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Research Article:

Impact of dietary milk thistle (*Silybum marianum*) seed powder on growth performance, carcass characteristics, and carcass cuts of Karadi lambs

Hawar Abdullah Latif, Arazu Abdullah Hama[1], Hozan Jalil Hamasalim[1]

[1]Animal Science Department, College of Agricultural Engineering Sciences, University of Sulaimani, Sulaimani, Iraq
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*** Corresponding author info:** Arazu Abdullah Hama (arazw.hama@univsul.edu.iq)

Abstract
Background: Karadi lambs usually have slow growth and only fair carcass yields because of local environmental and genetic factors. Milk Thistle Seed Powder (MTSP), which possesses antioxidant, antimicrobial, and hepatoprotective (liver-protecting) properties due to its bioactive compounds, could be added to feed to help improve performance and meat quality.
Aims: This study assesses how dietary MTSP impacts the growth, carcass properties, and cut yields of Karadi lambs.
Methodology: This study used twenty Karadi male lambs, aged four to five months, with an initial average body weight of 25 ± 1 kg. The lambs were randomly assigned to four groups and fed diets containing 0%, 1%, 2%, and 3% milk thistle seed powder over a ninety-one-day period. The study measured lamb growth, carcass traits, and carcass cuts. Statistical analysis using Duncan's Multiple Range Method (MRM) and Principal Component Analysis (PCA) showed that milk thistle seed powder supplementation had a measurable impact on most of the traits studied. The first two principal components accounted for over 99% of the total variation and separated the groups by MTSP level.
Results: Karadi lambs supplemented with 2–3% MTSP surpassed the control group in Average Daily Gain (ADG), feed conversion ratio ($P \leq 0.05$), hot carcass weight, cold carcass weight and dressing percentages ($P \leq 0.01$), as compared to the control group lambs. Improved carcass yield was demonstrated by larger major primal cuts like the leg, loin, and shoulder. Lambs fed 1% Milk thistle seed supplementation showed moderate improvements, while control group had the poorest performance.
Conclusion: Generally, adding 2–3% MTSP improved growth, feed conversion ratio, and carcass characteristics in Karadi lambs, confirming that milk thistle seed can be a practical natural feed additive for better ruminant performance.

Key words: *Milk thistle seed, Bioactive compounds, Lamb growth and Carcass traits.*

1. Introduction

Worldwide, the demand for high-quality animal-sourced protein, such as meat and milk, is rising, which necessitates improvements in livestock production efficiency, in ways that protect human and not harmful the environment [1]. In the Middle East, ruminant production stills central to rural livelihoods and local food (meat production) supply. In Iraq, the Karadi sheep is considered a major indigenous breed that is well-adapted to regional conditions. On the other hand, when Karadi lambs are raised on traditional feeding systems, they often show slow growth performance, poor feed utilization, and inconsistent meat quality. These limitations reduce their economic value and contribution to national meat output [2,3]. Animal nutrition research is now focusing more on natural alternatives to synthetic growth promoters, herbal feed additives derived from medical plant contain bioactive compounds such as flavonoids, antioxidant, polyphenols, and essential oils, which enhance feed digestion, metabolism, support immunity, and act as antioxidants and antimicrobials [4-6]. Initial studies have shown that milk thistle seed powder as feed additives can improve ruminant performance. For example, lambs fed milk thistle seed gained weight faster, consumed more diet, and converted it more efficiently [2]. Because milk thistle seed is rich in diverse bioactive compounds, it has been reported to improve carcass characteristics in small ruminants such as sheep and goat by increasing lean tissue and reducing fat deposition [3,7,8]. These improvements are especially important for high value carcass cuts such as shoulder, loin, and leg, where better muscle deposition directly increases profitability. Although, research on milk thistle seed use in small ruminants is still limited, current findings on lambs point to potential benefit in growth performance and carcass quality [7-9]. However, its specific effects on growth performance and carcass cuts distribution of Karadi male lambs have not yet been clearly established. Given the economic importance of this local breed to Iraq's livestock sector, further study is needed. Accordingly, this study examines the effect of different dietary levels of milk thistle seed on growth performance, carcass characteristics, and cut distribution in Karadi male lambs, aimed to provide practical evidence for milk thistle seed use as a natural and economic feed additive in sheep production. This research breaks ground as the first of its kind in Kurdistan and Iraq, assessing how local wild milk thistle (Silybum marianum) seed powder impacts the growth and carcass traits of Karadi lambs. Because these wild seeds contain active compounds, they could work well as a natural feed additive within the area.

2. Materials and Methods

2.1. Ethics Committee

The experiment was conducted in accordance with the ethical standards established by the Committee for the protection of animals used for scientific purposes and was approved by the committee under protocol number 2010/63/EU of the European Parliament and of the Council. And, the university's experimental farm provides essential infrastructure for controlled animal studies, including proper housing, feeding systems, and management protocols [10].

2.2. Animals, Experimental Design, and Diets

The study was conducted at the livestock research facility of the Department of Animal Science, College of Agricultural Engineering Sciences, University of Sulaimani (Bakrajo campus, Sulaymaniyah, Iraq). Twenty healthy male Karadi lambs, 4–5 months of age with an average initial body weight of 25 ± 1 kg, were used. The lambs were adapted for 21 days before the start of the trial to accustom them to the housing system and diets. Following adaptation, lambs were randomly allocated into four treatment groups (n = 5 per group) in a Completely Randomized Design (CRD). The treatments groups consist of: the control which given a basal diet without MTSP, while the other groups were supplemented with 1%, 2%, and 3% milk thistle seed (T2, T3 and T4, respectively) based on dry matter. The study lasted for ninety-one days.

2.3. Chemical Composition of Ingredients

Analysis of a subset of feed was performed to validate the precision of NIRS readings guide using standard laboratory procedures. The analysis covered the main proximate composition dry matter, ether extract, crude protein, ash, acid detergent fiber, neutral detergent fiber and crude fiber. these manually determined values were compared with NIRS estimates to confirm the calibration and consistency of the spectral results for each ingredient and formulated diet, as presented in Table 1. Using NIRS allowed rapid and non-destructive scanning of intact samples with high repeatability and dependable accuracy. Prior to analysis, all samples were homogenized, air-dried at room temperature, and ground to pass through a 1-mm screen for uniform particle size. NIRS calibration was performed using advanced chemometric models, including Partial Least Squares (PLS), Artificial Neural Networks (ANN), and Honig Regression (HR), and regularly validated against standard wet chemistry methods to ensure accuracy and for validation, a subset of samples was analyzed using conventional laboratory methods [11,12] to cross-check the NIRS predictions.

The milk thistle seeds (Silybum marianum) used in this study were obtained from a local herbal store in the Sulaimani Governorate. The value from milk thistle seed powder's proximate composition is related to the values that Rayni *et al.* reported in 2023 [9] crude protein, organic matter, ether extract, neutral detergent fiber, acid detergent fiber, ash, and dry matter. In addition, milk thistle seed powder's protein and fiber content make it a good alternative to wheat bran for consistent nutrition. Rayni *et al*. [9] showed milk thistle can replace wheat bran in lamb diets without changing feed intake or diet, indicating it can be a standard feed replacement. the major bioactive flavonolignans of MTSP have been quantified in previous studies [9,13], with reported concentrations of taxifolin (24.3 ± 0.7 mg/g), silychristin (112 ± 3.1 mg/g), silydianin (31.5 ± 0.7 mg/g), silybin A (111 ± 2.8 mg/g), silybin B (130 ± 3.5 mg/g), isosilybin A (68.5 ± 2.6 mg/g), isosilybin B (25.3 ± 0.9 mg/g), and 2,3-dehydrosilybin (5.4 ± 0.3 mg/g).

Experimental diets were formulated to meet or exceed the nutrient requirements of growing lambs as recommended by the NRC [14]. Rations consisted primarily of barley, corn, soybean meal, wheat, and wheat bran as basal ingredients. MTSP was incorporated into the treatment diets by replacing graded proportions of wheat bran at inclusion levels of 0%, 1%, 2%, and 3% of the diet, corresponding to control (T1), T2, T3, and T4, respectively, which are detailed in Table 2. Diet formulation aimed to be isonitrogenous and isoenergetic across treatments, thereby ensuring that observed differences in animal performance and carcass traits were attributable to MTSP inclusion rather than imbalances in energy or protein supply.

Table 1: Chemical composition of animal feed ingredients

Ingredient	DM %	CP%	CF%	ADF	NDF	EE %	Ash%	Mcal/kg DM
Soybean Meal Solvent 49% CP	91	53.14	3.0	6.0	9.0	1.24	6.3	3.1
Barley Grain	89.21	12.11	4.88	7.0	20.0	2.11	3.41	3
Wheat bran	90.02	13.2	11.0	13.0	46.0	2.5	3.0	2.5
Wheat grain	89	14.01	3.03	4.074	12	2.3	2.01	3.21
Corn Grain Whole	89	8.85	2.0	3.0	9.0	3.54	2.0	3.2
MTSP	96	13.1	28.5	29.5	45.3	5.6	5	4.5

DM: Dry Matter, CP: Crude Protein, CF: Crude Fiber, ADF: Acid Detergent Fiber, NDF: Neutral Detergent Fiber, EE:Ether Extract, Mcal/kg**:** Megacalories per kilogram.

Table 2: Formulation and chemical composition of the experimental diets.

Ingredient	**T1 (control)**	**T2 (1%MTSP)**	**T3(2%MTSP)**	**T4(3%MTSP)**
Barley grain	28	28	28	28
Corn	15	15	15	15
Soya bean meal	10	10	10	10
Wheat bran	24.5	23.5	22.5	21.5
Wheat grain	19	19	19	19
Bicarbonate sodium	1	1	1	1
Dicalcium phosphate	0.5	0.5	0.5	0.5
Vit and mineral	1	1	1	1
Nacl	1	1	1	1
Milk thistle seed	0	1	2	3
Composition				
Dry matter	86.38	86.2	86.5	86.56
ME Mcal/kg DM	2.84	2.85	2.88	2.89
Crud protein	15.92	15.91	15.9	15.9
Crud fiber	5.22	5.39	5.57	5.73
Ether extract	2.28	2.3	2.33	2.35
ADF	6.95	7.11	7.28	7.43
NDF	21.42	21.39	21.38	21.37
Ash	2.62	3.01	3.03	3.05

ADF: Acid Detergent Fiber, NDF: Neutral Detergent Fiber, ME Mcal/kg DM: Metabolizable Energy, Megacalories per kilogram of Dry Matter

2.4. Animals Feeding Management and Husbandry

Lambs were fed daily at a level equivalent to 3% of their live body weight, with the ration divided into two equal portions offered at 06:00 and 16:00. And feed refusals were collected and weighed daily for determine feed intake, and used for calculating feed conversion ratios. Clean, fresh drinking water was available ad libitum throughout the trial. To prevent feed contamination and spoilage, feeding was carried out under dry, well-ventilated conditions. Standard health and management practices were applied uniformly across all animal groups. All lambs were vaccinated and dewormed according veterinary protocol. Individual Pens were cleaned daily, and bedding was replaced whenever soiled to maintain hygiene. Adequate ventilation was maintained for clean and comfortable environment. The housing system allowed group feeding while preventing contact or cross contamination between lamb groups.

2.5. Growth Performance Measurements

Individual live body weights were recorded weekly using scale with an accuracy of ±100 gm to monitor growth performance. The initial body weight was calculated at the start of study, and the final weight was obtained on the end of experiment. Total weight gain was measured as the differences between final and initial weights. ADG was determined by dividing total weight gain by the number of feeding days [15]. Dry Matter Intake (DMI) was obtained as the differences between the feed presented and the feed refused [16]. Feed conversion ratio (FCR) was computed as the ratio of DMI to total weight gain [17].

2.6. Slaughter Procedure and Carcass Evaluation

At the end of feeding study, when the Karadi lambs reached at the average live weight of about forty-four kg, three Karadi lambs were randomly selected from each dietary feed additives treatment for slaughter. Prior to slaughter, each selected lambs were fasted for 12-hrs with free access to drinking water. This procedure minimized gut fill and ensured accurate carcass evaluation [18]. Slaughter Body Weight (SBW) was measured immediately before slaughter. Following bleeding and evisceration, empty body weight (EBW) was calculated by subtracting the weight of the digestive tract from the SBW. Hot carcass weight (HCW) was measured directly after dressing, after which carcasses were chilled at 4 °C for 24 hours. Subsequently, Cold Carcass Weight (CCW) was measured. Dressing percentage (DP) was calculated relative to either SBW or EBW depending on either HCW or CCW [19].

Each carcass was split longitudinally, and the left side was divided into eight standardized wholesale cuts according to conventional methods [20]. The primary cuts included the leg, rack, shoulder, loin, and whereas, the secondary cuts comprised the foreshank, breast, neck, and flank. Each cut was individually weighed, and the results were expressed as percentages of the CCW to account for variation in carcass size among treatments [19,20].

2.7. Reliable Data and Calibration

A precision animal balance was used to record daily live body weight, feed offered and refused, as well as carcass and cut weights. The chemical composition of the diets was analyzed using Near Infrared Reflectance Spectroscopy instrument. Calibration models yielded coefficients of determination (R^2) greater than 0.99 and low relative standard deviations, indicating high repeatability and reliability of the research data.

3. Statistical Analysis

Data of lamb growth, feed traits, carcass characteristics, and carcass cuts using the model of statistical analysis like (CRD) based on different dose of MTSP in the lamb feed. To assess treatments, used a One-Way Analysis of Variance (ANOVA). When differences were found (at $p \leq 0.05$ and $p \leq 0.01$), used Duncan's Multiple Range Method (DMRM) to compare means [21]. To examine associations among growth, carcass, and cut variables, PCA was applied. The PCA reduced data dimensionality and aided in visualizing the overall treatment patterns and relationships among traits [22]. All statistical analysis were performed using XLSTAT software program (Addinsoft, France) [23].

4. Results

4.1. Growth Performance

Table 3 shows the growth results for Karadi lambs given varied diets. Karadi Lambs receiving 3 MTSP (T4) grew faster than those on the basal diet (T1) in the second and third feeding pried ($P \leq 0.01$). In the 91days study, T4 Karadi lambs had the best ADG at 0.21 ± 0.01 kg/day, whereas T1 had the worst at 0.16 ± 0.01 kg/day ($P \leq 0.05$).

The feed conversion ratio was better for Karadi lambs fed the 3% MTSP diet than for those in the control treatment ($P \leq 0.05$). T4 had the lowest the feed conversion ratio (4.1 ± 0.2) in the third feeding phase, while T1 had the maximum (5.2 ± 0.2). This advantage continued throughout the trial, with treatment 4 lambs achieving a lower the feed conversion ratio (4.2 ± 0.3) compared to first treatment (5.7 ± 0.3; $P \leq 0.01$). Total body weight gain was also affected by MTSP supplementation ($P \leq 0.01$). In the second feeding period, T3 and T4 noted the highest Total body weight gain (8.6 ± 0.3 and 8.9 ± 0.3 kg, respectively), compared to lower values in T1 and T2 (7.3 ± 0.3 and 8.1 ± 0.3 kg, respectively). Likewise, T3 and T4 in the third feeding period recorded the highest Total body weight gain (8.6±0.3 and 8.9±0.3 kg respectively) compared with the lowest weight in first treatment (7.3±0.3 kg). Diet didn't much change dry matter intake, even if T4 Karadi lambs ate a bit more than T1 lambs. Generally, adding 3% milk thistle seed powder to the feed helped Karadi lambs grow better by increasing ADG and Total Body Weight Gain TBWG and lowering FCR, which shows that MTSP helps lambs grow.

The PCA biplot in first Figure accounts for 99.64% of the total variance. It distinctly separates MTSP supplemented groups (T2 and T4) from the control treatment. Third treatment shows positive relationships with final body weight, dry matter intake, and total feed intake. Lambs in T4 are strongly associated with total body weight gain and average daily gain, suggesting the biggest growth response. In contrast, control group is opposite to the FCR vector, which recommends poor feed efficiency. Second treatment shows moderate results. Overall, MTSP supplementation improved growth traits and feed efficiency, with T3 and T4 showing the respectable improvements.

4.2. Carcass Characteristics

Milk thistle seed powder feed supplements didn't change the slaughter weight, digestive system content, or empty body weight ($P \leq 0.01$). Table 5 shows that Karadi lambs given MTSP had better carcass yield. Hot carcass weight and cold carcass weight were higher ($P \leq 0.01$) in clusters T3 (24.9 ± 0.4 kg; 24.5 ± 0.4 kg) and T4 (25.2± 0.4 kg; 24.7 ± 0.4 kg) than in groups T1 (22.3 ± 0.3 kg; 21.9 ± 0.3 kg) and T2 (22.7 ± 0.4 kg; 22.3 ± 0.3 kg). Dressing percentages for Hot carcass weight and cold carcass weight were also higher ($P \leq 0.01$) in T3 (56.1 ± 0.9 %; 55.1 ± 0.9%) and T4 (57.5 ± 0.9%; 56.4 ± 0.9%) compared to T1 and T2. When compared to empty body weight, T4 had the highest dressing percentage (66.7 ± 1.3%; $P \leq 0.05$). The results suggest that 2–3% milk thistle seed in feed can make carcass yield improved without changing live or empty body weight. This recommends nutrients are better used to build carcass tissue.

The PCA biplot (Figure 2) described for 99.78% of the total variance, showing distinct links between carcass traits and diet. Fourth groups had a positive link with HCW, CCW, and DP, suggesting better carcass yield. Third groups clustered with SW and EBW, suggesting better growth. First groups and second groups, showed weaker links with carcass traits. In overall, higher milk thistle seed inclusion levels (2–3%) had a positive link with better carcass production.

4.3. Carcass Cuts

Cold carcass weight percentages showed differences (P ≤ 0.01) (Table 5). The shoulder percentage was highest in the third (15.9 %) and fourth groups (15.8 %), and lower in the first (12.8 %) and second groups (14.4 %). Loin yield increased with dietary MTSP), with T4 the highest (12.9 %) and T1 the lowest (10.8 %). Leg percentage was also higher in T3 (21.9 ± 0.1%) and T4 (21.6 ± 0.1%) than in T1 (18.4 ± 0.1%). There were some variations in neck percentage, with second groups of studied (9.8 ± 0.0%) and fourth groups (9.8 ± 0.07%) having higher numbers compared to third groups (9.7 ± 0.0%). Flank percentage was higher in second groups (4.1 ± 0.0%) and fourth groups (4.0 ± 0.0%) compared to first (3.9 ± 0.0%) and third (3.9 ± 0.0%). To sum it up, adding 2–3% MTSP improved the yield of valuable cuts like leg, loin and shoulder, and without making the lower-value cuts any smaller, improving the general carcass quality.

Figure 3 indications a PCA biplot of carcass cut data, accounting for 93.21% of the total variance. Factor 1 (57.87%) separated high value cuts (shoulder, loin, leg) from rack and foreshank, though Factor 2 (35.34%) separated neck and flank from breast. Shoulder, leg, and loin showed positive relationships, while rack and foreshank showed negative ones. Treatment distribution showed milk thistle seed influences: first grouped with rack and foreshank, second was positively related to neck and flank, third group was strongly related to high-value cuts, and fourth group showed positive relationships with both primal cuts and neck/flank. In conclusion, milk thistle seed supplementation changed carcass composition based on dosage.

Table 3: Growth measurements and feed utilization of Karadi lambs fed different levels of milk
thistle seed powder (Mean ± SE).

Table 3: Growth measurements and feed utilization of Karadi lambs fed different levels of MTSP (Mean ± SE).

Treatment	IBW (kg)	FBW(kg)	TBWG (kg)	ADG(kg)	TDMI (kg)	FCR	DMI(kg)	TFI(kg)
28days/ first 4 weeks								
T1	25.6 ± 1.6^{a}	28.8 ± 1.8^{a}	3.2 ± 0.4^{a}	0.11 ± 0.01^{a}	19.8 ± 1.1^{a}	6.5 ± 0.6^{a}	0.71 ± 0.04^{a}	22.9 ± 1.3^{a}
T2	25.7 ± 1.6^{a}	28.7 ± 1.8^{a}	3.3 ± 0.4^{a}	0.12 ± 0.01^{a}	19.7 ± 1.1^{a}	6.1 ± 0.6^{a}	0.70 ± 0.04^{a}	22.9 ± 1.3^{a}
T3	26.3 ± 1.6^{a}	29.4 ± 1.8^{a}	3.9 ± 0.4^{a}	0.14 ± 0.02^{a}	20.1 ± 1.1^{a}	5.5 ± 0.6^{a}	0.72 ± 0.04^{a}	23.2 ± 1.3^{a}
T4	26.5 ± 1.6^{a}	27.9 ± 1.8^{a}	4.6 ± 0.4^{a}	0.16 ± 0.01^{a}	20.2 ± 1.1^{a}	4.5 ± 0.6^{a}	0.72 ± 0.04^{a}	23.4 ± 1.3^{a}
28days/ Second 4 weeks								
Treatment	**IBW (kg)**	**FBW(kg)**	**TBWG (kg)**	**ADG(kg)**	**TDMI (kg)**	**FCR**	**DMI(kg)**	**TFI(kg)**
T1	29.9 ± 1.5^{a}	35.2 ± 1.8^{a}	7.3 ± 0.3^{b}	0.16 ± 0.01^{b}	23.4 ± 1.2^{a}	5.5 ± 0.4^{a}	0.84 ± 0.04^{a}	27.1 ± 1.4^{a}
T2	29.5 ± 1.5^{a}	35.4 ± 1.8^{a}	8.1 ± 0.3^{b}	0.18±0.01^{ab}	23.4 ± 1.2^{a}	4.6 ± 0.4^{a}	0.84 ± 0.04^{a}	27.1 ± 1.4^{a}
T3	31.1 ± 1.4^{a}	35.5 ± 1.8^{a}	8.6 ± 0.3^{a}	0.19±0.01^{ab}	24.3 ± 1.2^{a}	4.6 ± 0.4^{a}	0.87 ± 0.04^{a}	28.1 ± 1.4^{a}
T4	30.8 ± 1.5^{a}	35.2 ± 1.8^{a}	8.9 ± 0.3^{a}	0.21 ± 0.01^{a}	23.9 ± 1.2^{a}	4.1 ± 0.4^{a}	0.85 ± 0.04^{a}	27.6 ± 1.4^{a}
35 days/ third 5 weeks								
Treatment	**IBW (kg)**	**FBW(kg)**	**TBWG (kg)**	**ADG(kg)**	**TDMI(kg)**	**FCR**	**DMI(kg)**	**TFI(kg)**
T1	37.2 ± 1.8^{a}	45.2 ± 1.5^{a}	7.3 ± 0.3^{b}	0.21 ± 0.01^{b}	37.5 ± 1.5^{a}	5.2 ± 0.2^{A}	1.07 ± 0.04^{a}	43.4 ± 1.8^{a}
T2	36.7 ± 1.8^{a}	43.9 ± 1.7^{a}	8.1± 0.3^{ab}	0.23±0.01^{ab}	36.8 ± 1.5^{a}	4.6± 0.2^{AB}	1.05 ± 0.05^{a}	42.7 ± 1.8^{a}
T3	37.5 ± 1.8^{a}	44.7 ± 1.7^{a}	8.6 ± 0.3^{a}	0.25 ± 0.01^{a}	37.6 ± 1.5^{a}	4.4± 0.2^{AB}	1.07 ± 0.04^{a}	43.5 ± 1.8^{a}
T4	36.9 ± 1.8^{a}	42.9 ± 1.7^{a}	8.9 ± 0.3^{a}	0.25 ± 0.01^{a}	36.5 ± 1.5^{a}	4.1 ± 0.2^{B}	1.04 ± 0.05^{a}	42.2 ± 1.8^{a}
91days/ 13 weeks								
Treatment	**IBW (kg)**	**FBW(kg)**	**TBWG(kg)**	**ADG(kg)**	**TDMI(kg)**	**FCR**	**DMI(kg)**	**TFI(kg)**
T1	25.6 ± 1.6^{a}	45.2 ± 1.7^{a}	5.9 ± 0.6^{a}	0.16± 0.01^{B}	26.9 ± 2.1^{a}	5.7 ± 0.3^{a}	0.87 ± 0.04^{a}	31.2 ± 2.4^{a}
T2	25.7 ± 1.6^{a}	43.9 ± 1.7^{a}	6.5 ± 0.6^{a}	0.18±0.0^{AB}	26.6 ± 2.1^{a}	5.1 ± 0.3^{ab}	0.86 ± 0.05^{a}	30.9 ± 2.4^{a}
T3	26.3 ± 1.6^{a}	44.7 ± 1.7^{a}	7.1 ± 0.6^{a}	0.19±0.0^{AB}	27.3 ± 2.1^{a}	4.8 ± 0.3^{ab}	0.89 ± 0.04^{a}	31.6 ± 2.4^{a}
T4	26.5 ± 1.6^{a}	42.9 ± 1.7^{a}	7.4 ± 0.6^{a}	0.21± 0.01^{A}	26.9 ± 2.1^{a}	4.2 ± 0.3^{b}	0.87 ± 0.05^{a}	31.0 ± 2.4^{a}

- Means with different lowercase letters reflect significant differences (p≤0.01) between treatments for each trait & period.
- Means with different uppercase letters reflect significant differences (p≤0.05) between treatments for each trait & period.
- IBW = Initial Body Weight, FBW: Final Body Weight, TBWG: Total Body Weight Gain, ADG, TDMI: Total Dry Matter Intake, FCR: Feed Conversion Ratio, DMI: Dry Matter Intake, TFI: Total Feed Intake.

Table 4: Carcass traits and dressing yield of lambs fed different levels of MTSP (Mean ± SE).

Treat-ment	SW (kg)	DSC (kg)	EBW (kg)	HCW (kg)	CCW (kg)	DP% (HCW)	DP% (CCW)	DP% (HCW/EBW)	DP% (CCW/EBW)
T1	43.7 ± 0.5^{a}	5.8±0.1^{a}	3.8± 0.1^{a}	22.3±0.3^{b}	21.9±0.3^{b}	51.0±0.7^{b}	50.2±0.7^{b}	57.9± 1.1^{B}	57.9± 1.0^{B}
T2	43.8 ± 0.5^{a}	6.1± 0.1^{a}	3.8 ±0.1^{a}	22.7 ± 0.4^{b}	22.3 ± 0.3^{b}	51.9±0.8^{b}	51.0±0.7^{b}	59.4± 1.1^{B}	59.4± 1.1^{B}
T3	44.5 ± 0.5^{a}	5.6 ± 0.1^{a}	3.9± 0.1^{a}	24.9 ± 0.4^{a}	24.5± 0.4^{a}	56.1±0.9^{a}	55.1± 0.9^{a}	63.0± 0.2^{AB}	63.0±0.2^{AB}
T4	43.8 ± 0.5^{a}	6.7± 0.1^{a}	3.7± 0.0^{a}	25.2 ± 0.4^{a}	24.7± 0.4^{a}	57.5±0.9^{a}	56.4± 0.9^{a}	66.7± 1.3^{A}	66.7± 1.3^{A}

- Means with different lowercase letters reflect significant differences (p≤0.01) between treatments for each trait & period.
- Means with different uppercase letters reflect significant differences (p≤0.05) between treatments for each trait & period.
-SW: Slaughter Weight, DSC: Digestive System Content, EBW: Empty Body Weight, HCW: Hot Carcass Weight, CCW: Cold Carcass Weight, DP: Dressing Percentage.

Table 5: Carcass cuts percentages of lambs fed different levels of MTSP (Mean ± SE).

Treat-ment	Shoulder%	Rack%	Loin%	Leg%	Neck%	Foreshank%	Breast%	Flank%
T1	12.8 ± 0.1^{c}	10.9±0.8^{a}	10.8±0.1^{d}	18.4±0.1 ^{c}	9.7±0.0^{bc}	4.0± 0.0 ^{a}	7.3± 0.3 ^{a}	3.9± 0.0 ^{b}
T2	14.4± 0.1^{b}	8.7± 0.7^{a}	11.6±0.1^{c}	19.9±0.1^{b}	9.8±0.0^{ab}	4.0± 0.0 ^{a}	7.1± 0.4 ^{a}	4.1± 0.0 ^{a}
T3	15.9± 0.1^{a}	7.7± 0.6^{a}	12.4±0.1^{b}	21.9±0.1 ^{a}	9.7±0.0 ^{c}	4.0± 0.0 ^{a}	8.8± 0.4 ^{a}	3.9± 0.0 ^{b}
T4	15.8± 0.1^{a}	8.9± 0.8^{a}	12.9±0.1^{a}	21.6±0.1 ^{a}	9.8±0.0 ^{a}	4.0± 0.0 ^{a}	7.2± 0.4 ^{a}	4.0± 0.0 ^{a}

- Means with different lowercase letters reflect significant differences (p≤0.01) between treatments for each trait & period.
- Means with different uppercase letters reflect significant differences (p≤0.05) between treatments for each trait & period.

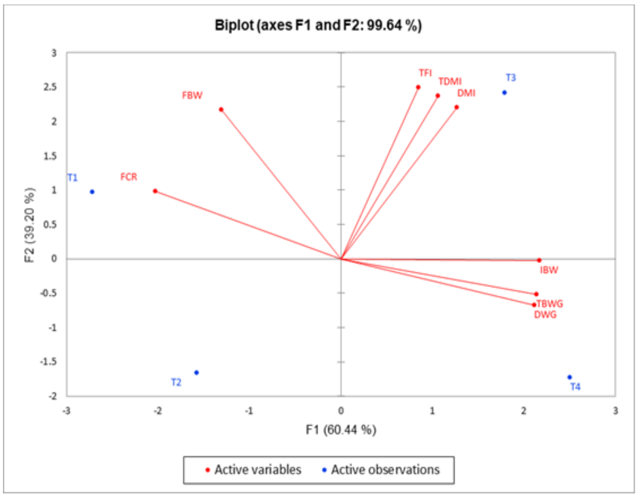

Figure 1. PCAbiplot viewing relationships between dietary MTSP and growth traits of Karadi lambs.

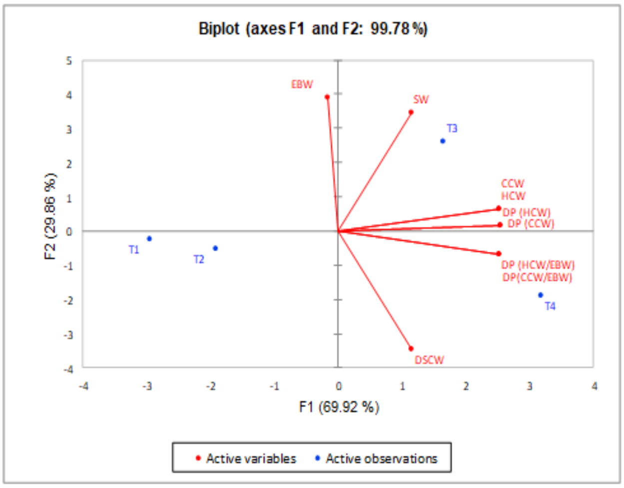

Figure 2. PCA biplot showing relationships between dietary MTSP and carcass characteristics of Karadi lambs.

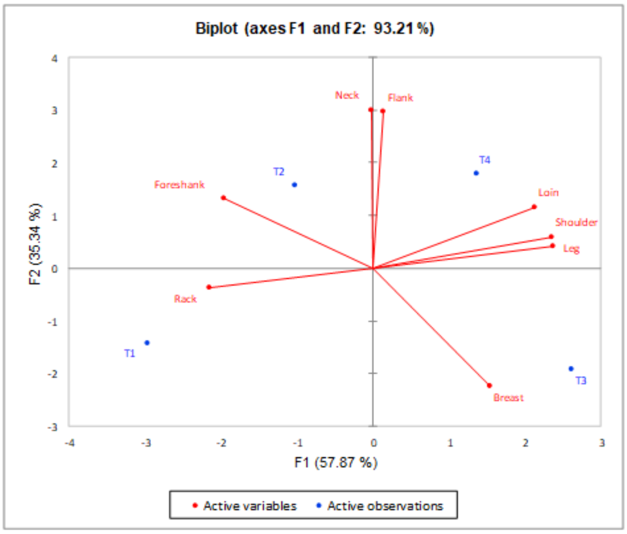

Figure 3. PCA biplot showing relationships between dietary MTSP and carcass cuts of lambs.

5. Discussion

Lambs fed 3% milk thistle seed (T4) presented better growth. The greatest ADG was 0.21 ± 0.01 kg/day, and total body weight gain was 7.4 ± 0.6 kg, with the lowest FCR (4.2 ± 0.3) during the 91-days study. This recommends that milk thistle seed at this level greatly improved how well they used supplement and their ability to grow. These gains happened even when there were no major differences in how much dry matter they ate. This means the lambs got better at turning what they ate into body mass instead of just eating more.

The improved daily weight gain and feed conversion are similar to the paper Nasiripour et al. [24] found. They said that lambs given two percentage of (milk thistle seed) gained more weight each day and had better feed conversion ratio compared to those that were not. They also had enhanced digestion, absorption and changes in rumen functions and characteristics (more propionate, less NH_3-N) [24]. Using a small number of animals in a research study can reduce its statistical power, making it more difficult to detect true differences between treatment groups. Small samples make it harder to get precise measurements and consistent outcomes. Therefore, studies with too few animals as models might lead to hard-to-apply conclusions [25]. Likewise, lambs fed MTSP showed better carcass features and growth, which supports the idea that milk thistle seed helps small ruminants [9]. Outside of milk thistle seed studies, a review of thirty-nine lamb feeding studies shows that plant-based additives (herbal medicine extracts, essential oils and plant bioactive compounds) can help growth by improving how nutrients are used. These additives did not greatly change how much they ate but did increase crude protein digestibility and average daily gain by about 5.77% [26]. The reasons for this might be better antioxidant levels, changes in rumen fermentation and characteristics (more volatile fatty acids shifting towards propionate), better rumen microbial protein production, and liver organ protection from silymarin in milk thistle seed. These things in cooperation with metabolic reduce oxidative stress [26,5]. As ruminant get used to milk thistle seed, these benefits may become clearer. This could explain the differences in daily weight gain and feed conversion ratio are more noticeable in the second and third feeding periods. Still, it's important to note some limits.

In general, feeding 3% milk thistle seed improved growth performance and feed characteristics in Karadi lambs. This lines up with other studies on milk thistle and plant-based food additives and could be a good way to help lamb performance.

This study found that milk thistle seed given as a feed additives did not change slaughter weight, organs system content, or empty body weight, perhaps the absence of differences in the effect of some traits is related to that small animal groups can make biological variation a bigger problem, effect experiment results because each animal's traits have a larger impact. Thus, figuring out the right group size statistically is key to being good while getting solid research data [27]. But carcass yield was higher in Karadi lambs that obtained 2–3% milk thistle seed in their diet. Karadi Lambs in third groups and fourth had higher hot and cold carcass weights than the control groups and the low used additives group (T2). This shows that milk thistle seed helps more of the Karadi lamb's live weight turn into carcass tissue. Dressing percentages showed the same trend, with cold and hot carcass weight values above 56% in third treatment and fourth treatment, but around 55% or less in first treatment and second treatment. The highest empty body weight-based dressing percentage was in fourth groups (66.65%). These numbers indicate that milk thistle seed powder positive benefits do not happen by increases in empty weight or total body. As an alternative, milk thistle seed powder seems to enhance nutrients are divided, so more energy and absorbed nutrients go to carcass formation. This observation aligns with the known functions of bioactive compounds such as flavonolignans and silymarin in milk thistle seed powder. These bioactive compounds safeguard the liver and function as antioxidants, improving nitrogen retention and metabolic function. The researcher recommends that lambs given feed additives or herbal medicine supplements show improved dressing percentages and carcass yield. These bioactive supplements change rumen fermentation in lambs, which helps muscle grow instead of non-carcass components. Nasiripour et al. [24] presented that lambs eating 2% feed additives as milk thistle seeds had higher dressing percentages and carcass weights than those not eating milk thistle seeds, agreement to our findings. Rayni et al. [9] also described those lambs getting milk thistle seeds had increased hot and cold carcass yields as they used feed more efficiently and had greater antioxidant protection in their muscle tissue. In finally, our data supports that 2–3% milk thistle seed is useful in improving carcass yield in Karadi lambs. This leads to both biological and economic benefits because it increases the amount of meat that can be sold without adding to non-carcass weight.

This study's carcass cut data shows that adding 2–3% milk thistle seed to the diet improved the proportion of valuable cuts: shoulder, loin, and leg without changing the foreshank and breast amounts. Lambs in third groups and fourth had the best shoulder (15.9 % and 15.8 %), loin (12.4 % and 12.9 %), and leg (21.9 % and 21.6 %) yields, which were better than the control group. These results recommend MTSP in the diet increases carcass yield and helps nutrients go to muscle growth in valued carcass parts (loin and leg). This might be from better ruminant rumen fermentation (volatile fatty acid profiles for propionate production) and reduced ammonia, which boosts energy use, improved microbial protein production, and increases lean production. These happened in metabolism could explain carcass yield improved and premium muscle areas grew more [9,24,28,29]. These results agreed with Rayni et al. [9] investigated, that lambs given milk thistle seed had more high value cuts. They thought bioactive compound as silymarin's antioxidant and liver protecting features helped with nutrient use and muscle growth. Likewise, Nasiripour et al. [24] studied leg and loin yield increases in lambs fed milk thistle seed, which is in line with our findings. Limited changes in neck and flank percentages did not negatively affect overall carcass. This reinforces that milk thistle seed increases the proportion of respectable cuts without harming others. Generally, these results suggest 2–3% milk thistle seed is a beneficial feeding strategy to improve carcass traits in Karadi lambs, which increases lamb production and profit by increased the yield of top-quality cuts.

The limitations of this research include the modest sample size of five animals and three carcasses which may reduce statistical power and obscure minor effects. In addition, no direct measurements of lamb physiological systems, such as rumen functioning, antioxidants, or liver biomarkers, were performed. Furthermore, PCA results should be interpreted as exploratory rather than definitive. Finally, this study focuses on local lambs produced in regulated farm conditions and requires further confirmation.

6. Conclusion

According to the conclusions of this research, adding two-three percentage of MTSP to the feed of Karadi lambs may increase lamb growth characteristics as well as feed and carcass qualities. Karadi male lambs fed MTSP at these levels had greater daily weight gain, an improved (lower) feed conversion ratio, and a higher dressing percentage, indicating superior nutrient utilization. MTSP also resulted in greater carcass cuts (shoulder, loin, and leg) while affecting fewer desirable areas, indicating improved nutrient distribution for muscle growth. These benefits are most likely due to bioactive compounds known as flavonolignans, specifically silymarin, which contains antioxidants and aids in ruminant metabolism. Principal Component Analysis revealed that the reaction was dose-dependent. Finally, milk thistle seed powder appears to be a beneficial and health-effective feed additive that improves Karadi lamb growth, feed characteristics, meat quality, and carcass characteristics.

7. Conflict of Interest

The authors declare that there are no conflicts of interest related to this publication. The research was conducted independently without any financial or personal influence.

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