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Impact of Incorporating Cactus, Argan, and Carob By-Products into Sheep Diets on Milk Quality and Lamb Growth

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ABSTRACT

This study set out to examine how feeding local ewes a diet including cactus fruit waste, or "cactus silage," affected their milk production and quality as well as how well their lambs did while nursing. On a farm, researchers studied the feeding habits of the Sardi breed, a native sheep species. The animals were divided into two groups; one was given a standard diet (CD) and the other cactus silage (SD). We The milk production was tracked every day and the milk composition features were analyzed every week. There was a 14.8% increase in milk yield, with the SD diet producing an average of 31.15 kg and the CD diet 27.14 kg. A significantly significant difference ($p<0.05$) in SD was seen in the average daily gain (ADG) of lambs during the lactation period when contrasted with the CD lot. In contrast to the CD lot 154 g/d ADG, the SD lot was 199 g/d. With the exception of fat content, which shown more variability for both treatments ($p<0.05$), the treatments did not impact the density, freezing point, or protein levels of the milk samples. There was significant fluctuation in the physicochemical properties of ewe's milk over the weeks of lactation, with values ranging from very high ($p < 0.001$) to very high ($p<0.01$). Cactus silage (SD) may be a good alternative to the conventional feed for female sheep, according to the research, since it has no discernible negative impact on their productivity. Cactus silage is a cost-effective alternative to other feeds for sheep in arid regions, thus it is reasonable to consider it.

Keywords: cactus silage, argan, carob pulp, dry areas, ewe's milk, lambs' growth.

INTRODUCTION

The ruminant cattle business is vital to Morocco's rural economy. This sector represents 25–30% of agricultural production value. According to socioeconomic analysis, 74% of the rural workforce-about one million people-works in agriculture. Its turnover is eight billion dirhams, or 700 million euros. These animals generate 300,000 tons of meat and 1.35 million tons of milk. However, because ruminant food is unavailable, expensive, and lacking in nutrients

(Mouhaddach et al., 2016), natural forages or plants that thrive in the local climate and soil should be promoted.

Optimizing the use of economical feed sources from the local area has the potential to significantly enhance the productivity of ruminant animals. In addition, Morocco possesses a wide range of agricultural by-products and rangeland plants that are plentiful but not properly utilized. The cactus, scientifically referred to as *Opuntia ficus indica*, serves as a particularly advantageous feeding resource for cattle inhabiting desert climates. This is due to its remarkable ability to thrive in dry climates and its outstanding nutritional value. This information is supported by the works of De Kock, (2001) and Tegegne et al. (2005). The selection of unconventional choices is limited. Other factors that contribute to its success include rapid proliferation, remarkable adaptation to barren soils and marginal terrains, low water requirements, and the ability to withstand water scarcity. Furthermore, they serve as a natural reservoir for water.

Replacing barley with spineless cladodes in the dietary intake of lambs and lambs had no impact on digestion, growth, and meat quality, as long as the energy levels were consistent. Furthermore, Abidi et al., (2009) demonstrated that cactus supplementation had a favorable cost-to-benefit ratio. Feeding dairy goats mostly with spineless cacti (*Opuntia ficus indica*), together with a small amount of concentrate, did not result in any notable effect on milk output compared to the control. The milk fat content was considerably lower in the cactus group when compared to the control group (Mouhaddach et al., 2016). Previous studies have found that cactus has a significant amount of readily digested carbohydrates, which makes it a valuable source of fermentable substances (Gebremariam et al., 2006; Tegegne et al., 2005; Vastolo et al., 2020). This text presents the idea of farmers employing the silage technique as a means of coping with drought conditions. Therefore, the utilization of cactus pads in nutrition helps to meet the water needs of animals living in dry and semi-arid areas (Siqueira et al., 2022). Nevertheless, the content, nutritional value, and physicochemical characteristics of ewe's milk are subject to various influences, such as the lactation stage, the livestock's nutritional condition, as well as environmental and genetic factors (Adamu, 2021; Zamberlin et al., 2012). The prickly pear silage, developed by the National Institute of Agronomic Research (INRA), is well-known for its cost-effectiveness when compared to traditional diets. In addition, this strategy creates a market for fruit output that was previously abandoned, representing more than 40% of the annual harvest (Bendaou and Omar, 2013). In Morocco, where the information regarding the nutritional value of cactus pear is lacking, the purpose of this research was to determine the effects of feeding sheep a diet consisting primarily of cactus silage on their milk production and lambs' growth, as well as to find the ways to make use of the by-products of cactus fruit, carob tree, and argan tree cakes as silage.

MATERIAL AND METHODS

Research design, selection of animals, and diets

The research experiments were carried in the rural area of Rhamna (80 km north of Marrakech), an arid region (34°39'36" N, 53°39'00" W). On the farm, feeding trials and experiments were carried out with a native breed known as Sardi. A total of one hundred ewes, ages 4 to 5, and with an average body weight between 40 and 45 kg, were employed. In order to investigate the impact of cactus silage on the milk production volume, milk nutritional quality, and lamb growth performance, two groups of animals were used: one group consisted of the ewes fed with cactus, while the other group was provided a customary (local) diet. Every animal had free access to water for drinking. The animals were given an unlimited amount of SD, a silage diet made of extra cactus fruit, Argan meal (*Argania spinosa* L.), alfalfa (*Medicago sativa*), wheat bran, carob pulp (*Ceratonia siliqua* L.), mineral/vitamin supplement, and ground straw. The traditional diet, referred to as the CD, included commercial foods found in stores, barley grains, alfalfa feed, wheat bran, and pulverized cereal straw. The proportion, chemical composition, and other nutritional details of each component in the two diets that were employed other than the control are shown in Tables 1 and 2. Ewes were acclimatized to the experimental and new feeding regimens before data collection.

Silage preparation

Silage is generated by the process of grinding the waste produced from cactus fruit and then isolating the seeds from the crushed material. Subsequently, the resultant paste is combined with a blend of mineral salts and wheat bran to form the first mixture. Next, the ground argan meal, alfalfa, carob pulp, and ground straw are combined with the mixture. Finally, the combination is kept without oxygen and proceeds through the lactic acid fermentation process. It is important to provide explanations for technical words, such as argan meal, when they are first introduced. After a time of storing for two to three weeks, silage is formed, and then the additive is added (Bendaou, 2010).

Milk yield

Prior to feeding the ewes, a weekly estimation of milk production was conducted on a weekly basis prior to the feeding of the ewes. During the suckling period, lambs were isolated from their mothers for a duration of 15 hours. Afterwards, the female sheep were milked both in the morning and in the evening, and the amounts of milk obtained during these two sessions were added together to determine the overall daily milk output (Akturk et al., 2009). A single milk sample was kept for the purpose of conducting a physicochemical evaluation.

Performance and lambs' growth

The lambs were weighed at the beginning and 90 days into the growth study. Every animal in the study had its daily growth determined using its weight and height measurements. Furthermore, the animals' weight was evaluated at 30, 60, and 90 days in order to observe their reactions to the diets used.

Laboratory analyses

The ingredients and feed samples were pulverized using an IKA WERKE MF 10 introductory laboratory shop, filtered through a 1 mm screen, and latterly stored in watertight plastic holders until they were examined. The AOAC (2005) procedures were employed to determine the amounts of crude fiber (CF), ash, ether excerpt (EE), dry matter (DM) and crude protein (CP).

The approach provided by (Van Soest et al., 2020) was employed to assess the acid detergent fiber (ADF), neutral detergent fiber (NDF) and acid detergent lignin (ADL). Hemicellulose was then estimated using the equation (NDF-ADF), whereas cellulose was determined using the equation (ADF-ADL). Referencing to Sniffen et al. (1992), it was possible to identify total carbohydrates (TC) and non-fibrous carbohydrates (*NFC*):

$$TC = 100 - (CP + EE + Ash) \quad (1)$$

$$NFC = 100 - (NDF + CP + EE + Ash) \quad (2)$$

Complexometric titration was used to analyze the calcium (Ca^{2+}) and magnesium (Mg^{2+}) levels in feed and milk. By combining an acidified mixture comprising ammonium molybdate, ascorbic acid, and antimony, the concentration of phosphorus (P) was measured (AOAC, 2005). Using a flame photometer, the mineral composition of potassium (K^+) and sodium (Na^+) was examined (Tikent et al., 2023).

An analysis was conducted on the chemical content and physicochemical parameters of the milk samples obtained from the experimental animals, including the fat content, solid-not-fat (SNF) content, density and gravity, protein content, lactose (the milk sugar), salt content, freezing point, and electrical conductivity. The equipment used to analyze milk, called the Lacto-Scan Milk Analyser, has a broad LCD display that shows results as numerical numbers. Following collection and processing, this device evaluates all raw milk samples at optimal conditions in a timely manner, as demonstrated by Konyali et al. (2010) and Saltijeral et al. (2015).

Statistical approach

The milk quality, milk yield and body condition were analyzed for their respective impacts caused by diet and lactation week through repeated measures ANOVA employing statistical analysis system software (Gobikrushanth et al., 2019; Rodriguez and Balan, 2006). Duncan's new multiple range test was used to compare means after triple analysis. The highest and lowest values were determined by setting the significance level at 0.05.

RESULTS

Feed intake and treatments

Tables 1 and 2 shows the chemical and nutritional content, feed values, and constituent fractions of the traditional diet (CD) and the silage diet (SD). The silage diet SD composed of 50% cactus waste fruit as a fermentable feed rich of energy source, alfalfa (15%) and wheat bran (14%) as fiber sources,

Table 1. The compositional characteristics of the two diets

The components (% fresh matter)	Silage meals (SD)	Control meals (CD)
Cactus waste fruits	50%	0
Argan meal	13%	0
Carob pulp	6%	0
Minerals and vitamins	2%	0
Barley grain	0	25%
Lucerne	15%	12%
Trade Food	0	24%
Wheat bran	14%	24%
Ground straw	0	15%
Composition	–	–
Crude protein (%)	14.25	14.12
pH	4.10–4.25	–
Dry matter (%)	48.6	75.43
Ash (%)	6.77	7.40
Crude fiber (%)	16.37	15.30
Ether extract (%)	3.42	2.31
NDF (%)	34.24	37.62
ADF (%)	25.52	32.49
ADL (%)	12.46	17.33
Hemicellulose (%)	8.72	12.13
SC (%)	44.74	33.36
TC (%)	74.98	78.68
CNF (%)	40.7	31.05
Na (%)	1.8	2.0
K (%)	8.2	5.7
P (%)	4.6	3.8
Ca (%)	7.2	6.8
Mg (%)	5.8	5.5
FU/kg DM	0.86	0.84
Cost (Dh/Kg FM)	3.13	3.42

Note: Acid detergent lignin (ADL); non-fibrous carbohydrates (NFC); soluble carbohydrates (SC); total carbohydrates (TC); acid detergent fiber (ADF); neutral detergent fiber (NDF); forage unit (FU).

Table 2. The chemical composition of various components included in both diets

Ingredients	pH	D.M (%)	C.F (%)	C.P (%)	Ash (%)	E.E (%)
Cactus fruit waste	6.7	8.5	1.1	2.1	0.8	0.9
Argan meal	–	90.4	21.3	47.1	12.3	15.5
Lucerne	–	98.6	14.6	19.6	8.8	3.9
Wheat bran	–	88.21	12.30	15.42	7.11	1.7
Ground straw	–	88.50	42.50	3.41	8.19	0.31
Barley	–	88.5	6.7	12.1	7.2	2.2
Carob pulp	–	91.31	7.4	6.4	4.9	2.4

Note: Ether extract (EE); crude fiber (CF); dry matter (DM); crude protein (CP).

Argan meal (13%) as protein and fat sources, carob pulp (6%) as a source of carbohydrates and minerals (2%). In contrast, the locally used control feed CD consisted of 25% barley grain, 24% trade food, 24% wheat bran, 15% barley straw, and 12% alfalfa. All animals utilized in this investigation ingested silage without any notable issues. Furthermore, as the levels of dry matter were amended with supplementary ingredients, no laxative effects were witnessed.

Physicochemical composition of milk

Table 3 shows the mean composition (mean ± SD) of ewe's milk based on diet type and lactation week. The density of milk ranges between 1028 and 1034 g/cm^3 and between 1022 and 1034 g/cm^3 for the SD and CD diets, respectively. The freezing points for the SD and CD diets were -0.526 °C and -0.540 °C, respectively. The measurements of milk density and freezing point could not find any statistically significant variations between the two treatments used in this work (p > 0.05).

Table 3. Analysis of the physico-chemical properties of ewe's milk based on variations in diet type and lactation period

Parameters	Diets type	Period lactation (LW)						Mean ± SEM	Signficance
		S1	S2	S3	S4	S5	S6		
D (g/cm^3)	SD	1028.3 ± 2.7	1029.1 ± 1.6	1032.9 ± 1.2	1034.2 ± 0.5	1034.1 ± 0.4	1034.1 ± 0.5	1032.1 ± 1.2	0.84 (ns)
	CD	1022.8 ± 2.5	1031.1 ± 1.3	1034.4 ± 0.7	1034.9 ± 0.6	1034.9 ± 0.8	1033.7 ± 0.6	1032 ± 1.1	
	Mean ± SEM	1035.1 ± 2.6	1031.8 ± 1.5	1027.3 ± 1.0	1034.5 ± 0.5	1034.5 ± 0.6	1034.4 ± 0.5	1032 ± 1.1	
	Significance	0.001 (***)							
MF (%)	SD	8.84 ± 1.21	6.11 ± 1.51	3.03 ± 0.5	3.04 ± 0.59	4.93 ± 0.34	4.97 ± 0.22	5.16 ± 0.74	0.13 (ns)
	CD	9.24 ± 1.20	5.24 ± 1.50	2.76 ± 0.98	3.05 ± 1.10	3.35 ± 0.52	4.11 ± 0.40	4.63 ± 0.95	
	Mean ± SEM	9.04 ± 1.21	5.67 ± 1.50	2.89 ± 0.74	3.04 ± 0.85	4.14 ± 0.43	4.54 ± 0.31	4.89 ± 0.85	
	Significance	0.001 (***)							
DM (%)	SD	16.3 ± 1.8	12.9 ± 0.8	11.9 ± 0.5	14.3 ± 0.4	14.5 ± 0.4	14.9 ± 1.3	14.2 ± 1.1	0.21 (ns)
	CD	20.3 ± 3.3	13.9 ± 1.1	12.9 ± 0.5	13.6 ± 0.7	14.6 ± 0.5	14.5 ± 0.2	14.1 ± 0.7	
	Mean ± SEM	18.3 ± 2.5	13.4 ± 0.9	12.4 ± 0.5	14.0 ± 0.5	14.6 ± 0.5	14.7 ± 0.5	14.1 ± 0.5	
	Significance	0.001 (***)							
C (mS)	SD	1.58 ± 0.30	2.41 ± 0.23	3.15 ± 0.23	2.90 ± 0.21	3.10 ± 0.26	3.20 ± 0.12	2.72 ± 0.22	0.08 (ns)
	CD	2.24 ± 0.21	2.97 ± 0.30	3.28 ± 0.17	3.03 ± 0.19	3.25 ± 0.19	2.99 ± 0.19	3.08 ± 0.20	
	Mean ± SEM	18.30 ± 2.50	2.69 ± 0.27	3.15 ± 0.20	2.96 ± 0.20	3.17 ± 0.23	3.09 ± 0.16	2.90 ± 0.21	
	Significance	0.001 (***)							
SNF (%)	SD	9.23 ± 0.66	8.68 ± 0.14	8.88 ± 0.08	9.57 ± 0.14	9.51 ± 0.11	9.41 ± 0.20	9.21 ± 0.22	0.44 (ns)
	CD	9.34 ± 0.50	8.99 ± 0.11	7.92 ± 0.08	9.49 ± 0.27	9.52 ± 0.19	9.19 ± 0.17	9.07 ± 0.22	
	Mean ± SEM	9.29 ± 0.58	8.84 ± 0.13	8.40 ± 0.08	9.53 ± 0.21	9.52 ± 0.15	9.17 ± 0.19	9.14 ± 0.19	
	Significance	0.003 (**)							
Pr (%)	SD	4.56 ± 0.27	4.35 ± 0.06	4.21 ± 0.03	4.23 ± 0.06	4.39 ± 0.05	4.36 ± 0.17	4.35 ± 0.10	0.52 (ns)
	CD	4.73 ± 0.23	3.25 ± 0.05	4.22 ± 0.04	4.44 ± 0.08	4.55 ± 0.09	4.59 ± 0.08	4.29 ± 0.10	
	Mean ± SEM	4.64 ± 0.50	3.80 ± 0.06	4.22 ± 0.04	4.34 ± 0.07	4.47 ± 0.07	4.48 ± 0.13	4.32 ± 0.10	
	Significance	0.0013 (**)							
FP(-°C)	SD	0.539 ± 0.030	0.517 ± 0.005	0.511 ± 0.007	0.535 ± 0.010	0.531 ± 0.008	0.523 ± 0.010	0.526 ± 0.012	0.28 (ns)
	CD	0.485 ± 0.020	0.509 ± 0.012	0.520 ± 0.009	0.725 ± 0.013	0.529 ± 0.012	0.513 ± 0.015	0.540 ± 0.014	
	Mean ± SEM	0.512 ± 0.030	0.513 ± 0.009	0.515 ± 0.008	0.630 ± 0.012	0.530 ± 0.010	0.518 ± 0.009	0.533 ± 0.013	
	Significance	0.48 (ns)							
Ash (%)	SD	0.69 ± 0.04	0.66 ± 0.01	0.67 ± 0.01	0.72 ± 0.01	0.71 ± 0.01	0.71 ± 0.01	0.69 ± 0.01	0.33 (ns)
	CD	0.70 ± 0.04	0.67 ± 0.01	0.59 ± 0.01	0.72 ± 0.01	0.72 ± 0.01	0.71 ± 0.01	0.69 ± 0.01	
	Mean ± SEM	0.70 ± 0.04	0.67 ± 0.01	0.63 ± 0.01	0.72 ± 0.01	0.72 ± 0.01	0.71 ± 0.01	0.69 ± 0.01	
	Significance	0.001 (***)							
L (%)	SD	4.03 ± 0.26	3.99 ± 0.07	4.18 ± 0.05	4.30 ± 0.06	4.27 ± 0.05	4.26 ± 0.07	4.19 ± 0.06	0.18 (ns)
	CD	4.13 ± 0.22	4.05 ± 0.05	3.54 ± 0.08	4.14 ± 0.07	4.27 ± 0.08	4.31 ± 0.97	4.07 ± 0.24	
	Mean ± SEM	4.08 ± 0.24	4.02 ± 0.06	3.86 ± 0.06	4.14 ± 0.06	4.27 ± 0.07	4.28 ± 0.52	4.13 ± 0.15	
	Significance	0.0031 (**)							

Note: (ns) not significant (p > 0.05); (*) p < 0.05; (**) p < 0.01; (***) p < 0.001.

After the trials, the mean protein content of the analyzed sheep milk samples was 4.35% (SD diet) and 4.29% (CD diet). The fat content ranges for SD and CD, respectively, from 3.03% to 8.84%, with an average of 5.16% and 2.76% to 10.46%, with an average of 4.63%. Nevertheless, there were notable differences in these outcomes among the three diet categories.

For the SD and CD diet, the lactose level of the milk was steady at 4.19% and 4.07%, respectively, indicating non-significant results. Regarding the milk's conductivity, SNF, and ash characteristics, the SD diet means were 2.72%, 9.20% and 0.69%, respectively, whereas the CD diet means were 3.08%, 9.08% and 0.69%, indicating a rise in conductivity and a drop in SNF. The two treatments showed no significant differences ($p > 0.05$). Throughout lactation weeks, the physico-chemical characteristics of ewe's milk showed a significant ($p < 0.01$) to profoundly significant ($p < 0.001$) variation, indicating the impact of feed and nutrition on the milk's quality. According to the results, it was observed that the average freezing points of the different milk samples did not show a significant difference ($p > 0.05$). Solid non-fat (SNF); protein (Pr); dry matter (DM); conductivity (C); freezing point (FP); lactose (L); lactation week (LW); density (D); milk fat (MF); silage diet (SD); control diet (CD). The mean ± SEM (standard error of the mean) of triplicate analyses is represented by each reading.

Lamb's growth and milk production

The milk yield results, which depend on feeding and on lactation period, are presented in Table 4. The average milk yield per day over the 6-week lactation period was 31.15 kg and 27.14 kg for diets SD and CD, respectively. This represents a 14.8% increase in milk production.

With mean values of 741.8 g/d and 648.6 g/d, respectively, the daily milk yield of ewes fed the silage diet developed in this study was considerably ($P < 0.01$) higher than the control lot, indicating a rise in the milk production rate. For both groups, lactation peaks were seen at around three weeks. For the standard and control dies, the persistence coefficients were 0.86 and 0.88, respectively.

Regarding lamb growth (Table 5), the inclusion of a silage diet seems to enhance the mean daily gain (ADG) at 90 days between 127 g/d (control diet) and 178 g/day (silage diet). In addition, a statistically significant difference was noted between both batches (SD and CD) in terms of

Table 4. Milk production (Mean ± SEM) in function of lactation period and diet type

Name	Diets	Lactation week (LW)						Mean ± SEM	Sign.
		S1	S2	S3	S4	S5	S6		
Milk yield (g/day)	SD	644.4 ± 43.1	834.1 ± 58.8	979.1 ± 95.3	850.7 ± 139.4	658.2 ± 47.6	476.8 ± 24.8	741.8 ± 37.5	0.002 (**)
	CD	629.3 ± 82.1	738.2 ± 110.7	789.8 ± 89.3	701.1 ± 105.9	547.5 ± 50.1	472.0 ± 41.6	646.3 ± 38.8	
	Mean ± SEM	636.8 ± 62.5	786.1 ± 84.7	884.4 ± 92.3	775.9 ± 122.6	602.8 ± 48.9	474.4 ± 33.2	694.1 ± 38.1	
	Sign.	0.001 (***)							

Note: (ns) not significant ($p > 0.05$); (*) $p < 0.05$; (**) $p < 0.01$; (***) $p < 0.001$ Silage diet (SD); control diet (CD); lactation week (LW); milk production (MP).

Table 5. Lamb's growth in function of diet type

Parameter	Diet type		Significance
	SD	CD	
Birth weight (g)	4062 ± 52	3880 ± 85	0.013 (*)
Average weight 30 days (g)	10884 ± 618	9620 ± 391	0.05 (*)
Average weight 60 days (g)	15150 ± 728	12340 ± 450	0.001(***)
Average weight 90 days (g)	20156 ± 852	15380 ± 472	0.001(***)
ADG 0-30 d (g)	232.5 ± 22.4	191.0 ± 13.1	0.08(ns)
ADG 0-60 d (g)	184.8 ± 12.1	140,8 ± 7.6	0.001(***)
ADG 0-90 d (g)	178.8 ± 9.3	127,6 ± 6.1	0.001(***)
Voluntary ingestion (kg MS/d)	1.7	–	1.27
Production cost (dh/kg)	29.8	33.9	–

Note: (ns) not significant ($p > 0.05$); (*) $p < 0.05$; (**) $p < 0.01$; (***) $p < 0.001$; the mean daily gain (ADG).

final weight, the fed lambs in the SD lot (20 kg) were comparatively higher than the CD lot (15 kg). Moreover, feed with SD allowed improving (+4.69%) birth weight of lambs compared to CD. The ADG (g/day) of lambs recorded during the first month (232.5 g/day and 190 g/day for the SD and CD groups, respectively) was higher than that of the second (184.8 g/day and 140 g/day for the SD and CD groups, respectively), and that of the third month (178.8 g/d and 127.5g/d for the SD and CD groups, respectively). Finally, the production cost of the silage diet (SD) was estimated at 3.13 dh/kg of FM, whereas the conventional diet (CD) was 3.42 g dry matter/kg diet (Table 1). Also, the production cost deduced from lamb's growth was 29.8 dh/kg and 33.9 dh/kg for the SD and CD groups, respectively (Table 5).

Chemical composition of treatment feeds

Clear differences were seen in the NDF, ADF and ADL contents in both diets (Table 1); their levels were higher in CD (an average of 376.2–324.9–173.3%, respectively) compared to that of SD (an average of 342.4–255.2–124.6%, respectively). The soluble carbohydrate and non-fibrous carbohydrates of SD were higher with 447.4 (g/kg/DM) and 407 (g/kg/DM) respectively, whereas they were only 333.6 (g/kg/DM) and 310.5 (g/kg/DM) in CD.

On the other hand, high level of hemicellulose, cellulose and total carbohydrates were determined in the CD diet compared to those in the silage diet (SD). There were no differences in Na and Mg contents in both diets; however, the values of Ca, K and P were higher in the SD diet compared to that of the CD diet.

DISCUSSION

Treatments and feed intake

It has been reported after the experiments that the animals fed with the cactus silage diets as compared to the ordinary diet showed a greater digestibility of the total carbohydrates of the feed and higher intakes of dry matter, which might have caused increment in the growth performance of the lambs (Nobre et al., 2023). The palatability of the silage diet was explained by the highest sugar and starch levels observed for this cactus silage and also reported by Filho et al. (2021) for forage cacti. As a result, dry matter intake was higher for SD (1.7 kg/d) than that for CD (1.27 kg/d) (Table 1), while for corn silage DMI was 1.97 kg/d (Obeidat et al., 2014), and 0.906 kg/d (Abidi et al., 2009). For instance, the silage used in this study had a high dry matter (DM) content of 486 g/kg, which is significantly higher than the mean DM content of 210 g/kg recorded for maize silage in a study conducted by McDonald, Edward, et al. (2002).

Earlier research using sorghum and corn silages showed that corn silage diets had the strongest negative correlation between the NDF concentration and intake (Nichols et al., 1998), whereas the high dietary intake of silage (1.57 kg DM/d) can be explained by the NDF level.

Milk physicochemical composition

The milk density results align with previous studies on ewe's milk. Studies by various authors report densities of 1036 g/cm^3 for Greek ewe's milk (Caballero-Villalobos et al., 2024; Nguyen et al., 2018), and 1.0347 to 1.0384 g/cm^3 (Caballero-Villalobos et al., 2024; Haenlein and Wendorff, 2006). The freezing point measurements are lower than those cited by Gonzalo et al., (2005) (-0.570 °C) and (-0.575 to -0.571 °C) (Scatassa et al., 2017). These results could be corelated with the present findings, showing the positive impact of cactus bases silage on the chemical parameters of the milk taken from these animals.

The protein and fat contents have always-great interest as the basic compound in cheese technology. The obtained results indicate lower protein and fat contents compared to Rouissi et al. (2005) (6.47% and 7.54%, respectively, for protein and fat). The figures (4.17% and 5.1%, respectively, for protein and fat) correlate with the findings published by Obeidat et al. (2014). These values may be due to the farming practices and the ewes used have not habit to practice milking.

It appears that lactose is the most stable constituent (Table 3). The lactose levels of milk align well with the results presented by Rouissi et al., (2005) and Marshall et al. (2023) (3.89–4.05%), although they are marginally lower than the findings of Martin et al. (2023) (Martin et al., 2023) (4.50%). The values for conductivity, milk ash and solids-non-fat are slightly lower than the mean values reported by Haenlein and Wendorff, (2006) (3.8%) for conductivity, Martin et al. (2023) (11.12%) for solids-non-fat and Anifantakis et al., (1980) (0.9%) for ash.

Additionally, throughout the lactation phase, there is an adverse relationship between the composition of milk and the amount produced. In particular, the percentage of milk components falls with increasing milk yield, probably as a result of rising milk water content. These outcomes agreed with the earlier research that was referenced here (Harjanti and Sambodho, 2020)

Cactus silage could help preserve milk composition and nutritive value in arid regions of the Morocco, where this wild plant is a prevalent green plant during the dry periods. Therefore, inclusion of this plant in the forages for the milking and meat animals could prove beneficial. This finding aligns with earlier research published by Abidi et al. (2009) and Gusha et al. (2013). The results of the present trials indicate that using the silage made from cactus and carob pulp could be a viable method for maintaining the physical and chemical characteristics of milk, which are important indications of milk quality.

Lamb's Growth and the milk yield

The findings of the present study depicted an increment in the milk production and lambs' growth as a result of feeding the special formulation developed in replacement of the common control diet. The main factors influencing milking quality and quantity include race, phase of lactant, milking system, and sheep diet (Vastolo et al., 2020). The findings of the conducted research suggest that milk quality and quantity were influenced by nutrition, which is dependable with the findings reported by Othmane et al. (2002); Yilmaz et al. (2011) and Zamberlin et al. (2012).

The persistence coefficients result for the conducted experiment are lower, compared to that of (Boggio et al., 2021) (0.93), which may be due to the effect of ram breed (Ile de France), diet type, and preparation conditions of animals.

Obeidat et al. (2014) reported a milk yield of 634 g/day for the Awassi ewes fed with wheat hay and corn silage, which was lower than our results.

Boujenane et al. (1996) reported that the same breed of ewes produced 28.8 kg of milk during the first six weeks of lactation when fed a diet including 250 g of dried beetroot pulp, 300 g of barley, 1000 g of alfalfa hay and 10 g of mineral supplement, with an average daily milk production of 685.71 g/day. These values are nearly in accordance with the considered CD group (27.14 kg) and are lower than that of the group receiving the silage diet SD (31.15 kg). As reported by Salama et al. (2003), Kuchtík et al. (2008), Othmane et al. (2002) and Yilmaz et al. (2011), each phase of lactation has an impact on the composition and yield of milk. Feeding silage seems to increase the median daily gain and lamb at birth in terms of growth. These results can be explained by the qualitative and the quantitative availability of the milk during different lactation phases, as well as the lamb's digestion capacity. However, several studies report the correlation of milk production and lamb's growth, therefore the quality and milk availability determine their growth status (Unal et al., 2007). The silage diet tends to improve the daily gain of lambs; this result is in relationship with the quality and milk availability. These findings support those documented by Mahouachi et al. (2012) and Nobre et al. (2023), who showed that incorporating cactus into a moderately concentrated diet can enhance the growth of young goats.

Treatment feeds composition

Table 2 presents the chemical and nutritional composition of the treatment diets. The elevated NDF concentration reduces diet digestibility and feed intake, subsequently causing a decrease in milk production and a significant increase in milk fat concentration (Katongole and Yan, 2020). The ADF and NDF contents of the silage diet was higher (25.5% and 34.2% respectively) compared to maize silage (McDonald, Edwards, et al., 2002), but lower than that of the A. angustissima cactus silage (53.3% and 27.2% for NDF and ADF respectively) (Gusha et al., 2013). These findings suggest that presence of total carbohydrates in the feed diet of the lambs, in the form of soluble and non-soluble dietary fiber promoted the milk production, thus increasing the yield of the milk; however, the chemical composition of the milk may be affected by the nutrients present in that silage, which are also dependent on the environmental and other factors.

CONCLUSIONS

Under the circumstances of this study, the milk volume produced as well as the weight and height of the lamb in terms of growth performance are impacted by the substitution of carob pulp, argan meal, and cactus waste for cereals in sheep diets. Daily milk yield of the ewes fed SD was significantly higher than CD. Furthermore, lamb daily gain was improved for the SD compared to

CD groups (33%). Taking into account the physicochemical properties of ewe's milk, the obtained results do not show any significant differences between the two diets. However, significant differences in these parameters were observed depending on the stage of lactation (weeks).

The ensiling technique is an alternative for the valorization of by-products with high humidity, as indicated by the results of feeding trials based on cactus silage. As a result, the ration tested in this study showed very encouraging results in terms of the ewes' production performance as well as an improvement in the growth performance of their lambs.

The cost of production for lamb, as compared with growth, was very competitive. As a result, it is possible that a diet based on silage made from discarded cactus fruit could be more economical than a conventional one, especially given the increasing cost of concentrates. Finally, it appears that cactus silage has the potential to become a viable alternative for feeding livestock during the dry season, and ultimately enhance the economic wellbeing of farmers residing in arid regions.

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