Letters in Animal Biology

Journal homepage: www.liabjournal.com

Effect of feeding on different levels of crushed cactus in total mixed rations on fattening performance, carcass characteristics, and meat quality of Awassi sheep

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Article info

Received: 28 December 2022
Received in revised form: 17 February 2023
Accepted: 18 February 2023
Published online: 24 February 2023

Keyword

Cactaceae
Sheep
Fattening performance
Carcass characteristics
Meat quality

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Abstract

A ten week feeding experiment was conducted to evaluate the effect of feeding total mixed rations containing different levels of cactus on growth performance, carcass characteristics, and meat quality of Awassi sheep. Twelve lambs with initial body weight of 28.67±2.29 kg and 120 days average age were distributed in complete randomized design into three dietary groups according to crushed cactus level (T_1 = 0%, T_2 = 10%, and T_3 = 15%) in four replicates. At the end of the feeding period three lambs from each dietary group were randomly slaughtered to determine the carcass characteristics and meat quality. The means of the tested parameters were tested for significance using analysis of variance followed by least significant differences at 95% confidence level. Lambs fed T_3 diet showed numerically higher ($P > 0.05$) total weight gain (15.3 kg) and average daily gain (219.1 g). T_2 group had numerically higher ($P > 0.05$) hind quarter perimeter (D), maximum width carcass (Wr), chest depth (Th), and pelvic limb length (F) than T_1 and T_3. Left half carcass weight (10.5 kg), anterior rib (8.3%), pelvic limb (36.3%), and first quality (66.4%) were numerically higher ($P > 0.05$) in T_2. Results of meat quality presented numerically higher ($P > 0.05$) water holding capacity (23.7) and lower cooking loss percent (30.6%) in T_3, these results were reflected on sensory evaluation as well where T_3 recorded significantly higher ($P < 0.05$) scores in texture and flavor of meat. Therefore, adding crushed cactus up to 15% level in diet of sheep could affect the carcass characteristics and meat quality differently.

1. Introduction

Intensive system is the most practiced in rearing livestock especially small ruminants (sheep and goat) in dry and semidry areas such as some countries in Middle East, Africa, and South America. Production and availability of forage and roughages in such areas is affected by the length of dry season, resulting in lower performance of animals. Hence the challenge is feeding animals with diets good in nutritional values and prevent energy loss which is attributed to grazing and search for pastures (Neto et al 2016). Small ruminants are the most reared livestock in Qatar and counts 85.5% of the total population of livestock (1,476,363 heads). Sheep represents 62.2% and Awassi sheep breed estimated to be 57% of total sheep number is well adapted to harsh climatic condition of the country (QAC/ER 2021). Most sheep flocks are bred under traditional fanciers' level and closed zero grazing system is the only practiced livestock management system (Al-Marri and Atta 2014; Ahmed et al. 2021). Sheep contribute 67% of the total production of red meat locally and thus its demand is high which drives more production. Qatari consumers preferred lamb meat at light weight (25-40 kg) and younger than 180 days age. Quality attributes for lamb meat at such age and characterization are not well studied. Carcass conformation and meat quality of lambs are influenced by feeding system (Priolo et al. 2002; Carrasco et al. 2009).

Cactus plant belongs to cactaceae family which is widely spread in arid and semiarid zones of the world (Ali et al. 2005).

It is successfully grown in semi-arid regions of the world and considered as important animal feed contributing to food security and reducing hunger and poverty. Numerous species of cactus spread in different semiarid regions of the world and most of them used as livestock feed include *Opuntia ficus-indica* Mill, *O. lindheimeri Engelm, O. ellisiana, O. engelmannii Salm Dyck, O. chrysacantha Berg, O. amyclae, O. rastrera Weber, O. stricta Haw*, and *Nopalea cochenillifera Salm Dyck* (Dubeux et al. 2021). There are different factors which determine the nutritive value of cactus *viz.* season, age, variety, harvesting, and ecology (Dubeux et al. 2010; Alves et al. 2016; Souza et al. 2017; Pessoa et al. 2020). In dry season it regarded as an important source of energy and water for animals, particularly ruminants (Costa et al. 2009). However, its use is limited by drastic variation in chemical composition, such as dry matter (3.7 – 94%), crude protein (3.3 – 11.6%), crude fiber (8.5 – 34%), and in vitro digestibility (66.7 – 90%). These drastic variations may result in non-pathological diarrhoea, bloat, and weight loss when cactus is used as the only source of fiber in small ruminant feeding (Tegegne et al. 2007; Maciel et al. 2018; Silva et al. 2021). Therefore, it is used in combination with different types of feedstuffs to reduce these unwanted outcomes, such as Tifton 85 hay (Vieira et al. 2008), soybean hulls (Souza et al. 2009), whole cotton seed (Costa et al. 2012), sugarcane bagasse (Pessoa et al. 2013), Maniçoba hay and silage (Maciel et al. 2018), and wheat bran as energy concentrate (Silva et al. 2021). Considering optimizing dietary energy level and endorsing ruminal health, this study was conducted with the objective to evaluate the effects of adding different levels of crushed cactus on the fattening performance, carcass characteristics, and meat quality of confined sheep.

2. Materials and methods

2.1 Experimental site

The study was carried out during April – July 2022, at Animal Production Research Station of Al Shahaniya Municipality. The station is located in the centre of Qatar state (25°21' N and 51°14' E) about 25 km west of the capital Doha. The temperature ranged from 34 to 42 °C and dew point of 65-86 during the experimental period (www.weatherspark.com).

2.2 Animal care

The study was approved by the Ethics of Animal Resources Department/Ministry of Municipality/State of Qatar in compliance with standard ethical norms considering the prescribed use of animals for experimental and scientific purposes.

2.3 Experimental animals, diets, and management

Sixteen non-castrated, vaccinated, dewormed, and ectoparasite treated male Awassi lambs from the station farm flock were used with an average weight of 28.67±2.29 kg and average age of 120 days. The experimental period was of 84 days, in which the first fourteen days period was proposed as an adaptation to the new diet and the remaining 70 days were for data collection. The animals were weighed before allocation to individual confined cages measuring 1.9×1.5 m^2 and equipped with feeder and water source. Daily cleaning of cages, feeders, and drinkers was done with daily removal feed residues for adjusting the feed intake of animals.

Complete randomized design with four treatments and four replicates was used. Four diets was formulated by adding different levels of crushed cactus to total mixed ration (T_1 = 0%, T_2 = 10%, T_3 = 15%, and T_4 = 20%) during the adaptation period (14 days). However, the sheep in T_4 group developed diarrhea and hence the research team decided to cancel the 4th treatment group. Thus, three treatment diets (T_1 = 0%, T_2 = 10%, and T_3 = 15%) were continued up to the end of feeding trail. The basal diet contained molasses, rhodes hay, soybean cake, wheat bran, crushed barely grains, limestone, and salt as shown in Table 1. 0.5 kg of dried alfalfa were provided weekly for each lamb. Crushed cactus used as roughage source in this study was collected from Rawdat Al Faras Research Station, Department of Agricultural Research. It was cultivated, harvested, sun-dried on metallic shelves, crushed, and subjected to proximate analysis (AOAC 2000).

Table 1 Inclusion rate of different ingredients in the experimental diet

Ingredients (%)	T_1	T_2	T_3
Molasses	5	5	5
Cactus	0	10	20
Rhodes hay	30	20	10
Soybean meal	23	23	23
Wheat bran	30	30	30
Barely grains	10	10	10
Limestone	1	1	1
Salt	1	1	1
Total	100	100	100
Dry matter (%)	70.33	76.25	79.21
Crude protein (%)	17.57	17.88	18.04
Metabolizable energy (MJ/kg)	7.90	8.32	8.53
Calcium (%)	0.57	0.65	0.68
Phosphorus (%)	0.45	0.49	0.51

2.4 Feedlot performance, slaughter method, and carcass evaluation

Live body weight of each lamb was recorded at the beginning of the experiment and every week throughout the experimental period at 7:00 AM before offering feed. Daily feed intake was determined by subtracting the residual feed offered. Average daily gain (g/day) was obtained by subtracting initial live body weight from final live weight followed by division by number of days fed. Feed conversion rate was calculated by dividing the total feed intake (kg) by the weight gain (kg) throughout the experiment.

At the end of the experimental period nine randomly selected lambs were transported to Al-Shahaniya Central Slaughterhouse eleven kilometers away from the Research station after 16 hours of fasting with free access to drinking water. The lambs were slaughtered following Islamic Method according to Ministry of Municipality/Animal Resources Department/Quarantine Section Regulations and slaughter body weight (SBW) was recorded.

Head, four feet, skin, viscera, pelvic and abdominal organs, and fat (pelvic, kidney, scrotal, and gut) were removed to determine the hot carcass weight (HCW). Hot carcass yield (HCY) was calculated as follows:

$$(HCY = HCW/SBW \times 100).$$

The full and empty gastrointestinal tract weights were determined to calculate the empty body weight (EBW) by subtracting the GIT content from slaughter body weight and estimating true carcass yield (TCY) as follows:

$$TCY (\%) = HCW/EBW \times 100$$

2.5 Carcass dissections

Carcasses were hanged by gastrocnemius muscle tendon on the hooks at 4 °C for 24 hours and then weighed to estimate the cold carcass weight (CCW) and chilling loss (CL).

$$CL (\%) = (HCW - CCW)/HCW \times 100$$

Cold carcass yield (CCY) was determined as follows:

$$CCY (\%) = CCW/SBW \times 100$$

The following morphological measurements of the carcasses were taken as well using metric tape: hind quarter perimeter (D), hind quarter wide (G), maximum width carcass (Wr.), pelvic limb length (F), half carcass length (L), chest depth (Th) (Colomer-Rocher et al. 1988). The carcass compactness (CCW/L), pelvic limb compactness (pelvic limb weight/F), G/carcass internal length index (G/L), G/pelvic limb length index (G/F), and chest roundness index (Wr./Th) were calculated based on the above morphological measurements. After removing the tail, the carcasses were split down longitudinally into two halves. The left half was weighed and dissected into commercial cuts following Colomer-Rocher et al. (1998) *viz.* thoracic limb, breast, pelvic limb, neck, anterior-rib, and loin-rib. Each cut was weighed as expressed as percentage of left half weight. The cuts were grouped into three categories *viz.* first category composed of anterior-rib, pelvic limb, and loin-rib; second category composed of thoracic limb; and third category composed of neck and breast.

2.6 Meat sample preparation and quality determination

Chilled longissimus dorsi (LD) muscle (4 °C for 24 hours) from right and left sides of the carcasses starting from 5th rib to 1st lumbar vertebrate were taken for determination of cooking loss (CL), water holding capacity (WHC), and sensory evaluation. All analysis was conducted in laboratory unit of the Al Shahaniya Animal Production Research Station.

2.6.1 Cooking loss estimation

Steaks of meat from adjacent positions of 2.5 cm length from chilled LD muscle were precisely weighed before cooking (W1). The samples were immersed in water bath (Model 2301, Fisher Scientific, Marietta, USA) at 80 °C for 90 minutes in thin-walled polyethylene bags and subsequently removed from water bath and instantly cooled under running tap water at 25 °C for 20 minutes. The samples were removed from the bags and wiped using filter paper and weighed again (W2) to determine the cooking loss percentage as follows (Honikel 1998):

$$\text{Cooking loss } (\%) = (W1 - W2)/W1 \times 100$$

2.6.2 Water holding capacity determination

Water holding capacity was determined using method described by Jauregui et al. (1981) with minor modifications in rotor speed of 10000 rpm for 40 minutes (LYNX 4000 centrifuge, Thermo Fisher Scientific, Osterode Am Harz, Germany).

2.6.3 Sensory evaluation

Meat samples from chilled LD muscle were cut with dimensions 2.5×2.5×3 cm and cooked with no seasoning agents in an electric commercial stainless-steel grilling oven (Model 1K-120RCL Ikon, China) until temperature 80 °C was achieved at the core of samples. Based on an 8-point hedonic scale, with 8 being extremely desirable and 1 being extremely undesirable, fifteen semi-trained panelists (8 men and 7 women, 25 to 45 years) participated to evaluate four quality attributes *viz.* colour, tenderness, juiciness, and flavor of cooked meat (Cross et al. 1978).

2.7 Statistical analysis

The means of the tested growth performance, carcass, and meat quality traits were tested for significance using analysis of variance of IBM SPSS version 25 followed by least significant differences at 95% confidence level for separation of means.

3. Results

3.1 Fattening performance and carcass conformation traits

The results of total feedlot performance of Awassi lambs fed different levels of dried cactus are presented in Table 2. It revealed no significant effect of cactus level on the studied performance and carcass traits ($P > 0.05$), however lambs having in T_3 group recorded numerically higher total weight gain and average daily weight gain (15.3 kg and 219.1 g), and chilling loss percentage (3.1). Although T_3 and T_2 lamb group recorded higher ($P < 0.05$) average daily intake (1195.9 g), and total feed intake (83.7 kg); the hot carcass weight (20.7 kg), cold carcass weight (20.2 kg), total carcass yield (53.2 kg), hot

Table 2 Gross performance and carcass traits of fattening lambs using different levels of cactus

Parameters	T_1	T_2	T_3	SEM	P value
Initial body weight (kg)	28.3	30.3	27.3	0.76	0.2963
Slaughter body weight (kg)	43.5	44.5	42.7	0.82	0.7173
Body weight gain (kg)	15.2	14.2	15.3	1.16	0.9276
Average daily weight gain (g)	216.7	202.4	219.1	16.57	0.9334
Total feed intake (kg)	77.1^{b}	81.1^{a}	83.7^{a}	1.06	0.0174
Daily feed intake (g)	1101.7^{b}	1158.5^{a}	1195.9^{a}	15.15	0.0174
Feed conversion ratio	5.4	5.7	5.7	0.38	0.9334
Empty body weight (kg)	38.9	39.8	37.4	0.61	0.3026
Hot carcass weight (kg)	20.7	20.4	19.7	0.39	0.4256
Cold carcass weight (kg)	20.2	19.8	19.1	0.31	0.3171
TCY (%)	53.2	51.2	52.6	0.51	0.3140
HCY (%)	47.6	45.8	46.2	0.61	0.5206
CCY (%)	46.6	44.5	44.8	0.60	0.3613
Chilling loss (%)	2.2	2.9	3.1	0.28	0.5031

T_1 = Total mix ration with 0% crushed cactus, T_2 = Total mix ration with 10% crushed cactus, T_3 = Total mix ration with 15 % crushed cactus, TCY = True carcass yield based on empty body weight, HCY = Hot carcass yield based on slaughter body weight, CCY = Cold carcass yield based on slaughter body weight,
SEM= Standard error of mean
Means bearing same superscript letters do not differ significantly

carcass yield (46.6 kg), and cold carcass yield (47.6 kg) were numerically higher ($P > 0.05$) in T_1 lambs group.

3.2 Carcass dissections measurements

As illustrated in Table 3, none of the zoometric carcass measurements were affected ($P > 0.05$) by different cactus levels. However, Hind quarter wide (G), maximum width carcass (Wr), chest depth (Th), and pelvic limb weight/F were numerically higher in lambs of group T_2 followed by T_1 group except for hind quarter perimeter (D) where it was followed by T_3 group (60.5 cm). Similarly, T_1 group showed numerically higher values for pelvic limb length (F), carcass internal length

Table 3 Zoometric carcass measurement traits of fattening lambs fed different levels of cactus

Parameters	T_1	T_2	T_3	SEM	P value
Hind quarter perimeter, D (cm)	59.8	60.8	60.5	0.28	0.3196
Hind quarter wide, G (cm)	19.8	19.5	20.0	0.22	0.7118
Maximum width carcass, Wr (cm)	20.6	21.2	20.3	0.27	0.4610
Pelvic limb length, F (cm)	37.5	37.1	37.3	0.12	0.4092
Half carcass internal length, L (cm)	61.6	60.8	60.3	0.60	0.7255
Chest depth, Th (cm)	28.4	29.5	28.3	0.42	0.4766
Chest roundness index, Wr/Th	0.73	0.72	0.72	0.02	0.9716
Pelvic limb compactness, Pelvic limb/F (g/cm)	78.7	88.0	78.5	1.97	0.0524
G/F	0.53	0.53	0.54	0.01	0.7268
Carcass compactness, CCW/L (g/cm)	325.9	320.3	316.3	4.21	0.7050
G/L	0.32	0.32	0.33	0.01	0.7244

T_1 = Total mix ration with 0% crushed cactus, T_2 = Total mix ration with 10% crushed cactus, T_3 = Total mix ration with 15 % crushed cactus,
SEM= Standard error of mean

Table 4 Commercial cuts from left side carcasses of fattening lambs fed different levels of cactus

Parameters	T_1	T_2	T_3	SEM	P value
Left carcass weight (kg)	10.3	10.5	10.1	0.15	0.6102
Anterior rib (%)	7.1	8.3	7.9	0.38	0.4667
Pelvic limb (%)	33.6	36.3	34.3	0.79	0.3691
Loin rib (%)	22.1	21.8	21.0	1.01	0.9237
Thoracic limb (%)	19.67	17.86	19.71	0.46	0.1725
Neck (%)	6.7	6.9	7.7	0.42	0.6918
Breast (%)	10.9	8.8	9.5	0.56	0.3274
Commercial meat cuts					
First quality (%)	62.7	66.4	63.2	0.97	0.2639
Second quality (%)	19.67	17.86	19.71	0.78	0.6574
Third quality (%)	17.6	15.7	17.1	0.46	0.1725

SEM= standard error of mean
First quality cuts (anterior-rib, pelvic limb, and loin-rib), Second quality cuts (thoracic limb), Third quality cuts (neck and breast)

index (L), chest roundness index (Wr/Th), and carcass compactness (CCW/L).

Cactus levels had no significant effect ($P > 0.05$) on commercial carcass cuts (Table 4). However, lambs in T_2 group scored numerically higher weight (10.5 kg) and percentage cuts of left half carcass *viz*. anterior rib (8.3%), pelvic limb (36.3%), and first quality (66.4%) carcass cuts. T_1 lamb group revealed numerically higher percentage of breast (10.9%), second (19.67%), and third (17.6%) quality commercial cuts.

3.3 Meat quality traits

Water holding capacity (WHC) and cooking loss (CL) percent were not influenced by the level of cactus feeding in total mixed ration of fattening lambs (Table 5). However, T_3 lamb group had numerically higher WHC but lower CL value followed by T_2 lamb group. The results of sensory evaluation of meat from fattening lambs fed total mixed ration with different levels of cactus are presented in Table 6. Lamb in group T_3 showed the higher score ($P < 0.05$) in texture (7.3) and flavor (7.5) compared to T_1 and T_2 lamb groups which did not differ significantly from each other. No significant effect was observed on the colour and juiciness score of lamb meat.

4. Discussion

Several factors could affect growth performance of fattening animals such as nutritional level, length of fattening period, animal's age, and environmental conditions. The numerically higher total and daily weight gain in T_3 diet group might be attributed to increase in feed utilization and breakdown rate of the digesta by microorganisms in rumen (Van Soest 1994; and Atsbha et al. 2021). However, ADG observed in this study (216.7 – 219.1 g/day) were lower than that reported by Suliman et al (2021) (310 g/day) but higher than that of Shaker et al (2002) (207 g/day), and Jawasreh et al (2019) (180 g/day) for the same breed. Slaughter weight (42.7 – 44.5 kg), hot carcass weight (19.7 – 20.7 kg), and cold carcass weight (19.1 – 20.1 kg) varied considerably, whereas, cold carcass yield (44.5 – 46.6 %) and chilling loss (2.2 – 3.1 %) were corroborated by earlier studies (Greer and Jones 1997; Carrasco et al. 2009; Suliman et al. 2021; Silva et al. 2021; Atsbha et al. 2021).

Ramírez-Retamal et al (2013) found that carcasses with smaller D values but more F value showed the highest compactness which is in line with the results of earlier studies (Carrasco et al. 2009; Diaz et al. 2002). Most of the studies have reported that the first quality of commercial meat cuts represents more than 60 % of the carcass weight (Caneque et

Table 5 Water holding capacity and cooking loss of mutton from fattening lambs fed different levels of cactus

Parameters	T_1	T_2	T_3	SEM	P value
Water holding capacity	22.2	23.4	23.7	1.83	0.9451
Cooking loss %	36.9	32.5	30.6	2.18	0.5132

T_1 = Total mix ration with 0% crushed cactus, T_2 = Total mix ration with 10% crushed cactus, T_3 = Total mix ration with 15 % crushed cactus, SEM= Standard error of mean

Table 6 Sensory evaluation mutton of fattening lambs fed with different levels of cactus

Parameters	T_1	T_2	T_3	SEM	P value
Colour	7.4	7.0	7.4	0.101	0.2556
Texture	6.4^b	6.7^a	7.3^a	0.146	0.0458
Flavor	6.4^b	6.6^b	7.5^a	0.155	0.0081
Juiciness	6.5	6.4	7.1	0.139	0.1168

SEM= standard error of mean
First quality cuts (anterior-rib, pelvic limb, and loin-rib), Second quality cuts (thoracic limb), Third quality cuts (neck and breast)

al. 2004; Diaz et al. 2006; Carrasco et al. 2009) which is line with the results of present study.

The inverse relationship between WHC and CL observed in this study was supported by earlier studies as well (Rubiano et al. 2009; Venturini et al. 2020). However, the CL values observed in this study were lower than those reported by Rubiano et al (2009). Sensory attributes of meat is a generally accepted helpful tool for evaluation of meat quality. It has been reported that the reduction in WHC of meat could affect its sensory attributes mainly texture and flavor by releasing water and other nutritional components (Zeola et al. 2007). However, on the 8-point hedonic scale Suliman et al (2021) reported the sensory attributes of Awassi sheep lower than that observed in the present study.

5. Conclusions

It was concluded that using crushed cactus up to the level of 20% in diet of sheep has not adverse effects on the fattening performance. However, slight positive effects can be observed on the meat quality. Therefore, crushed cactus along with Rhodes hay could be an economical alternative forage resource for feeding sheep in arid and semi-arid areas such as Qatar state.

Declarations

Funding: Not available

Conflict of interest: The author declares no conflict of interest could influence the work reported in this paper

Ethical approval: The study was approved by the Ethics of Animal Resources Department/Ministry of Municipality/State of Qatar in compliance with standard ethical norms considering the prescribed use of animals for experimental and scientific purposes.

Acknowledgements: The authors acknowledge Mitsui & Co. Ltd. for providing the financial grant.

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