-products (Sadh et al., 2018; Sun et al., 2024; Yafetto et al., 2024; Al-Khaza'leh and Obeidat, 2025b). The result could be a poor growth rate, a low immune system, and higher mortalities among the lambs. To address these challenges, alternative feeds are considered: agro-industrial by-products, forages, and legumes (Hassan and Tawffek, 2009; Al-Mamouri and Al-Ani, 2024; Boudalia et al., 2024). These can be sourced locally, are cheaper, and nutritional. Including such alternative feeds into the diet of lambs will diversify the farmers' options to improve feed security and enhance the growth of lambs, reducing their dependency on conventional feed supplies (Omer et al., 2019) and can contribute to environmental conservation and resource efficiency. Such strategies call for carefully formulating balanced diets to meet all

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nutritional needs. Despite availability, alternative feeds are a feasible approach to optimal animal performance (Shirzadegan and Jafari, 2014; Al-Khaza'leh and Obeidat, 2025b). Sesame hulls (SH), a byproduct of sesame seed processing, have been considered a potential alternative feed for small ruminants, including lambs, because of their abundant availability and fiber content (Elleuch et al., 2007; Obeidat et al., 2025). Due to the increasing agricultural byproducts worldwide, alternative feed resources such as SH are being considered to decrease feed costs while meeting the nutritional needs of livestock (Mahmoud and Bendary, 2014). SH are moderate in fiber, making them an excellent source of roughage that can complement traditional feeds such as grasses, legumes, and concentrates in the diets of ruminants, which contributes to improved ruminal fermentation and can positively influence growth performance and feed utilization in ruminants (Abou-Gharbia et al., 2000; Adeola et al., 2021). The inclusion of SH in ruminant diets promises to improve the nutritional profile of animal feeds (Kaya et al., 2022). In this regard, SH has been shown to improve the energy value of rations because of its moderate levels of ether extract and metabolizable energy (Ghorbani et al., 2018; Wei et al., 2022). In addition, SH contains some essential minerals and bioactive compounds that may benefit animal health and productivity (Elleuch et al., 2007; Kamal-Eldin et al., 2011). As an alternative feed in small ruminants, it has been associated with increased dry matter (DM) intake, higher digestibility of fiber fractions, and increased weight gain in lambs and goats (Obeidat et al., 2010; Abdullah et al., 2011). Moreover, incorporating SH and other alternative feeds in rations could reduce feeding expenses due to their lower prices as byproducts compared with conventional feedstuffs (Al-Ruqaie et al., 2011; Mahmoud and Bendary, 2014; Salam et al., 2014; Edache et al., 2017; Al Sagan et al., 2020). The present study investigates the incorporation of SH in diets fed to growing lambs at various dietary levels of DM in terms of growth performance and feed intake cost-effectiveness, as well as other parameters, including digestibility and blood parameters. These findings can be counted as one among many that will lead to the sustainable utilization of agricultural by-products for feeding animals.

MATERIALS AND METHODS

Lambs and experimental diets

The experiment was conducted at the Al-Khanasry Station for Livestock Research, National Center for Agricultural Research and Extension, Baqa'a, Jordan. The Institutional Animal Care and Use Committee of the Jordan University of Science and Technology (JUST) has approved all procedures used in this study and the research was funded by JUST (Grant #: 68/2024). Twenty-four ram lambs (initial body weight = 21.8 ± 1.35 kg; age = 75 ± 2.5 days) were assigned randomly to three dietary groups, with 8 lambs per each group. The groups differed in the level of SH in their diets; the CON was fed 0 g/kg SH, while the other two were fed either 75 g/kg (SH75) or 150 g/kg (SH150) of SH on a DM basis, replacing barley grain. All diets were isonitrogenous, providing 160 g/kg of CP, and formulated to meet the nutritional requirements for growing lambs as per the NRC (2007). In detail, ingredients, diets, and SH chemical composition are presented in **Table 1**.

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Table 1. Ingredients and chemical compositions of the diets fed to lambs.

Item	Diet[1]		
	CON	SH75	SH150
Ingredients (g/kg DM)			
Barley grain	370	295	215
Corn grain	150	150	150
Soybean meal	190	190	195
Sesame hulls[2]	0	75	150
Wheat hay	170	170	170
Wheat bran	100	100	100
Salt	10	10	10
Limestone	9.0	9.0	9.0
Vitamin-mineral[3]	1.0	1.0	1.0
Cost (US$/1,000 kg)[4]	436	408	382
Nutrients			
DM, g/kg	915	913	911
CP, g/kg	161	160	161
NDF, g/kg	279	278	277
ADF, g/kg	119	123	128
EE, g/kg	17.8	28.8	39.7
ME, Mcal/kg[5]	2.50	2.59	2.68

[1] The diets were (1) no sesame hulls (CON), (2) 75 g/kg of sesame hulls (SH75), and (3) 150 g/kg of sesame hulls (SH150).
[2] The sesame hulls contained 98.8, 211.2, 135.0, and 162.1 g/kg of CP, NDF, ADF, and EE, respectively.
[3] The composition per kg was vitamin A, 600,000 IU; vitamin D3, 200,000 IU; vitamin E, 75 mg; vitamin K3, 200 mg; vitamin B1, 100 mg; vitamin B5, 500 mg; lysine, 0.5%; DL-methionine, 0.15%; manganese oxide, 4,000 mg; ferrous sulphate, 15,000 mg; zinc oxide, 7,000 mg; magnesium oxide, 4,000 mg; potassium iodide, 80 mg; sodium selenite, 150 mg; copper sulphate, 100 mg; cobalt phosphate, 50 mg; and dicalcium phosphate, 10,000 mg.
[4] The values were calculated based on ingredient prices in 2025.
[5] The values were calculated based on the tabular value of NRC (2007).

The lambs were individually (1 m × 1.5 m) housed and fed twice daily at around 08:00 and 15:00. Ten days of acclimatization was allowed before the 110-day feeding trial. There were *ad libitum* supplies of feed and water throughout the trial. The amount of feed left over was measured daily, and 10% of leftovers were subsampled, dried for 48 hours at 55°C, and processed through a 1-mm screen for further analysis. The samples were then stored in nylon bags at −20°C until DM and other nutrient analyses were performed to assess daily nutritional intake. Lamb weights were recorded before morning feed intake at the commencement of the study and biweekly thereafter. Average daily gain was determined by dividing the difference between final and initial weight by the number of days. Total weight gains and feed conversion ratio (FCR), calculated as total DM intake divided by total weight gain, were also measured. Feed and refusal samples were analyzed according to AOAC (1990) methods for ether extract (EE, by Soxtec method), CP, by Kjeldahl method, and DM by drying at 100°C for 24 h in an air-forced oven. Fiber content was also analyzed by the ANKOM^{2000} fiber analyzer (ANKOM Technology Corporation, Fairport, NY) for NDF and ADF according to the procedure by Van Soest (1991). A partial budget analysis was then conducted to determine the profitability of each diet after adding different levels of SH to the lambs' diets. The overall price of each diet was calculated in US$/1,000 kg by adding all the ingredients prices according to the current market price. Labor, water, and electricity costs were also included in this cost calculation. The gain cost was calculated by multiplying FCR with the diet cost in US$/kg.

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Digestion and nitrogen balance experiment : On day 49, 4 group lambs from all treatments were randomly selected and transferred to individual metabolic cages (1.05 m × 0.80 m) to determine nutritional digestibility and N balance. After acclimatization to the cage conditions, a five-day data recording ensued. During this phase, feed consumption and refusals were recorded daily, the feces were collected, weighed, and their amount registered, and then 10% of the feces were retained and stored for further analysis. To estimate N balance, including N intake, N loss in feces and urine, retained N (g/d), and N retention (%), urine was collected and stored in plastic buckets beside the fecal collection apparatus. The remaining 5% was stored at −20°C. Each bucket contained 50 mL of 6 N HCl to preserve ammonia. Each lamb's composite fecal sample was prepared from all collected samples. These fecal samples were subsequently dried at 50°C using a drying oven and allowed to equilibrate to the same dry matter weight, grounded over a 1-mm screen. Fecal sample DM, NDF, ADF, CP, and EE were analyzed using the previously mentioned methods. Pooled urine samples were prepared for each lamb to make one composite sample for each lamb on nitrogen content determined by the Kjeldahl procedure.

Blood parameters : On the last day of the study, blood samples were drawn from each lamb jugular vein at 8.00 AM before feeding using plain vacutainers. The samples were centrifuged at 3,000 rpm for 30 minutes at 9:00 AM to separate the serum, which was then transferred to tubes and stored at −20°C until analysis. Serum levels of different biochemical parameters such as triglycerides, creatinine, LDL, HDL, cholesterol, urea nitrogen, and serum glucose were measured using a JENWAY 6105 UV/Vis spectrophotometer (Model 6105, Janeway LTD, Felsted, Dunmow ESSEX CM6 3LB, UK). Liver enzyme activities such as AST, ALP, and ALT were determined by using commercial kits from Biolabo S.A.S., Less Hautes Rivers, Maizy, France.

Statistical analysis

Data were analyzed using ANOVA with the MIXED procedure of SAS (2013). In the statistical model, dietary treatments (CON, SH75, SH150) were considered fixed effects, while the individual lamb was considered the experimental unit. Least-square means were computed, and pairwise t-tests were used when significant effects were detected ($p \leq 0.05$).

RESULTS AND DISCUSSION

The inclusion of SH did not affect the composition of the diets except for the increase in the EE and ME content in the SH-containing diets compared with the CON diet (**Table 1**). However, the cost of diets decreased by 7 and 14% in the SH75 and SH150 diets, respectively, compared with the CON diet. Intakes of DM, CP, NDF, ADF, and ME were greater ($p < 0.05$) in the SH75 and SH150 diets than in the CON diet (**Table 2**). In contrast, EE intake was the highest ($p < 0.05$) for the SH150 group, followed by the SH75 group, and lowest in the CON group. Growth performance traits were reported in (**Table 3**). Final BW, total gain, and average daily gain were greater ($p < 0.05$) in the SH-containing diets than in the CON diet. However, no difference was reported among the SH diets. The cost of gain decreased ($P < 0.05$) in the SH groups compared to the CON diet. DM, CP, and NDF digestibility improved ($p < 0.05$) in the SH-containing diets compared to the CON diet (**Table 4**). The dietary treatments had similar ADF digestibility. EE digestibility was greater ($p < 0.05$) in the SH groups compared with the CON diet. Except for the fecal N loss, which was greater in the CON group, no differences were detected among the groups regarding N intake, N lost in urine, retained N, and N retention. The

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inclusion of SH as an alternative feed among the diets did not affect all blood traits (i.e., blood urea nitrogen, glucose, cholesterol, HDL, LDL, triglycerides, AST, ALT, or ALP), as shown in (**Table 5**).

Table 2. Effects of dietary sesame hulls (SH) on lambs' nutrient intake

Item	Diet[1]				
	CON (n = 8)	SH75 (n = 8)	SH150 (n = 8)	SE	p value
Dry matter, g/d	1135[a]	1267[b]	1259[b]	47.2	0.0244
Crude protein, g/d	183[a]	203[b]	203[b]	7.6	0.0290
Neutral detergent fiber, g/d	317[a]	352[b]	348[b]	13.1	0.0320
Acid detergent fiber, g/d	135[a]	156[b]	161[b]	5.8	0.0011
Ether extract, g/kg	20[a]	37[b]	50[c]	1.5	<0.0001
Metabolizable energy, Mcal/d	2.84[a]	3.28[b]	3.37[b]	0.121	0.0012

[1] The diets were (1) no sesame hulls (CON), (2) 75 g/kg of sesame hulls (SH75), and (3) 150 g/kg of sesame hulls (SH150).
[a,b,c] Within a row, means without a common superscript letter differ ($p < 0.05$)

Table 3. Effects of dietary sesame hulls (SH) on lambs' growth performance and cost of gain.

Item	Diet[1]				
	CON (n = 8)	SH75 (n = 8)	SH150 (n = 8)	SE	p value
Initial weight, kg	22.75	21.63	20.94	1.345	0.4191
Final weight, kg	46.00[a]	4914[b]	51.71[b]	1.382	0.0236
Total gain, kg	23.25[a]	27.51[b]	30.78[b]	1.483	0.0084
Average daily gain, g/d	211.33[a]	250.10[b]	279.78[b]	18.544	0.0084
FCR[2]	5.62	4.95	4.72	0.509	0.2183
Cost ($US/kg gain)	2.45[a]	2.02[b]	1.80[b]	0.216	0.0267

[1] The diets were (1) no sesame hulls (CON), (2) 75 g/kg of sesame hulls (SH75), and (3) 150 g/kg of sesame hulls (SH150).
[2] FCR: feed conversion ratio.
Different letters indicate a significant difference at $p < 0.05$.

The findings of SH nutrient contents agree with the observed results of previous studies, showing that SH (Abou Gharbia et al., 2000) or sesame meal (Ghorbani et al., 2018) contains a high proportion of lipids, thereby increasing EE's value when incorporated into ruminant diets. An increase in EE and ME contents is expected because SH is a by-product of relatively high-fat content compared to other feed ingredients, such as cereal grains (Obeidat and Gharaybeh, 2011). Although the nutrient profile changed, adding SH to lambs' diets was economically viable, while the cost of SH75 and SH150 diets decreased by 7 and 14%, respectively, compared with the CON diet. This reduction in the cost of the diet is in agreement with several studies proving the economic value of including alternative feeds like SH in animal nutrition (Al-Khaza'leh and Obeidat, 2025a, 2025b; Obeidat, 2025). For instance, local agricultural by-products like SH replacing the more expensive conventional feed components such as barley or soybean meal can reduce the cost of feeds by a large margin (Ghorbani et al., 2018). According to Abdullah et al. (2011), SH is relatively cheaper than traditional feedstuffs; hence, they are a cheaper feed alternative that will lower diet costs. The inclusion of SH as an ingredient also aligns with the growing interest in using agricultural by-products as feed ingredients to help lower feed costs and ensure sustainability in livestock production. This factor has been realized by various authors such as Obeidat et al. (2024), the inclusion of by-products like SH not only reduces feed costs but is also accompanied by additional environmental

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benefits due to a reduction in the demand for more resource-intensive conventional feed ingredients. Thus, the results of this study suggest that the inclusion of SH at appropriate levels can be both nutritionally viable and economically viable for the growth of lambs. These findings support that SH can be a promising alternative feed ingredient that is sustainable and low-cost in lamb nutrition, as shown by similar studies focused on using by-products from agriculture in animal feeding (Abdullah et al., 2011).

Table 4. Effects of dietary sesame hulls (SH) on the nutrient *in vivo* digestibility and N balance of lambs.

Item	Diet[1] CON (n = 4)	SH75 (n = 4)	SH150 (n = 4)	SE	p value
Digestibility coefficients					
Dry matter	80.63[a]	84.69[b]	84.17[b]	1.436	0.0541
Crude protein	80.95[a]	86.32[b]	84.94[b]	1.739	0.0499
Neutral detergent fiber	62.57[a]	67.29[b]	70.89[b]	1.831	0.0112
Acid detergent fiber	55.22	59.38	60.72	3.111	0.2602
Ether extract	81.32[a]	86.37[ab]	89.06[b]	2.496	0.0537
N balance					
N intake, g/d	36.67	35.02	38.44	1.670	0.2035
N in feces, g/d	9.40[b]	7.19[a]	8.28[ab]	0.569	0.0230
N in urine, g/d	10.63	10.83	11.84	2.840	0.9026
N retained, g/d	16.64	17.00	18.33	2.599	0.7989
Retention, g/100 g	44.57	49.56	47.65	8.182	0.8217

[1] The diets were (1) no sesame hulls (CON), (2) 75 g/kg of sesame hulls (SH75), and (3) 150 g/kg of sesame hulls (SH150).
[a,b]Within a row, means without a common superscript letter differ ($p < 0.05$)

Results showed that SH-containing diets elevated the intakes of DM, CP, NDF, ADF, and ME compared with the CON group. This finding agrees with previous studies showing that increasing the inclusion of fibrous feed ingredients such as SH can lead to higher DM and fiber intakes in ruminants since they are usually more palatable and highly fibrous (Obeidat et al., 2024). This result agrees with the higher nutritional values of SH for fat and energy compared to other commonly used feed ingredients, as Abdullah et al. (2011) reported. Since SH is a lignocellulose- and fat-rich byproduct, increasing its inclusion in the diet will enhance the energy density and fat content, which must have contributed to the increased EE values in the SH diets. The increased fiber and fat contents of the SH-containing diets also can explain the high ME content since digestible energy from fat and fiber significantly contributes to the total available energy for the animal (Ghorbani et al., 2018). Greater inclusion of SH also increases the levels of NDF and ADF, which exert additional physiological responses in the rumen. For instance, stimulation for rumination and salivation is essential in maintaining appropriate rumen health (Awawdeh et al., 2014), and digestive functions depend mainly on the proportion of fiber. High levels of fiber depress the digestibility of other available nutrients, perhaps accounting for some of the intake variations recorded in this study among diets. These results further confirm that SH could be a highly valued addition to the diets of ruminants, especially at higher inclusion levels, by providing both fiber and energy and thus improving overall feed efficiency and intake in growing lambs. Awawdeh et al. (2014) reported that when SH was included in the diets of growing goats at 10, 15, or 20% of dietary DM levels, histopathological effects on

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ruminal walls were not impacted among the SH diets compared with the CON diet.

Table 5. Effects of dietary sesame hulls (SH) on blood metabolites in lambs

Item	Diet[1] CON (n = 8)	SH75 (n = 8)	SH150 (n = 8)	SEM	p value
Blood metabolites					
Blood urea nitrogen, mg/dL	25.6	29.7	28.9	4.06	0.5840
Glucose, mg/dL	84.8	86.1	88.6	5.71	0.7920
Cholesterol, mg/dL	66.3	62.9	69.0	6.11	0.6142
HDL[2], mg/dL	37.8	34.8	39.8	3.49	0.3799
LDL[2], mg/dL	26.8	28.7	34.6	8.10	0.6137
Triglycerides, mg/dL	8.8	9.6	10.0	0.839	0.3392
Creatinine, mg/dL	0.69	0.80	0.75	0.110	0.6004
Liver enzymes					
AST[2], IU/L	32.4	35.8	37.8	2.40	0.1118
ALT[2], IU/L	11.9	13.5	12.6	2.08	0.7418
ALP[2], IU/L	51.3	60.8	54.3	13.67	0.7807

[1] The diets were (1) no sesame hulls (CON), (2) 75 g/kg of sesame hulls (SH75), and (3) 150 g/kg of sesame hulls (SH150).
[2] HDL: high-density lipoprotein, LDL: low-density lipoprotein, AST: aspartate aminotransferase, ALT: alanine aminotransferase, ALP: alkaline phosphatase.

Besides, such findings have pointed out the possibility of agricultural by-products like SH being used as alternative, low-cost feed ingredients that contribute positively to livestock diets' nutritional profile and energy content. In summary, the study shows that increased inclusion of SH in the diet results in higher intake of essential nutrients such as CP, NDF, and fiber while also improving the energy value of the diet. Results from (**Table 3**) show that the inclusion of SH thus improved the growth performance of the growing lambs. The final body weight, total gain, and ADG were higher in the SH75 and SH150 diets than in the CON diet. Because of this finding, many studies reported that supplementing some fibrous byproducts, such as SH, improved the growth performance of ruminants. For example, SH contains fiber that can improve the functionality of the rumen, digestion, and intake of feeds for better weight gain (Obeidat and Aloqaily, 2010). Besides, the increased energy content in the SH-containing diets, especially in the SH group, may further account for the improvement in growth performance since increasing energy intake supports higher weight gain and growth in growing animals (Abdullah et al., 2011). Although the final body weight, total gain, and ADG were higher with the SH75 and SH150 diets, no significant differences existed between the two SH-containing diets. This suggests that 75 g/kg SH is sufficient for stimulating growth performance, compared to the higher inclusion level of 150 g/kg SH, since both levels provide the correct balance of nutrients and energy. This is supported by various works indicating that moderate inclusion rates of the fibrous byproducts may be as efficient as higher rates in enhancing growth rates, especially when the whole diet is formulated to meet the nutritional needs of the animals (Obeidat and Aloqaily, 2010; Ghorbani et al., 2018). Apart from these improvements in growth performance, the gain cost was significantly lower in both the SH75 and SH150 groups than that obtained for the CON diet. This presents the economic benefit of using SH as an alternative ingredient. The price of SH is relatively low compared to conventional feed ingredients such as cereal grains and protein meals, which may have contributed to the lower cost of gain obtained with SH-containing diets. The lower gain cost could be attributed to the cost-effectiveness of SH, a byproduct from sesame seed processing often available at a lower price than conventional feed components (Ghorbani et

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al., 2018). Since feed costs comprise a significant portion of the overall production cost in livestock, the inclusion of low-cost, locally available feed ingredients like SH would minimize the overall production cost with no compromise on animal performance. These findings indicate that SH is a promising alternative feed ingredient supporting better growth performance in growing lambs, besides reducing feed costs. Such advantages align with other studies that have sought to outline the economic benefits of using agricultural by-products, such as SH, in livestock feeding (Shirzadegan and Jafari, 2014). In all, the present results from this study indicate that SH, at least at medium inclusion levels, represents a potential and cost-effective feedstuff for improving the growth performance of lamb with a reduction in feeding costs. Overall, SH supplementation in lamb diets improved growth performance, body weight, and total gain compared to the CON diet without showing any significant difference between the two SH inclusion levels. Additionally, the lower gain cost in SH-containing diets reinforces the economic viability of using SH as an alternative feed source. These findings agree with earlier studies on the nutritional and economic advantages of byproducts in livestock feeding (Shirzadegan and Jafari, 2014; Bonos et al., 2017; Ghorbani et al., 2018). According to the results in **Table 4**, adding SH to the lamb growing diet significantly increased the digestibility of DM, CP, and NDF as opposed to the CON group. These findings suggest that SH can generally enhance the apparent total tract digestibility of various essential nutrients in the diet. Previous studies have reported the positive implications of nutrient utilization to different extents through fibrous co-products; for instance, studies on SH in ruminants have already supported it. The increase in DM, CP, and NDF digestibility in the SH-containing diets could be attributed to the rumen fermentation properties of SH. Being a fibrous by-product, SH provides a source of lignocellulose that, when appropriately fermented in the rumen, may increase fiber digestibility by promoting the proliferation of the fiber-digesting microorganisms. An improvement in CP digestibility in the SH-containing diets would indicate that including SH can also improve the rumen's potential to degrade and utilize protein. This may be associated with the ability of some bioactive compounds present in SH (Elleuch et al., 2007) to promote microbial growth and, hence, enhance protein fermentation in the rumen. The increase in NDF digestibility by SH diets indicates that supplementation with SH enhances rumen motility and microbial digestion, leading to improved utilization of fibrous components of feeds. The digestibility of ADF did not significantly differ among the dietary treatments. Therefore, SH did not significantly affect this fiber fraction. ADF is a more lignified and less digestible fraction of fiber than NDF; that is the probable reason ADF's digestibility improvements have not been seen, as reported by Van Soest et al. (1991). This aligns with the general understanding that high-fiber byproducts such as SH can improve NDF digestibility but may have a more limited effect on ADF digestion due to the more resistant nature of the latter (Van Soest et al., 1991). In addition to improvements in fiber digestibility, EE digestibility was significantly greater in the SH-containing diets compared with the control diet. This may be because SH contains a higher percentage of fat; it is very rich in lipids. Fat is an important energy source for ruminants, and digestibility can be affected by both the fat content of the feed and the efficiency of the rumen's microbes capable of fat digestion (Obeidat and Aloqaily, 2010). Higher EE digestibility in SH diets suggests

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that the fat in SH can be efficiently utilized by lambs, which is probably another contributing factor in the observed improvement in growth performance and feed efficiency. Overall, these results suggest that including SH in lamb diets can enhance the digestibility of specific key nutrients, particularly DM, CP, and NDF, while also improving fat digestibility. These findings align with other studies that have shown the effectiveness of using agricultural by-products, primarily those rich in fiber and fat, in improving nutrient digestibility and overall performance in ruminant animals (Aljamal et al., 2021). Besides, the low effect on ADF digestibility is consistent with the general understanding that more lignified fiber fractions are less digestible in ruminant diets (Van Soest et al., 1991). In other words, the increased digestibility of DM, CP, NDF, and EE in the SH-containing diets suggests that SH can be a highly valued addition to ruminant diets, improving nutrient use and overall feed efficiency. These results indicate the potential of SH as an alternative, sustainable feed ingredient for improving ruminant nutrition. As shown in (**Table 4**), except for fecal N loss, the N balance parameters did not show any significant difference among the control group and SH inclusion groups of SH75 and SH150 in N intake, N lost via urine, retained N, and N retention. This suggests that the inclusion of SH in the diet did not markedly affect the overall N metabolism in the lambs compared with the CON diet. Fecal N loss was greater for the CON than for SH-containing diets, perhaps due to higher fiber content. Increased intakes of dietary fiber, especially from by-product sources like SH, result in an altered pattern of N utilization and, consequently, an altered pattern of microbial fermentation in the rumen. Fiber fermentation in the rumen can change the N flow, potentially reducing fecal N loss by promoting more efficient microbial utilization of available N. In contrast, the higher fecal N loss in the CON group may indicate the lower efficiency in N utilization, probably due to the differences in fiber content between the control and SH-containing diets. There were no other significant differences in N intake, urinary N excretion, retained N, or percent N retention except for the fecal N loss noted above. These findings suggest that, although microbial fermentation and, consequently, fecal loss of N are influenced by dietary fiber content, this has little to no effect on overall N utilization efficiency. This finding is in agreement with studies that pointed out that, although high-fiber by-products may alter some parameters related to N metabolism, they have a negligible impact on the N retention of animals, especially when diets are formulated to meet the animals' nutritional requirements (Abdullah et al., 2011; Obeidat and Gharaybeh, 2011). These findings suggest that SH can safely be incorporated into ruminant diets without compromising N utilization and, as such, represents a suitable and sustainable feed resource that may have minimal impact on N metabolism. The greater fecal nitrogen loss of the CON group supports the potential benefit of incorporating fibrous byproducts in the diet to improve nitrogen efficiency. However, further research is needed to fully understand the mechanisms involved. The results of the blood traits of the lambs fed with or without SH inclusion in their diets are presented in (**Table 5**). The values of blood traits were within the same range obtained in other studies for Awassi lambs (Mhmoud and Bendary, 2014). As can be seen, no significant effect was found on BUN, glucose, cholesterol, HDL, LDL, triglycerides, AST, ALT, or ALP. These results suggest that the addition of SH as an alternative feed ingredient did not affect the lambs' major metabolic parameters or liver enzymes, indicating that SH at the tested rate did not impose any adverse physiological

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effect on the animals throughout the experiment. The absence of significant changes in blood urea nitrogen and other biochemical parameters such as glucose, lipoproteins HDL and LDL, triglycerides, and liver enzymes AST, ALT, and ALP suggests that the nutritional profile of the SH-containing diets, while higher in both fiber and fat compared to the control diet, had no adverse influence on nitrogen metabolism or the lipid metabolism of the lambs. BUN is generally considered an indicator of protein metabolism and kidney function, and the absence of significant differences between treatments indicates that the inclusion of SH did not affect the efficiency with which protein was used or nitrogen excreted in lambs. Similarly, the non-significant effect on glucose and lipid profiles suggests that SH inclusion did not adversely affect carbohydrate or lipid metabolism, which is essential in ensuring energy balance and, by extension, general health in dairy cows (Shirzadegan and Jafari, 2014). The activities of liver markers such as AST, ALT, and ALP did not change to support further the fact that SH inclusion did not result in any damage or stress to the liver of the lambs. These enzymes generally arise from liver functions and damage, while ALP is related to bone metabolism and liver health. No significant variations in any of these markers; thus, it showed that SH has neither detrimental effects on liver health nor impaired liver function among lambs and could be used as a safe ingredient for animal feeding. These results indicate that using SH as a novel feed ingredient does not affect the blood biochemical parameters and liver enzymes of the lamb population. Furthermore, these results suggest that SH could be safely used as part of diets in ruminants with no adverse effects on vital metabolic and physiological activities. These findings align with earlier studies demonstrating that agricultural byproducts, such as sesame hulls, are safe and nutritionally adequate for livestock feeding (Obeidat and Aloqaily, 2010; Obeidat and Gharaybeh, 2011).

CONCLUSION

In summary, dietary inclusion of sesame hulls at 75 and 150 g/kg improved feed digestibility and growth performance without adverse effects on nitrogen balance or blood metabolic parameters in growing lambs. The SH-based diets increased dry matter intake, crude protein, and neutral detergent fiber while increasing ether extract and metabolizable energy contents. In addition, the diets of SH75 and SH150 significantly reduced the cost of diets and gain. These results imply that sesame hulls can be a good, efficient alternative feed ingredient for growing lambs. Thus, the findings in the present study support the utilization of sesame hulls in lamb diets for improved feed utilization and economic viability.

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

DECLARATION OF FUND

The authors declare that they have not received a fund.

AUTHOR/S DECLARATION

We confirm that all Figures and Tables in the manuscript are original to us. Additionally, any Figures and images that do not belong to us have been incorporated with the required permissions for re-publication, which are included with the manuscript.

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AUTHOR'S CONTRIBUTION STATEMENT

B.S.O. and M.M.S. were responsible for designing, funding, analyzing the data, and writing the manuscript. M.K.L. is responsible for conducting fieldwork, collecting samples, and conducting laboratory work. L.A. is responsible for the statistical analysis. B.S.O., M.M.S., M.K.A., and L. A. composed the manuscript.

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تأثير قشور السمسم في النمو ومكونات الدم لدى الحملان العواسية

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المستخلص

أجريت هذه الدراسة بهدف بيان تأثير إدخال قشور السمسم ((SHفي علائق الحملان النامية. تم توزيع أربعة وعشرين حملاً (21.8 ± 1.35 كجم، وزن الجسم الأولي؛ 75 ± 2.5 يومًا، العمر) عشوائيًا بالتساوي على 3 علائق. كانت العلائق بدون قشور السمسم (عليقة الشاهد)، أو 75 جم / كجم من المادة الجافة الغذائية ((SH75، أو 150 جم / كجم من المادة الجافة الغذائية (SH150).استمرت الدراسة 120 يومًا، مع استخدام 10 أيام للتكيف، تليها 110 أيام لجمع البيانات. كان تناول المادة الجافة والبروتين الخام وألياف الحمض المتعادل وألياف الحمض الحمضية والطاقة الأيضية أعلى في العلائق SH75 و SH150 مقارنة بعليقة الشاهد. وعلى العكس من ذلك، أظهرت المجموعة SH150 أعلى القيم من حيث تناول الدهون الخامة. كان الوزن النهائي ومعدل زيادة الوزن اليومية أعلى في مجموعات قشور السمسم مقارنة مع مثيلاتها في مجموعة الشاهد. أظهرت النتائج بإن تكلفة الكيلوغرام من النمو كانت أقل لكل لدى مجموعتي قشور السمسم مقارنة بمجموعة الشاهد. لم تختلف نتائج تحليل عينات الدم بين المجموعات. ووفقًا لهذه النتائج، يمكن أن إدخال قشور السمسم في علائق الحملان النامية كعلف بديلً نظرًا لقيمته الغذائية وقيمته من حيث التكلفة.

الكلمات المفتاحية: الأعلاف البديلة؛ هضمية العناصر الغذائية؛ التوازن النيتروجيني؛ كلفة النمو