EFFECT OF REPLACING SOYBEAN MEAL WITH VARYING LEVELS OF SESAME MEAL IN THE PRODUCTIVE PERFORMANCE OF AWASSI EWES

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ABSTRACT

This study evaluated sesame meal (SM) as a substitute for soybean meal (SBM) in Awassi ewe diets during late pregnancy and early lactation. Nine pregnant ewes were randomly assigned to three treatments: control (SBM), 80 g/kg DM SM (SM1), and 150 g/kg DM SM (SM2). Milk yield and composition, ewe and lamb body weights, and nutrient digestibility were assessed over 12 weeks. Results indicated that SM inclusion did not significantly affect overall milk yield, milk composition, or ewe and lamb body weights. However, lactation stage significantly influenced milk yield and composition, with a notable interaction between SM level and lactation stage observed for early lactation milk yield and lamb body weight. Nutrient digestibility and dry matter intake were similar across treatments. The results suggest that SM could replace SBM in ewe diets without compromising performance, offering an economical alternative for ruminant feeding.

Keywords: feed efficiency, protein source, alternative, animal performance.

INTRODUCTION

Animal feed is considered the biggest expense in farm animal projects which is more than 70% of the total cost. Among all feed ingredients, crude protein is the most expensive feed ingredient, which increases the animal diet's cost [17, 18]. For decades farmers used different protein sources to feed their animals including forage protein, protein from animal origins and plant by-products which could reduce feed expenditure [25, 35]. Since 2000 the use of protein from animal origin has been banned due to health conditions. This led to a dramatic increase in the use of plant by-products such as soybean meal (SBM) in animal rations [31]. Soybean meal is the most common source of protein in livestock diets in Iraq and worldwide [6, 9]. However, due to the high demand for using SMB in the livestock diet, especially in pigs and poultry fluctuation and high prices were noticed every year. This pushed ruminant producers to necessitate the exploration of alternative home-grown protein sources with lower costs in ruminant nutrition [1, 13].

Agricultural or industrial byproducts (rich in nutrient content) might be a suitable alternative that could be used to replace part of the conventional ingredients in the ruminant diet. These by-products such as sesame meal (SM) are typically much lower in cost than conventional feeds, which would reduce the cost of the diet and increase the profitability of raising ruminant animals [4].

Sesame seeds (*Sesamum indicum*) are one of the important oilseeds that are locally cultivated to be used in human nutrition, especially for the production of tahini in whole Middle Eastern countries. Sesame by-products (sesame meal) from the tahini industry might be used in animal nutrition [12, 29]. Sesame meal is a nutritious by-product that shows good potential ingredients to replace SBM as a source of protein in the ruminant ration [27]. Sesame meal is potentially characterised by having a high crude protein content (200 to 300 g/kg), along with high levels of essential amino acids [5]. This makes it an important protein source in ruminant feed, particularly in regions where traditional protein sources are scarce or expensive. Using such ingredients might reduce the cost of the diet and increase the animal project profitability [26].

Different published studies were conducted to investigate the effect of sesame by-products in the animal diet on lamb, poultry, and dairy cow production [4, 10, 30].

Awassi ewes are commonly used for milk production in the Middle East due to their ability to produce relatively high quantities of milk under harsh conditions [22]. Milk yield is a critical trait in Awassi ewes, as it directly influences the growth and survival of lambs during early life [5]. Higher milk production also enhances the overall productivity and economic return of Awassi sheep flocks, especially in semi-intensive systems. To our knowledge, there is a lack of scientific studies evaluating the use of SM with an optimum level as a protein source in the diets of Awassi ewes during late pregnancy and nursing ewes during the early lactation period. Therefore, the objective of this study was to investigate the effect of replacing soybean meal with different levels (0, 80 or 150 g/kg DM) of SM in ewes' diets on their performance during late pregnancy and early lactation.

MATERIALS AND METHOD

The experiment was conducted at the Animal Project, Animal Production Department, College of Agricultural Engineering Science, University of Duhok from December to February 2023, to study the effect of replacing soybean meal with different levels of sesame meal (0, 80 and 150 g/kg DM) as a protein source in a concentrated diet of ewe's ration. Nine pregnant Awassi ewes on third party with average body weight 52.4±3.6kg (approximately eight weeks prepartum) were used in this study. Ewes were fed a control concentrated diet (Table 1) and wheat straw (300 g/ ewe/ day) for the first two weeks (group feeding) as an adaptation period. Six weeks prepartum ewes were weighed and body condition scored then divided into three equal groups (Three ewes per group) based on their parity, live weight and body condition score. Ewes from each group received one of the experimental concentrate diets where SBM: control diet without SM, SM1: replacing 80 g/kg DM of soybean meal of control diet with SM, and SM2: replacing 150 g/kg DM soybean meal of control diet with SM as shown in Table (1). Ewes were then kept individually in pens (2 m^2 with wood shaving bed) during the experimental period (six weeks prepartum and 8 weeks post-partum).

The diet was formulated to meet the requirements of single-bearing ewes (average body weight 45 kg) producing one litre of milk according to AFRC [3] Guidelines. The composition and chemical analysis of the three experimental diets is presented in Table (1). In the first 21 days of the experiment, the ewes were offered 500 g/ ewe/ day of the concentrate; then increased to 750 g/ ewe/ day from day 22 until ewe's lambing and then increased to 1250 g/ ewe/ day after lambing. Wheat straw and water were offered *ad libitum* to all ewes. Samples of each experimental diet were collected weekly during the experimental period and later analysed for dry matter (DM), organic matter (OM), crude protein (CP), and ether extract (EE) according to AOAC [8]. The neutral detergent fibre (NDF), acid detergent fibre (ADF), metabolizable protein (MP) and metabolizable energy (ME) for the concentrate

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diet were calculated according to the standard NDF, ADF, MP and ME of raw materials [21].

Measurement of live weight change

Ewes were weighed weekly for 14 weeks. After the ewes lambed, the birth weight of the lambs was recorded. Lambs' weights were also recorded weekly for eight weeks (weaning) using portable scales (510 kg).

Table 1. The feed component and chemical analysis of the diet.

Ingredients g/kg DM	**Diets**		
	SBM	**SM1**	**SM2**
Barely	300	300	300
Wheat bran	350	350	350
Wheat	190	170	150
Soybean	160	100	50
Sesame meal	0	80	150
Feed cost* $/ton	369	314	211
Chemical composition g/kg			
Dry matter	870	882	883
Organic matter	950	945	955
Crude protein	161	158	156
Neutral detergent fibre**	215	241	264
Acid detergent fibre**	72	95	103
Ether extract	43	60	80
Nitrogen free extract**	509	446	397
Metabolizable energy MJ/kg DM**	12.93	12.75	12.65

* According to the local Iraqi market prices in 2021. ** calculated according to McDonald et al [17]

Measurement of feed digestibility

Dietary DM, OM, and CP digestibility were measured using acid-insoluble ash as an internal marker. In the fourth week post-partum, approximately 40 g of fresh faeces were collected directly from the anus of each ewe at noon over three consecutive days. Faecal samples were kept in small plastic pots and directly dried at 60^{o}C for 48 hours each day. For each ewe, the dried faecal samples (20g for three-day collection) were pooled and milled through a 1 mm screen. A 5 g subsample was then used, in duplicate, to determine DM digestibility following the method described by Van Keulen and Young [34].

Milk yield and composition

The milk yield of each ewe was recorded weekly from week 2 to week 8 post-partum. To measure yield, lambs were separated from their dams from 21:00 until 9:00 the following morning. The ewes were then manually milked, and the yield was measured using a measuring cylinder. Milk samples (50 ml) from

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each ewe were collected weekly and stored at -20^{o}C for later analysis. Frozen milk samples were thawed in the refrigerator for 24 hours prior to analysis. Samples were analysed for fat, lactose, protein, ash and total solid using an EcoMilk Minor (EcoMilk Minor, Milkotester Ltd., Bulgaria).

Statistical analysis

Statistical analysis of milk yield, composition, and dam and lamb body weights was performed using a mixed-effects model in Minitab 21. This determined the effects of dietary soybean meal replacement with sesame meal (SM; 0, 80, or 150 g/kg DM), lactation period (7-day intervals), and their interaction, while ewe effects were fixed. Post-hoc analysis employed Tukey's test (α=0.05) to assess significance. Total milk yield, feed intake, lamb birth weight, dam birth weight, digestibility, and diet prices were analysed via one-way ANOVA in Minitab 21, with Tukey's post-hoc test (α=0.05) for treatment effects. Principal Component Analysis (PCA) was conducted on milk yield, composition, and dam and lamb body weights across the lactation period using R's prcomp function [32] to explore trait clustering and mutual influences. Visualization was achieved using factextra [19], FactoMineR, and ggbiploSM1. Results showed total feed intake per kg milk yield was similar across diets (P=0.09), suggesting consistent feed utilization efficiency.

RESULTS AND DISCUSSION

Milk yield and composition

The effect of replacing soybean meal (SBM) with two concentrations of sesame meal (SM1 and SM2) on total daily milk yield (TDMY), dam body weight, lamb body weight, and milk composition is presented in Table (2). Throughout lactation, sesame meal supplementation did not significantly affect TDMY, dam body weight, lamb body weight, or milk composition variables like fat, solid non-fat (SNF), protein, lactose, and total solids (TS) ($p > 0.05$). However, lactation stage significantly affected some variables. TDMY ($p = 0.002$), dam's body weight ($p = 0.011$), lamb's body weight ($p = 0.001$), SNF ($p = 0.010$), protein ($p = 0.031$), lactose ($p = 0.003$), and TS ($p = 0.011$) were all affected by lactation stage. Milk fat percent was tending to significance ($p = 0.061$). Total daily milk yield tended to maximize in the vicinity of days 14–28 before decreasing. Body weight of dam was variable, with increasing trend in advanced lactation, while lamb body weight increased over time. Milk SNF, protein, lactose, and TS followed a similar trend, which increased initially and decreased as lactation progressed.

There was significant interaction between sesame meal level and lactation stage for TDMY ($p = 0.006$), lamb body weight ($p = 0.054$), and lactose content ($p = 0.009$). As can be seen from Figure 1-A, SM2 ewes had higher TDMY on day 14 compared to control and SM1. In addition, milk yield fluctuations were milder in SM1 and SM2 compared to the control. Lamb body weight (Figure 1-B) was larger in the SM1 and SM2 groups, particularly at early lactation, with more stable growth by SM1 than other groups.

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Table 2. Influence of varying sesame levels and lactation stages on milk yield(ml), milk composition yield(gm), dam body weight(kg), and lamb body weight(kg).

Factors	TDMY	Dam BWt	Lamb BWt	Fat	SNF	Protein	Lactose	TS
Treatment								
Control	446	48.83	9.46	15.41	44.32	20.95	19.85	59.87
1	311	43.57	10.18	10.03	30.36	14.18	13.80	40.41
2	411	43.28	10.04	12.26	40.73	19.19	18.36	53.01
Days of lactation								
14	547a	45.13ab	6.08e	21.89	56.67a	27.78a	24.47a	78.56a
21	407abc	43.81b	7.38d	11.85	39.99ab	18.70ab	18.13abc	51.84ab
28	489ab	44.37ab	8.41d	15.00	50.28ab	24.43ab	21.94ab	65.28ab
35	377abc	44.99ab	9.79c	10.90	35.96ab	16.40ab	16.70abc	46.93ab
42	425abc	46.24a	11.04b	11.64	39.58ab	17.75ab	18.77abc	51.30ab
49	199c	45.39ab	12.92a	9.33	21.31b	10.70b	9.91c	30.74b
56	282bc	46.65a	13.65a	7.37	25.51b	11.08ab	12.41bc	33.02b
Pooled SD	72.97	1.44	0.70	8.67	17.84	10.28	6.68	24.14
p-value								
Treatment	0.550	0.510	0.911	0.503	0.480	0.436	0.539	0.462
Period	0.002	0.011	0.001	0.061	0.010	0.031	0.003	0.011
T * P	0.006	0.442	0.054	0.565	0.066	0.213	0.009	0.95

TDMY, test day milk yield; BWt, body weight; SNF, solid non-fat; TS, total solid. Means with different superscripts within each column differ significantly (P< 0.05).

These results imply that replacing SBM with sesame meals (SM1 or SM2) has no significant influence on average milk yield, dam or lamb weight, or milk composition during the whole lactation period. This means that sesame meal can effectively replace soybean meal in lactating ewe diets without having a detrimental impact on these vital parameters. This concurs with Makkar [20], who observed the potential of locally available feed resources as alternatives to conventional protein sources.

The extensive impact of lactation stage on milk composition is in agreement with established physiological patterns in ruminants, where milk yield generally increases after parturition, peaks, and then ultimately decreases due to endocrine fluctuations and metabolic demands [23]. Alteration in milk composition, such as initial high fat and subsequent changes in protein and lactose, are also part of the normal lactation trajectory.

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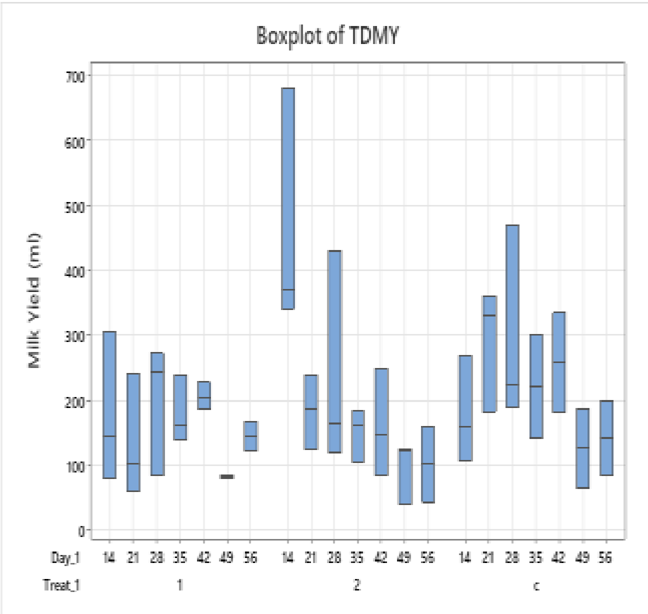

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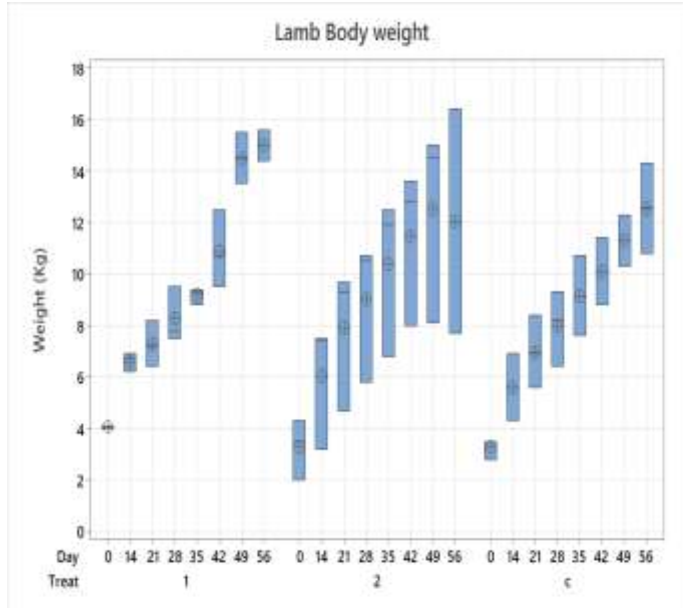

B

Figure 1. A Interaction effect of different sesame levels and lactation period on test day milk yield (ml).

B. Interaction effect of different sesame levels and lactation period on lamb body weight

The observed interaction of lactation stage and treatment in the case of TDMY, lamb body weight, and lactose is another source of information. The higher TDMY level on day 14 in the SM2 group may reflect an acute lactogenic effect caused by sesame meal nutrients or bioactive substances. This is supported in goat studies [14], where the addition of sesame meal was favourably affecting milk yield at specific levels.

Although overall milk composition was not significantly different among treatments, added lamb weight in SM1 and SM2, particularly in early lactation, suggests enhanced nutritional contribution. Reduced variation in lamb growth in SM1 may suggest more consistent quality or availability of milk. Lactose, a key regulator of milk quantity, was affected by treatment by lactation stage interaction. This suggests sesame meal may have an effect on lactose synthesis at certain stages of lactation, perhaps through changes in energy balance or availability of nutrients.

Other studies have reported varying effects of sesame meal on milk composition. For instance, Ani et al. [7] noted increased fat and protein at some levels of inclusion in goats, perhaps due to species variation, processing of sesame meal, or diet formulation. The body weight of the dam did not change across treatments shows that dietary protein and energy were perfectly balanced without any visible metabolic stress due to replacing SBM with sesame meal.

Birth weight and nutrient digestibility

Table (3) shows the effects of sesame meal replacement on birth weight and nutrient digestibility of lambs. Differences were not statistically significant, yet lambs from ewes in group SM1 tended to have larger birth weights. As birth weight plays a critical role in neonatal survival and development [11], this tendency is

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of interest to be further developed in large-scale investigations. No significant variations were observed in dry matter intake (DMI), dry matter digestibility (DMD), organic matter digestibility (OMD), or crude protein digestibility (CPD) in treatment. These findings indicated that sesame meal was equally digestible as SBM and did not have any negative impact on nutrient utilisation. Adejuyigbe et al. [2] are agreed with the current results that animals can utilize substitute protein effectively without compromising digestibility. Surprisingly, DMI was numerically less in SM1 and SM2 groups, but milk yields and lamb weights were equal or better. This can simply better feed efficiency in sesame meal diets due to possibly higher nutrient density or amino acid profile. NRC [24] places strong emphasis on nutrient balance to obtain efficient utilization of feed in small ruminants. Dam body weight at parturition was not significantly affected by treatment, suggesting that prepartum energy and protein requirements were adequately met in all groups. This is advantageous to ewe health and future productivity [33].

Table 3. Total milk yield, dam birth weight, lamb birth weight, and digestibility as affected by dietary sesame meal replaced by soybean meal in ewes.

Traits	**Treatment**			**Pooled SD**	**P-Value**
	SBM	**SM1**	**SM2**		
Total milk yield (L)	20.30	17.34	28.07	8.55	0.35
Weight at birth (Kg)					
Dam	49.33	42.37	40.10	7.81	0.38
Lamb	3.27	4.07	3.27	0.71	0.35
Digestibility					
DM	0.667	0.680	0.667	0.023	0.734
OM	0.680	0.677	0.673	0.016	0.869
CP	0.649	0.680	0.680	0.027	0.323
Daily DMI	1.38	1.34	1.35	0.037	0.427

SBM: soybean meals, SM: sesame meals, DM, dry matter; OM, organic matter; CP, crude protein; DMI, dry matter intake.

Milk composition and physical properties

Table (4) presents the effect of sesame meal replacement and lactation stage on chemical composition and physical properties of milk. Table (4). Influence of varying sesame levels and lactation stages on chemical composition (%) and physical properties of milk.

Sesame meal supplementations (SM1 and SM2) did not significantly affect milk fat, SNF, protein, lactose, TS, density, freezing point, or the 'Z' parameter. Treatment × lactation stage interactions were also not significant. Whereas lactation stage did not influence pH, water, density, or protein content, it influenced milk fat ($p = 0.034$) and total solids (TS) ($p = 0.037$) in lactation. Fat and TS were higher in early and late lactation and lower in mid-lactation. This pattern is characteristic for physiological change whereby colostrum is rich in fat, stabilizes, and then rises due to a decrease in volume of milk [28]. The lack of significant changes via sesame meal treatment confirms its viability as a reliable protein source that does not negatively impact milk quality during lactation. Gun et al. [16] who observed similar

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results when evaluating alternative protein sources in goats and ewes.

Table 4. Influence of varying sesame levels and lactation stages on chemical composition (%) and physical properties of milk of Awassi ewes.

Factors	Fat	SNF	Protein	Lactose	TS	Density	FP	Z
Treatment								
SBM	3.51	9.87	4.66	4.44	13.39	31.90	-0.54	1.45
SM1	3.60	9.77	4.57	4.43	13.38	31.43	-0.52	1.46
SM2	3.01	10.29	4.99	4.49	13.29	34.04	-0.56	1.57
Days of lactation								
14	4.71	10.38	5.09	4.45	15.09	32.85	-0.57	1.57
21	2.89	9.67	4.47	4.45	12.56	31.61	-0.52	1.58
28	3.17	10.48	5.15	4.50	13.64	34.70	-0.57	1.59
35	2.86	9.58	4.39	4.44	12.44	31.26	-0.52	1.57
42	2.54	9.31	4.18	4.42	11.85	30.51	-0.50	1.39
49	4.63	10.85	5.50	4.50	15.49	34.93	-0.60	1.30
56	2.83	9.56	4.39	4.43	12.37	31.26	-0.52	1.47
Pooled SD	1.55	1.43	1.21	0.11	2.44	5.52	0.09	0.19
p-value								
Treatment	0.619	0.507	0.533	0.213	0.993	0.313	0.418	0.225
Period	0.034	0.308	0.285	0.661	0.037	0.592	0.238	0.058
T * P	0.971	0.218	0.232	0.197	0.616	0.211	0.237	0.331

SNF, solid non-fat; TS, total solid; freezing point; Z, viscosity, SBM: soybean meal, SM: sesame meal

Multivariate relationships: principal component analysis

The scree plot in Figure 2A revealed that the first six dimensions reflected data variability, with the first two dimensions having an eigenvalue larger than one accounting for 82% of the overall variance. The first dimension accounted for 70.2% of the variance in the data, which was defined by milk yield and composition. The grouping of total solid, SNF, protein, lactose, TDMY, TMY, and fat demonstrates their interconnection. The interrelation of variables together may be attributed to the positive linear association between milk yield and milk composition, except for fat, which showed a negative linear correlation (Figure 2B). As a result, during the lactation period, both the milk yield and the milk composition varied. These are demonstrated by the fact that sesame, SBM replacement with SM in the ewe's diets has a non-significant impact effect on TDMY and lactose, however, the interaction of treatment and lactation period has a substantial impact (Table 1). The second dimension contributed to 12.4% of the variance, showing that dam and lamb body weights were the primary factors influencing data variation (Figure 2A, C). The negative linear association between dam and lamb body weight (Figure 2B) can be related to the improvement of fast foetal growth during late pregnancy, which resulted in an increased lamb growth rate and improved milk quality. This is evident from the level of sesame to SM replacement in the diets, with 1 SM1 having greater lamb birth weight and 2 SM2 having similar birth weight compared to the SBM (control), despite the control SBM having a higher dam body weight than the other groups (Table 3). Strong evidence suggests that a lamb's birth weight, which is a predictor of lamb mortality, is significantly influenced by the pregnant ewe's diet [15]. The directions of the quantitative variables indicated

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that dam and lamb body weight were the key factors influencing variance in the second dimension. Milk yield and composition, on the other hand, better explained the variation in the first dimension (Figure 2D). Therefore, when evaluating supplemental feeds in lactating animal diets, factors such as the ewe's body weight, lactation stage, and a larger sample size should be taken into account.

Economic efficiency

The feed cost analysis revealed significant differences among the experimental diets (Table 5).Replacing soybean meal (SBM) with sesame meal (SM) at varying levels (0, 80, and 150 g/kg DM) influenced both daily and total feed costs. The concentrate cost decreased progressively with higher sesame meal inclusion, from $0.369/kg (SBM) to $0.211/kg (SM2), reflecting the lower cost of sesame meal as an alternative protein source. The daily total feed cost was highest for the control diet (SBM: $0.43) and lowest for SM2 ($0.35; P=0.01). Over 84 days, this translated to a substantial reduction in total feed cost, with SM2 yielding savings of $6.9 compared to SBM ($29.7 vs. $36.6). The cost of milk production (kg/$) showed a trend toward improvement with sesame meal inclusion (SM2: $0.81 vs. SBM: $1.02; P=0.08), though statistical significance was marginal. Total feed intake per kg of milk yield was similar across diets (P=0.09), suggesting that sesame meal did not compromise feed utilization efficiency. The reduction in feed costs with sesame meal aligns with its economic viability as a locally available, lower-cost protein alternative to soybean meal. The significant savings in total feed cost (up to 18.8% with SM2) highlight its potential to enhance profitability in ewe production systems without adversely affecting feed intake or milk production efficiency. The marginal P-values for milk production cost (P=0.08) and feed intake (P=0.09) may indicate subtle trade-offs warranting further investigation, such as long-term impacts on milk composition or ewe health. These findings support the partial replacement of soybean meal with sesame meal in Awassi ewe diets, particularly in regions where soybean meal is expensive or less accessible. This study showed that using sesame meals as an adequate and economically important alternative to soybean meals in the Awas ewe's diet during late pregnancy and early lactation. While the overall animal performance including milk yield, milk composition, and body weight changes was largely comparable, there were significant interaction between sesame meals inclusion and stage of lactation that indicated a subtle effect on milk production and lamb growth at specific times. Notably, the economic analysis indicated that there were significant reductions in feed cost with increasing sesame meal levels, leading to a trend towards increased cost-effectiveness of milk production without any loss in feed utilization. These findings support the partial to significant replacement of soybean meal with sesame meal, particularly where it is economically advantageous, and would enhance the profitability and sustainability of ewe production systems, though future research can optimize inclusion levels and ascertain long-term impacts.

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Table 5. Economic efficiency for replacing soybean meal with sesame meal at different inclusion in ewes' diets

Traits	Treatment			SED	P-Value
	SBM	SM1	SM2		
Daily conc. cost $	0.37	0.34	0.29	0.002	0.01
Daily straws cost $	0.062	0.065	0.065	0.0014	0.09
Total conc. cost $ 84 days	31.12	27.48	24.33		
Total feed cost $ 84 days	36.6	32.9	29.7		
Daily Total cost $	0.43	0.39	0.35	0.002	0.01
Cost of milk production kg/$	1.02	0.96	0.81	0.841	0.08
Total Feed intake kg/kg milk yield	1.46	1.48	1.48	0.011	0.09

SBM: soybean meal, SM: sesame meal, conc.: concentrate diet.

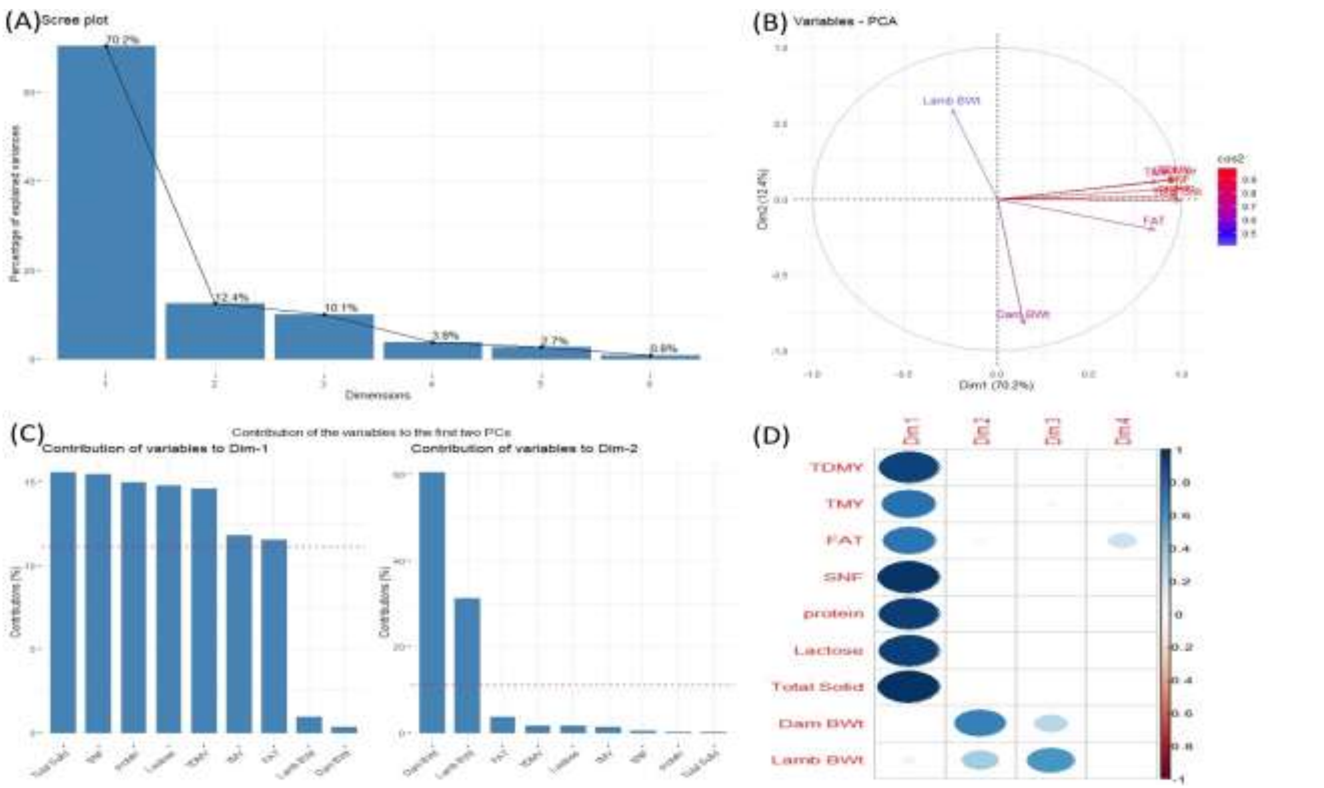

Figure 2. Principal component analysis (PCA) of examined variables in ewes fed varied levels of sesame during late pregnancy and lactation: (A) Scree plot showing the number of dimensions retained after PCA, (B) contribution of groups of variables to the initial two dimensions, (C) contribution of variables to the first two principal components (Dim-1 and Dim-2), and (D) plot illustrating each variable's contribution to the first four dimensions for all measured attributes. The scale next to the figure represents the cos² values of the corresponding parameters. TDMY = test day milk yield,

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TMY = total weekly milk yield, SNF = solids non-fat, Dam BWt = dam body weight, Lamb BWt = lamb body weight.

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