Influence of corn-dried distiller’s grain with solubles on growth performance and blood metabolites of Awassi lambs offered a concentrate diet

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ABSTRACT
Objective of this study was to evaluate the effect of partial replacement of soybean meal and barley grain with corn-dried distiller’s grains with solubles (DDGS) on growth performance of Awassi lambs. Thirty lambs (3 to 4 months of age; 24.9 ± 1.93 kg; initial BW) were randomly assigned to three diets; (1) control diet (CON), (2) treatment diet containing 75 g DDGS/kg dietary dry matter (DM) (DDGS75) or treatment diet containing 150 g/kg DDGS/kg dietary DM (DDGS150). The study lasted for 63 days. Lamb BW and blood samples were measured on day 0, 21, 42, and 63 before the morning feeding. At the end of the feeding trial, 6 lambs from each treatment group were chosen at random and housed in metabolic cages to evaluate nutrient digestibility and N balance. Intakes, nutrient digestibility and N balance measures were similar \((p > .05)\) among dietary treatments. Initial BW, final BW, ADG as well as feed efficiency were similar \((p > .05)\) among the dietary treatment diets. Cost of gain reduced \((p < .05)\) in lambs fed DDGS150 compared with the CON and DDGS75 diets. Serum concentrations of urea N, glucose, total protein, aspartate aminotransferase, alanine aminotransferase, alkaline phosphatase and albumin were similar \((p > .05)\) among diets. Results demonstrated that inclusion the DDGS at 75 or 150 g/kg of diet DM could replace part of the soybean meal and barley grain without affecting nutrient intake and growth performance while it reduced the cost of feed and cost of gain.

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Introduction
The scarcity of traditional feeds in addition to increased cost of feeds are the two most important challenges confronting sheep farmers in Jordan and throughout the semi-arid world. As a result, expected profits from raising sheep have declined while the prices of livestock products such as milk and meat have increased. Soybean meal (SBM) is considered to be the main protein source utilised by livestock in the Middle East, due to its high nutritive value (energy and crude protein concentration) and digestibility (NRC 2007). However, using SBM in high levels in ruminant diets is not cost effective. Thus, suitable usage of alternative feeds is important to increase the profit of livestock production. Feeding agro-industrial by-products such as corn-dried distiller’s grain with solubles (DDGS) to livestock is a practice that can potentially decrease the cost of meat production and, as a result, improve profits. Distiller’s grain is the residue of bioethanol industry (Klopfenstein et al. 2008) that is used as feed for animals. The content of crude protein of DDGS is about 200 to 300 g/kg dry matter (DM), and therefore it can be used as a protein supplement to substitute SBM in the diets of sheep (Tjardes and Wright 2002; Kleinschmit et al. 2007; McEachern et al. 2009). Thus, addition of DDGS in feeding sheep will help livestock producers reduce the worldwide rise in feed cost, which makes DDGS a potential feed to replace the protein and energy sources in the diet; the most expensive sources (Vasconcelos and Galyean 2007; Klopfenstein et al. 2008; McEachern et al. 2009). The large increase in production of ethanol leads to increased production of large amounts of DDGS. Therefore, the use of these residues will have a positive impact on improving the performance of ruminants and reducing the cost of conventional feed (Windhorst 2007). The continued increase in feed prices and increasing ethanol industry stimulates the use of these residues as an alternative for grain and SBM (McEachern et al. 2009).

A few studies have been published on replacing barley grain with wheat DDGS (Charles et al. 2012;...
Avila-Stagno, Chaves, Graham, et al. 2013; Avila-Stagno, Chaves, He, et al. 2013; Graham et al. 2013), while limited literature is available on the use of corn DDGS in sheep diets. Additionally, most studies have been conducted on sheep breeds raised in temperate climates. For example, replacing up to 400 g/kg of barley with wheat DDGS was found to improve growth performance, feed intake (Avila-Stagno, Chaves, Graham, et al. 2013) and wool production (Graham et al. 2013) in Merino and its cross with Dorper sheep.

Jordan is a semi-arid country that can model other regions in the Middle East. The availability of traditional feeds can sometimes be limited due to high costs. Awassi, a fat-tailed breed, is the predominant sheep breed in this region. No previous work is available on the use of DDGS in Awassi sheep under such environmental conditions. Thus, this study was designed to investigate the effects of feeding corn DDGS on nutrient intake, digestibility, N balance, growth performance and blood metabolites of fat-tailed Awassi lambs fed concentrate diets. The hypothesis of this study was that replacing soybean meal and the most expensive ingredients; with corn DDGS during the growing period would not affect nutrient intake and growth performance of Awassi lambs in arid and semi-arid areas where the traditional feedstuffs are limited.

Materials and methods

The experiment was conducted at the Agricultural Research and Training Unit (ARTU) at Jordan University of Science and Technology (JUST). The study area was classified as semi-arid at latitude 32°30’N and elevation of 510 m above sea level. All procedures used in the study were approved by JUST Institutional Animal Care and Use Committee.

Animals, experimental procedures

In a completely randomised design experiment, thirty Awassi ram lambs (24.9 ± 1.93 kg initial body weight; BW and 3 to 4 months of age; ten lambs/treatment) were randomly assigned to three dietary treatments: (1) control diet (CON), (2) treatment diet containing 75 g DDGS/kg dietary dry matter (DM) (DDGS75) or treatment diet containing 150 g/kg DDGS/kg dietary DM (DDGS150). The chemical composition of the DDGS was 888, 273, 341, 83.8, 52.4 g/kg DM for DM, crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF), and ether extract (EE), respectively. The S content in the DDGS was 9.9 g/kg DM. At the beginning of the study, all lambs were treated for internal parasites. Throughout the study, diets were offered ad libitum to the lambs. All diets were formulated to be similar in CP content (160 g/kg CP; DM basis) and to meet the requirements for growing Awassi lambs (NRC 2007). Throughout the study, lambs were housed individually in shaded pens (1.5 × 0.75 m) with concrete flooring, and fed twice daily (two equal meals at 09:00 and 14:00 h). Pens were cleaned weekly or as needed to keep the housing area dry and clean. An adaptation period of one-week was allowed prior to the experimental period. The study lasted for 63 days.

The experimental diet was offered as a total mixed ration. Water was offered with free access throughout the experiment. Feed refusals were weighed daily throughout the study and stored at −20°C for chemical analysis. Dietary DM and other nutrients intakes were measured by the difference between the offered and refused feed. Lambs were weighed at the beginning of the experiment and subsequent weights were recorded on day 0, 21, 42 and 63 before the morning feeding throughout the study. Average daily gain (ADG) was calculated by dividing the difference between the final and the initial BW by the duration of the study.

At the end of the feeding period (i.e. 63 days), six lambs from each group were randomly selected (eighteen lambs, total) and housed individually in metabolism crates (1.05 × 0.80 m) to evaluate nutrient digestibility and N balance. Lambs were allowed a period of 5 days to adapt to the crates followed by a collection period of 5 days where feed intake and refusals were recorded and sampled for further analysis. Daily faecal output was collected, weighed, and recorded, and 10% was kept for subsequent analyses. Daily collected faecal samples were pooled and one sample was analysed/lamb. Using plastic containers, urine was collected, weighed, and recorded, and then 5% was kept to evaluate N retention. Each container had 50 mL of 6 N HCl added to prevent ammonia losses. Faecal samples were dried at 55°C in a forced-air oven to reach a constant weight, air equilibrated, and then ground to pass through 1 mm sieve and kept for further analysis.

Laboratory procedures

Composited diets and refusal samples were dried at 55°C in a forced-air oven to reach a constant weight, air equilibrated, ground to pass through 1 mm sieve (Brabender OHG Kulturstrasse, Duisburg, Germany) and kept for further analysis. Diets and refusals were analysed following AOAC (1990) procedures for DM (100°C in air-forced oven for 24 h), CP (Kjeldahl...
procedure) and EE (Soxtec procedure, SXTEC SYSTEM HT 1043 Extraction Unit, TECATOR, Box 70, Hoganas, Sweden). Additionally, samples were analysed for NDF and ADF according to the procedure described by Van Soest et al. (1991) with modifications for use in the ANKOM<sup>2000</sup> fibre analyser apparatus (ANKOM Technology Cooperation, Fairport, NY). The NDF and ADF analyses were performed using sodium sulphite and a heat stable alpha amylase and expressed with residual ash content.

Blood samples were taken on day 0, 21, 42, and 63 from the jugular vein in plain vacutainers at 8:00 h (before feeding). Blood samples were centrifuged at 2200 × g for 15 min) after 1 h of collection. Serum samples were separated immediately and stored at −20 °C till the day of analysis. All serum concentrations (i.e. glucose, urea N, alanine aminotransferase (ALT), aspartate aminotransferase (AST), alkaline phosphatase (ALK-P), total protein and albumin) were analysed with a spectrophotometer (JENWAY 6105 UV/VIS, Model 6105, Jeneway LTD Felsted, Dunmow Essex CM6 3LB, UK) using commercial kits (BioSystems, S. A. Costa Brava, Barcelona, Spain) and according to the manufacturer’s specifications.

**Statistical analysis**

All data were analysed using the MIXED procedure of SAS (version 8.1, 2000, SAS Inst. Inc., Cary, NC) where the lamb was the random variable. For performance data, treatment was the fixed effect. Initial body weight was used as a covariate for analysing differences in body weight gain. However, for the serum data, treatment, day, and their interaction were considered as fixed effects and lamb nested within treatment was a random effect with the day as a repeated effect. Because there were no day × treatment interactions, only the main treatment effects are discussed. Least square means of the MIXED procedures of SAS were used to further identify significant differences among means. Significant differences were considered at \( p < .05 \).

**Results**

The inclusion of DDGS at 75 and 150 g/kg in the diets of growing Awassi lambs did not negatively impact the health of the animals. Intakes of DM, CP, NDF and ADF (Table 1), and DM digestibility (Table 2) were not affected \( p > .05 \) by dietary treatments. Digestibility of CP, NDF and ADF followed the same pattern \( p > .05 \). Also, N intake, N losses in the faeces and urine and as a result, retained N were similar \( p > .05 \) for all three treatment diets (Table 2). Initial body weight, final body weight, ADG and feed conversion ratio (FCR) were similar \( p > .05 \) among treatments diets (Table 3). Cost of gain reduced \( p \leq .05 \) in lambs fed DDGS150 compared with the CON and DDGS75 diets. Serum concentrations of urea N, glucose, total protein, albumin, AST, ALT, and ALK-P were unaffected \( p > .05 \) by diets (Table 4).

**Discussion**

Using soybean meal and barley grain, the main protein and energy sources, in the diets of feeding sheep is quite costly. Any replacement of these ingredients by agro-industrial by-products can have a tremendous positive impact on raising sheep in the region and worldwide. Corn DDGS is a potential candidate to be used in sheep diets. Due to the high production of DDGS worldwide, livestock producers tend to use it to replace some of the conventional feeds mostly in feeding dairy and beef cattle. However, this is the first study to introduce DDGS in feeding Awassi lambs. In general, most of the alternative feeds such as DDGS
Table 3. Effect of feeding dried distiller’s grain with solubles (DDGS) on growth performance of Awassi lambs fed concentrate diets.

| Item                        | CON, n = 10 | DDGS75, n = 10 | DDGS150, n = 10 | SEM |
|-----------------------------|-------------|----------------|-----------------|-----|
| Initial body weight, kg     | 24.8        | 24.5           | 25.5            | 1.926 |
| Final body weight, kg       | 36.7        | 36.3           | 38.8            | 2.18 |
| Average daily gain, g       | 189         | 187            | 212             | 11.57 |
| FCR                         | 5.39        | 5.41           | 5.03            | 0.301 |
| Cost/kg gain, US$           | 1.73a       | 1.61a          | 1.39b           | 0.091 |

*Diets were: control diet (CON; n = 10), 75 (DDGS75; n = 10) or 150 g/kg (DDGS150; n = 10) DDGS of dietary dry matter (DM). 

Table 4. Effect of feeding dried distiller’s grain with solubles (DDGS) on blood metabolites of Awassi lambs fed concentrate diets.

| Item                        | CON, n = 10 | DDGS75, n = 10 | DDGS150, n = 10 | SEM |
|-----------------------------|-------------|----------------|-----------------|-----|
| Urea N, mg/dL               | 26.5        | 26.9           | 25.9            | 1.55 |
| Glucose, mg/dL              | 49          | 51             | 48              | 2.1  |
| Total protein, g/L          | 73          | 72             | 74              | 1.3  |
| Albumin, g/L                | 35          | 32             | 31              | 1.0  |
| Aspartate aminotransferase, U/L | 20.6  | 22.4           | 21.6            | 2.17 |
| Alanine aminotransferase, U/L | 6.4       | 7.1            | 7.3             | 1.10 |
| Alkaline phosphatase, U/L   | 86          | 90             | 76              | 9.0  |

*Diets were: control diet (CON; n = 10), 75 (DDGS75; n = 10) or 150 g/kg (DDGS150; n = 10) DDGS of dietary dry matter (DM). 

are less expensive than the conventional feeds, which confirm that the replacement of conventional feed with DDGS can decrease dietary costs for growing Awassi lambs. Previous studies had agreed that when replacing traditional high-priced feed such as SBM with a low-cost alternative feeds, the cost of production declines (as the cost of feed constitutes the largest part), leading to increased profitability (Obeidat Abdullah, et al. 2016; Obeidat, Mahmoud, et al. 2016). The chemical composition of DDGS reflects its good content of CP and energy for the replacement of the high-cost ingredients for sheep and other ruminants. In addition, chemical composition of the treatment diets indicates that the inclusion of the DDGS does not change nutrient content among different treatments except the slight increase in the NDF, EE as well as the S content. 

One of the most important problems that livestock breeders may encounter is the variation in chemical composition of DDGS, according to different sources and quality, which makes it necessary to analyse the nutrient contents before placing it in the diets of livestock. For example, the EE content of DDGS in the current study (52.4 g/kg DM) was lower compared with 103; 145 or 131 g/kg DM as reported by others (NRC 1996; Stock et al. 2000; Murillo et al. 2016, respectively). The concentration of the EE that was reported in DDGS in the current study did not change the overall content of total dietary fat; however, due to greater concentrations of fat in other studies, livestock producers should take it into consideration when including DDGS in the diets. The greater concentrations of fat in DDGS may impact ruminal fermentation and microbial activities (Zinn et al. 2000; Relling and Reynolds 2007) and, as a result DDGS addition may decrease total DM intake.

Another issue that must be discussed is the variability of NDF content among different sources. According to Van Soest (1994), the concentration of NDF in the diets can control DM intake in ruminant animals. Other studies have reported either greater or lower concentrations of NDF in DDGS. For example, Murillo et al. (2016) reported that DDGS contained 268 g/kg DM NDF; whereas NRC (1996) reported that NDF content was on average 425 g/kg and in our study was 341 g/kg DM. In summary, the variations in the nutritional content in the DDGS confirmed that this by-product must be analysed before any inclusion in the diets of ruminants and other animals.

In the current study, including DDGS at level 0, 75 or 150 g/kg in the diets of growing Awassi ram lambs had no effects on DM and other nutrient intakes (Table 1). In agreement with this study reported here, Abdelrahim et al. (2014) reported that DM intake was not affected when lambs were fed DDGS at 0, 127 and 254 g/kg DM and DM intake was not affected when beef cattle were fed a concentrate diet that contained DDGS at 230 g/kg DM (Beliveau and McKinnon 2008). On the other hand, other studies have found that nutrient intakes were either improved or not affected when growing lambs or beef steers were fed DDGS fed at variable concentrations (Huls et al. 2006; Buckner et al. 2008; Mckeown et al. 2010; Felix et al. 2012).

The inclusion of DDGS at either 75 or 150 g/kg DM in diets of growing Awassi lambs did not affect nutrient digestibility and N balance. In general, digestibility can be affected by the concentration of fibre, mainly NDF and ADF, in the diet; therefore, the similarity in intake and fibre content herein did not affect the digestibility and N balance among diets. However, Felix et al. (2012) reported that DM digestibility decreased linearly when feedlot lambs were fed diets containing 200, 400, or 600 g/kg DM DDGS whereas NDF digestibility was not affected among dietary treatments. Similarly, DM digestibility was reduced in feedlot cattle fed diets containing 600 g/kg.

In the current study, lamb growth rate increased in all diets throughout the experiment without any
differences in the final BW, ADG and FCR among diets. The lack of difference in ADG in lambs could partially be attributed to the similarity in intake, digestibility, and N balance that was observed among the different diets. In agreement to our results, Beliveau and McKinnon (2008) observed that body weight gain and feed conversion ratio were not affected when beef cattle were fed a concentrate diet contained DDGS at 230 g/kg DM compared with the control diet. Moreover, Gibb et al. (2008) have reported that ADG was similar among feedlot cattle that were fed finishing diets containing DDGS at 200, 400 or 600 g/kg DM DDGS replacing barley grain. In contrast to our results, several studies have reported improvements in ADG and feed efficiency in beef cattle fed DDGS (McKinnon and Walker 2008; Black 2009; Walter et al. 2010). Felix et al. (2012) observed that ADG was improved when feedlot lambs were fed DDGS at 200 g/kg; whereas no significant differences were observed when included at 0, 400, or 600 g/kg DM.

The inconsistency in the performance results (i.e. ADG or feed efficiency) when animals were fed DDGS could be attributed partially to differences in the diet composition among different studies or to the dietary content of S. Sulfur is an important mineral for rumen metabolism as it is needed for the synthesis of S-containing amino acids. The current dietary recommended tolerable concentration of S for sheep should not be more than 4 g/kg DM (NRC 2007). During the process of ethanol production, sulphuric acid is added and starch is removed; therefore, the final content of S could increase in the DDGS due to the addition and concentration of S. In the current study, the concentration of S was 1.76, 2.29, and 2.84 g/kg DM for the CON, DDGS75 or DDGS150, respectively (Table 5). Even though, the level of S increased with the increasing of DDGS, no obvious signs of toxicity developed in lambs fed the DDGS diets. This is because our diets were below the maximum-tolerated concentration of S (4 g/kg; NRC 2005). However, care must be taken to verify the S content in DDGS and to be included at concentrations not exceeding the tolerance concentration that might cause health problems.

Concurrent with previous studies that were reported in our lab (Obeidat et al. 2012; Obeidat Abdullah, et al. 2016; Obeidat, Mahmoud, et al. 2016; Oberidat 2017), this study proved that corn DDGS, as a by-product of the ethanol production process, is safer and would be more economical to feed growing Awassi lambs compared with the other ingredients such as barley grain and soybean and as a result it showed the benefits of using corn DDGS in the ration. The inclusion of DDGS at 75 and 150 g/kg of dietary DM reduced the cost of feed by 7.5 and 15% than the control diet. In addition, the cost of gain decreased in the DDGS150 diet compared with the CON and DDGS75 diets.

In addition to the above, feeding Awassi lambs diets containing DDGS at 0, 75 or 150 g/kg DM did not negatively impact the blood metabolites and liver enzymes indicating that this by-product is safe and should not cause any health problems. Even though, there are no detrimental effects on including DDGS at levels 0, 75, or 150 g/kg DM, it’s recommended to evaluate blood metabolites and liver enzymes especially when DDGS is fed at longer periods.

DDGS is a by-product of the ethanol production process. Along with being inexpensive, DDGS is high in CP, EE or NDF content making it a decent source of nutrients for ruminants. With protein and energy sources being the most expensive ingredients of ruminant diets, replacing part of soybean and/or barley grain as indicated in the current study with DDGS can decrease the price of feed thus reducing the cost of production (Obeidat, Abdullah, et al. 2016).

**Conclusions**

Results of the current study demonstrate the inclusion possibility of corn DDGS at a concentration up to 150 g/kg DM in the diets of feedlot Awassi lambs without affecting the growth performance and
blood metabolites. Further studies are needed to address the effect of higher inclusion rates of DDGS in sheep diets.

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Disclosure statement

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