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Influence of corn stover on the growth and blood parameters of Awassi lambs fed a concentrate diet

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ABSTRACT

This study was conducted to evaluate the effects of substituting wheat straw with corn stover (CS) on the growth performance and blood parameters of lambs fed on a concentrate diet. Male lambs were split into two groups, with 16 lambs in each. Following a 7-days adaptation period, one group received a diet containing 0 g/kg CS (CS0) and the other group received 100 g/kg CS (CS100) for 56 days. The following growth-related parameters were evaluated: feed intake, digestibility, N balance, total weight gain, average daily gain and blood parameters. The production cost was also assessed. Dry matter (DM) and crude protein (CP) intake increased ($p \leq .05$) for lambs fed the CS100 diet. Lambs introduced to the CS100 diet were better able to digest ($p \leq .05$) DM, CP, neutral detergent fibre, and acid detergent fibre. N intake and retention improved, while N lost in faeces tended to increase ($p \leq .08$) in lambs fed the CS100 diet. Average daily weight gain was greater ($p = .03$), and cost of gain was lower ($p = .001$) for lambs fed the CS100 diet. Blood glucose increased while creatinine was reduced ($p < .05$) for lambs fed the CS100 diet. These results indicate that feeding lambs the CS100 diet is efficient and would increase profitability. In conclusion, feeding corn stover had a positive impact on growth rate, reduced production costs, and had no negative effect on health. Therefore, we recommend that lambs should be fed diets that include CS100.

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Introduction

Sheep farmers in Jordan and other semi-arid areas worldwide face serious problems due to increasing costs and the decreased production of traditional feeds. Reducing feed costs and increasing profits for the livestock industry might be possible if alternative feeds, including by-products from traditional crops, were added to ruminants' rations.

Corn is an important crop that is cultivated in different areas of Jordan. Corn production was estimated to be around 25 thousand tons during 2020 (FAO 2020), while the global production of corn stover (CS) was estimated to be approximately 1 billion tons (Li et al. 2014). Approximately 50% of the dry matter (DM) from the corn plant remains in the field after harvesting the grain, including cobs, leaves, and stalks (Wang et al. 2017). This by-product, which is left behind after the harvesting process, is known as CS and is widely used for ruminant feed worldwide (Elkholy et al. 2009; Ali et al. 2012; Wei et al. 2018; Hao et al. 2021). Glassner et al. (1999) stated that approximately 1 kg of CS remain per kg of harvested corn grain. Researchers report that CS is thought to be low-quality forage due to its chemical composition. It consists mainly of fibres including cellulose, hemicellulose, and lignin (340, 375, and 220 g/kg, respectively) (Tirado-Estrada et al. 2011; Feng et al. 2012; Fayyaz et al. 2018).

During the season when green fodder is insufficient, CS is used as a good low-price source of feed to enhance livestock productivity (Ali et al. 2012; Sun et al. 2018; Hao et al. 2021). A recent study by Amuda and Okunlola (2020) revealed that ensiled CS could provide the energy requirements for sheep and increase the digestibility and intake of nutrients during their growth stage. Also, as reported by Shi et al. (2014), mixing CS with other alternative feeds had no negative impact on blood composition or cattle health.

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Most studies reported on the effect of treated CS on livestock growth (Ali et al. 2012; Shi et al. 2015; Fayyaz et al. 2018), whereas limited research has been done on the effect of untreated CS on the growth and health of sheep. Therefore, our hypothesis for this study was that replacing wheat straw with CS during the growth stage would improve the intake and digestibility of nutrients, the blood composition, and the growth rate of Awassi lambs. Consequently, the aim was to examine the effect of offering a concentrated diet of CS on the growth rate and blood components of Awassi lambs during the growth stage.

Materials and methods

The study protocols and procedures were approved by the Institutional Animal Care and Use Committee at Jordan University of Science and Technology where the experiment was performed.

Animals and experimental procedures

In a completely randomised design experiment, 32 male Awassi lambs with initial body weight of 26.7 ± 1.45 kg and aged approximately 3–4 months (16 lambs/treatment) were allocated randomly to two different dietary treatments: (1) the control diet with 0 g/kg of CS (CS0) or (2) the treatment diet containing 100 g/kg CS (CS100) of dietary DM. The chemical composition of CS was 880, 40, 521, 241 g/kg DM, crude protein (CP), neutral detergent fibre (NDF), and acid detergent fibre (ADF), respectively. The roughage to concentrate ratio was 32.5:67.5% for both diets. At the start of the study, all lambs were given anthelmintics to protect them against internal parasites (2 mL/lamb; Ivermectine 1%, Ivermic, Laboratorios Microsules Uruguay S.A, URUGUAY). Diets were offered *ad libitum* to lambs daily and were formulated weekly with the same proportion of CP (160 g/kg DM) to meet growing lambs' CP requirements to gain 200–250 g/day as specified by the NRC (2007). The cost of the diets was calculated based on the prices of the ingredients in 2021.

During the study, lambs were distributed between eight open-sided 4 × 4 m pens. Four pens were assigned to each treatment diet, with four lambs per pen. Lambs were fed twice daily with total mixed rations at 09:00 and 14:00 h each day. Lambs had free access to water and cleaning protocols were followed throughout the study. The lambs had an adaptation period of 7 days before the start of the experimental period that lasted for 56 days.

Feed offered and feed refused were recorded while samples from each were stored (at −20 °C) for chemical analysis every day. Nutrient intake was measured based on DM by calculating the difference between feed offered and feed refused. The lambs were weighed on day 0, 21, 42, and 56 of the experiment before the 09:00 h feed was offered. The average daily gain (ADG) was calculated by dividing the difference between the final and initial body weight by the number of days in the experimental period.

At the end of the study, six lambs were randomly selected from each experimental group to assess their ability to digest nutrients and their nitrogen balance. To do this, they were housed individually in 1.05 × 0.80 m metabolic crates. After 5 days of adaptation, collections from the cages were performed for 5 days. During this period feed and refused feed were recorded and sampled. Total faecal output per 24 h was collected at 8:00 h before feeding and recording the lambs' weight. Samples of faecal output (10 g/100 g) were kept at −20 °C for further chemical analysis. Total urine output was collected in plastic containers. These were weighed and the weights recorded, and about 5 g/100 g from the total amount was stored frozen at −20 °C to evaluate the amount of nitrogen retained compared with nitrogen lost in faeces and urine. To prevent the loss of ammonia 50 ml of 6 *N* HCl was added. Samples of faeces were dried at 55 °C in an oven and then ground through a 1 mm sieve and stored for further analysis.

Laboratory procedures

Samples of feed and refused feed were dried to constant weight at 55°C in a forced-air oven, then ground to pass through a 1 mm sieve and stored for further analysis (Brabender OHG Kulturstrase, Duisburg, Germany). Analysis of samples of DM, prepared by drying at 100 °C in an air-forced oven for 24 h, and CP (prepared by the Kjeldahl procedure) took place according to AOAC (990) protocols. In addition, samples were examined for NDF and ADF according to the protocols used by Van Soest et al. (1991) with adjustments for use in the ANKOM^{2000} fibre analyser apparatus (ANKOM Technology Cooperation, Fairport, NY).

Blood samples were collected on days 0, 21, 42, and 60 at 8:00 h before feeding. The samples were drawn from the jugular vein using plain vacutainers, then centrifuged at 1008 g for 15 min. After centrifugation the serum samples were instantly frozen at −20°C until analysis. Serum concentrations of glucose, urea, alanine aminotransferase, aspartate aminotransferase, alkaline phosphatase, and creatinine were analysed using a spectrophotometer (JENWAY 6105 UV/Vis, Model 6105, Jeneway LTD Felsted, Dunmow ESSEX CM6 3LB, UK) and commercially available kits (BioSystems, S. A. Costa Brava, Barcelona, Spain), following the manufacturer's instructions.

Statistical analysis

The SAS MIXED procedure was used to analyse the data (version 8.1, 2000, SAS Inst. Inc., Cary, NC). The random variable was the lamb and treatment was defined as the fixed effect for the analysis of data performance. Differences in body weight gain were calculated using the initial body weight as a covariate. For the serum data, the day, and the changes in serum constituents on subsequent days, were considered as fixed effects. Conversely, the lamb was considered a random effect and a nested factor within each treatment with day as a repeated effect. Analysis revealed no interactions between day and treatment. Significant differences were considered at ($p \leq .05$) as the least square means method of the MIXED procedure was used.

$$Y_{ijk} = \mu + B_i + \varepsilon_{ij}$$

where:

Y_{ij} the dependent variable
μ is the overall mean
B_i is the treatment effect
ε_{ij} is the random error

Table 1. Ingredients and chemical composition of treatment diets offered to Awassi lambs.

	Diets[a]		
Item	CS0	CS100	CS
Ingredients, g/kg DM			
Barley grain	460	475	
Soybean meal, (440 g/kg CP; solvent)	190	185	
Corn Stover (CS)	0	100	
Wheat straw	330	220	
Salt	10	10	
Limestone	09	09	
Mineral vitamin premix[b]	1	1	
Feed cost/ton (US$)[c]	373	338	
Nutrients			
Dry matter, g/kg DM	904	898	880
Crude protein (CP), g/kg DM	162	163	40
Neutral detergent fibre, g/kg DM	350	329	521
Acid detergent fibre, g/kg DM	159	142	241
Metabolisable energy, Mcal/kg	2.26	2.29	3.21

[a]Diets were: the control diet (CS0) or 100 g/kg CS (CS100) of dietary dry matter (DM).
[b]Composition per kg contained (vitamin A, 600,000 U; vitamin D3, 200,000 U; vitamin E, 75 mg, vitamin K3, 200 mg; vitamin B1, 100 mg; vitamin B5, 500 mg; lysine 0.5%; DL-methionine, 0.15%; manganese oxide, 4000 mg; ferrous sulphate, 15,000 mg; zinc oxide, 7000; magnesium oxide, 4000 mg; potassium iodide, 80 mg; sodium selenite, 150 mg; copper sulphate, 100 mg; cobalt phosphate, 50 mg, dicalcium phosphate, 10,000 mg.
[c]Calculated based on the prices of diet ingredients in 2021.

Table 2. Effect of feeding corn stover (CS) on nutrient intake of Awassi lambs.

	Diet[a]			
Item	CS0 ($n = 16$)	CS100 ($n = 16$)	SEM	p Value
Nutrient intake, g/day				
Dry matter	1090	1172	17.4	.045
Crude protein	177	191	2.57	.031
Neutral detergent fibre	381	385	8.47	.759
Acid detergent fibre	173	167	3.70	.300

[a]Diets were: the control diet (CS0; $n = 16$) or 100 g/kg CS (CS100; $n = 16$) of dietary dry matter (DM).

Results

Data shown in Table 1 illustrate that CS is a better source of protein (40 g/kg) than wheat straw. In addition, the fibre content (NDF, 521 g/kg DM and ADF, 241 g/kg DM) in CS is considered high which indicates that it would be a good alternative feed for use as a partial replacement of wheat straw during ration formulation. Also, addition of CS to the formulated diet (CS, 100 g/kg) reduced the cost of feed by 9% in comparison with the control diet.

The addition of CS had a positive effect on nutrient intake as shown in Table 2. Intake of DM and CP increased by 7.5% and 7.9% respectively ($p \leq .05$) for lambs fed the CS100 diet compared with the control diet. However, intake of NDF and ADF was similar ($p \geq .30$) between the two diets. The digestibility of nutrients improved for lambs fed CS as shown in Table 3. Lambs fed the CS100 diet showed greater ability to digest ($p \leq .05$) DM, CP, and ADF than those fed CS0. The digestibility of DM in the treatment with 100 g/kg CS was 9.32% higher than for the control treatment. Digestibility of NDF tended to be greater ($p = .06$) for lambs fed CS100 and N intake (g/day) and retention (g/100 g) was also increased ($p < .05$) for this group as illustrated in Table 3. Nitrogen lost in faeces (g/day) and N retained (g/day) tended to be greater ($p \leq .08$) in lambs fed the CS100 diet compared to those fed the CS0 diet.

The growth rate of lambs offered CS is shown in Table 4. Body weight (kg) and feed efficiency did not differ ($p \geq .25$) for lambs consuming the two different diets. Lambs fed the CS100 diet had greater ADG (g/day) ($p = .03$) and the cost of gain was lower ($p = .001$) compared with those fed the CS0 diet. Total gain (kg) tended to be greater ($p = .067$) for lambs consuming CS100 compared with those on the CS0 diet.

Table 3. Effect of feeding corn stover (CS) on feed digestibility and N balance in Awassi lambs.

	Diet[a]			
Item	CS0 ($n = 6$)	CS100 ($n = 6$)	SEM	p Value
Digestibility coefficients				
Dry matter	72.9	79.7	1.45	.015
Crude protein	77.4	81.8	1.39	.043
Neutral detergent fibre	56.31	67.1	2.62	.056
Acid detergent fibre	50.0	62.1	1.64	.013
N balance				
N intake, g/day	24.4	28.2	1.157	.044
N in faeces, g/day	7.82	5.05	0.76	.082
N in urine, g/day	5.74	6.08	0.74	.769
N retained, g/day	10.8	17.0	1.90	.068
Retention, g/100 g	44.37	59.8	3.06	.037

[a]Diets were: the control diet (CS0; $n = 6$) or 100 g/kg CS (CS100; $n = 6$) of dietary dry matter (DM).

Table 4. Effect of feeding corn stover (CS) on growth performance of Awassi lambs.

	Diet[a]			
Item	CS0 ($n = 16$)	CS100 ($n = 16$)	SEM	p Value
Initial weight, kg	26.6	26.8	1.45	.768
Final weight, kg	37.2	39.3	1.60	.251
Average daily gain, g/day	189.7	223.0	10.1	.033
Feed efficiency (DMI:ADG)[b]	6.40	5.30	0.75	.387
Total gain, kg	10.63	12.50	0.69	.067
Cost/kg (US$)	2.38	1.80	0.13	.001

[a]Diets were: the control diet (CS0; $n = 16$) or 100 g/kg CS (CS100; $n = 16$) of dietary dry matter (DM).
[b]DMI:ADG: dry matter intake:average daily gain.

The addition of CS increased ($p = .051$) blood glucose content, while most other serum constituents, including urea nitrogen, cholesterol, triglycerides, high-density lipoprotein, low-density lipoprotein, aspartate and alanine aminotransferases, and alkaline phosphatas, remained unchanged ($p \geq .27$) as shown in Table 5. However, the creatinine content was reduced ($p = .006$) for the CS100 group compared with the CS0 group.

Discussion

It can be quite expensive to reach the required energy, protein, and fibre content to formulate sheep rations using traditional feed. Therefore, using alternative feeds or by-products as ingredients can enhance profitability by reducing feed costs while maintaining animal health. As reported in the literature, CS, a by-product used widely as a low-priced source of fibre, positively enhances the productivity and health of livestock. However, limited literature was found to investigate the effects of CS on Awassi lambs. Therefore, this study was designed to focus on the impact of replacing traditional feedstuff with CS on the productivity and health of Awassi lambs. Additionally, the chemical composition of CS, as presented in Table 1, reflects its high content of CP and moderate content of NDF compared with wheat straw, which encouraged sheep producers to use it as a replacement for more expensive ingredients. Moreover, the chemical composition of the treatment diet showed no differences in nutrient content compared with the control diet indicating that the addition of CS had no negative impact on feed composition (Table 1). Others have reported similar results regarding the chemical composition of CS showing that it has a high fibre content and a moderate CP and energy content (Elkholy et al. 2009; Feng et al. 2012; Wang et al. 2017).

Table 5. Effect of feeding corn stover (CS) on blood metabolites in Awassi lambs.

	Diets[a]			
Item[b]	CS0 ($n = 12$)	CS100 ($n = 12$)	SEM	p Value
Urea N, mg/dL	25.7	23.5	1.627	.3145
Glucose, mg/dL	48.5	54.2	2.055	.0513
Cholesterol	53.1	50.5	2.320	.4510
Triglycerides	16.4	16.4	1.029	.9895
HDL	33.9	31.6	1.365	.2489
LDL	15.8	15.6	1.375	.9121
AST, U/L	37.4	38.6	4.480	.8487
ALT, U/L	14.5	12.3	1.771	.3907
ALP, U/L	62.8	54.9	7.272	.2723
Creatinine	0.65	0.61	0.0133	.0061

[a]Diets were: the control diet (CS0; $n = 16$) or 100 g/kg CS (CS100; $n = 16$) of dietary dry matter (DM).
[b]HDL: high-density lipoprotein; LDL: low-density lipoprotein; AST: aspartate aminotransferase; ALT: alanine aminotransferase; ALP: alkaline phosphatase.

Including CS in the diet (at 100 g/kg), enhanced nutrient intake (Table 2). The intake of DM and CP increased, while NDF and ADF intake was the same for both diets offered which indicates that the addition of CS did not negatively affect the composition of the treatment diet and therefore intake was unaffected. Similarly, Ali et al. (2012) reported that adding CS to the diet effectively improved DM intake by enhancing the palatability of the feed to the sheep. Conversely, others reported a decrease in DM intake when the amount of CS silage in the diet increased from 25% to 100% (Amuda and Okunlola 2020). The results illustrated in this study suggest that lambs would use CS efficiently in the diet if it was offered with concentrated supplements.

The inclusion of CS in the diet affected the digestibility of nutrients and the N balance. Adding CS increased the digestibility of DM, CP, NDF, and ADF (Table 3). In general, the digestibility of nutrients is affected by the amount of NDF and ADF in the diet. Van Soest (1994) stated that the concentration of NDF in the diet can regulate the intake of DM in ruminants. In this study, increased DM and CP intake by lambs consuming the CS diet enhanced the digestibility of DM and CP. Conversely, fibre intake was unaffected by the inclusion of CS while fibre digestibility increased which indicates that lambs used the NDF and ADF content more efficiently. This result could be related to an improvement in the fermentation process of fibrolytic bacteria in the rumen of lambs offered the CS diet (Loy et al. 2007).

In this study, N intake (g/day) and retention (g/100 g) increased due to the inclusion of CS in the lambs' diet, while N in faeces (g/d) and N retained (g/day) slightly increased. This result could be related to the increased intake and digestibility of CP for lambs consuming CS. Other studies focussing on the effect of using ammonia-treated CS reported that this treatment increased the number of nitrogenous compounds entering the rumen and consequently stimulated cellulolytic bacteria. This increased the production of ammonia in the rumen and therefore increased the excretion and retention of nitrogen (Elkholy et al. 2009). Increased levels of nitrogen could be related to greater intake of CP, deamination of amino acids, and increased free ammonium ions in the rumen after digestion of the feed, as reported by Bach et al. (2005).

Lambs consuming CS increased their ADG by 17% while the total gain was slightly enhanced in this study. Other growth parameters including final weight and feed efficiency appeared enhanced without showing a significant difference between the different diets. The improvement in lambs' weight gain consuming CS in this study could be attributed to the enhancement in their DM, CP, and nitrogen intake, and improvements in nutrient digestibility for these lambs. In agreement with our results, Amuda and Okunlola (2020) reported an improvement in ADG for sheep consuming CS offered with concentrate diet (750 and 250 g/kg of DM, respectively). The researchers related this result to the enhancement of CS use due to the addition of concentrated diet which improved the microbial fermentation of CS in the rumen.

Feed type and nutrient content are thought to be significant factors affecting the growth of sheep (Xu et al. 2017). As reported, the ADG of growing lambs can be improved by increasing the protein content of the diet. As the level of CP increased, the nutrient intake, nutrient digestibility, and fermentation efficiency of rumen microbial cells increased and as a result, live weight gain improved (Prima et al. 2019). The chemical composition of CS in this study showed that the CP content of CS was sufficient for the growing Awassi lambs as reflected by the enhancement of their growth during the experimental period when CS replaced a proportion of the wheat straw. Moreover, as found in previous studies (Shi et al. 2014; Fayyaz et al. 2018; Hao et al. 2021), this study indicated that using an alternative feedstuff in lamb rations reduced feed cost and enhanced profitability. The addition of CS to the diet reduced the cost of feed by 9% relative to the control diet. Making producers aware of this result will encourage them to include CS in feed since it would be more economical to add this by-product to the diet of growing lambs rather than using other traditional fodder like wheat straw for diet formulation.

Additionally, the inclusion of CS in lambs' diets had no significant effect on any of the blood components or kidney functioning enzymes examined and caused no negative impact on their health. Adding CS to the diet slightly elevated blood glucose while lowering the concentration of creatinine. Inclusion of alternative feeds in lambs' rations, as described by other researchers, is safe if it shows minimal changes in blood metabolites and causes no damage to vital organs (Awawdeh et al. 2020). The slight increase in blood glucose for lambs consuming the CS100 diet might be related to their greater use of fibre in the rumen, as feeding the treatment diet with concentrates leads to the release of more soluble and highly absorptive sugars during fermentation. Conversely, the creatinine level was reduced for lambs consuming CS which indicates that the inclusion of this by-product had no negative effects on kidney function (Garba and Adeola 2020). Although this study found that including CS in lamb feed did not negatively affect their health, we recommend that blood metabolites and vital organ functions are continually assessed if CS is fed to growing Awassi lambs for longer periods.

Conclusions

This study proved that CS could be added at a concentration of 100 g/kg DM to the diet of growing Awassi lambs with no negative impact on nutrient intake and digestibility, growth, or blood serum parameters. Additional studies are recommended to investigate the effect of including higher levels of CS in the diet of Awassi sheep.

Disclosure statement

No potential conflict of interest was reported by the authors.

Ethical approval

The study protocols and procedures were approved by the Institutional Animal Care and Use Committee at Jordan

University of Science and Technology where the experiment was performed.

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Data availability statement

Data will be available by Belal S. Obeidat upon request.

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