The impact of feeding corn dried distillers grains with solubles on milk yield and composition in lactating Awassi ewes and digestibility and N partitioning in Awassi ewe lambs

Sharaf N. Alshdaifat and Belal S. Obeidat

Department of Animal Production, Jordan University of Science and Technology, Irbid, Jordan

**Abstract**

The effect of corn dried distillers grains with solubles (DDGS) on milk yield, milk composition and body weight (BW) and digestibility were evaluated by using lactating ewe (Exp. 1) and Awassi ewe lambs (Exp. 2). Dietary treatments were (1) no DDGS (CON), (2) 200 g kg⁻¹ DDGS (DDGS200) or (3) 300 g kg⁻¹ DDGS (DDGS300) of dietary dry matter (DM). In Exp. 1, 30 lactating Awassi ewes were randomly assigned to the corresponding diets. Nutrient intakes were determined daily throughout the experiment which lasted for 8 weeks. Body weights of ewes and lambs were measured on days 0, 28 and 56 of the study whilst milk yield and composition were recorded on days 18, 36 and 54. Ewe BW changes were similar amongst treatments. Ewes consuming the DDGS diet showed increased milk production \((p < .045)\) over those provided the CON diet. Cost of diets and milk production reduced \((p = .01)\) in DDGS-containing diets compared with the CON diet. Digestibility of DM and ADF was lower \((p < .017)\) for the CON diet than for the DDGS diets. Digestibility of CP and NDF increased \((p < .036)\) in the DDGS200 diet than the CON diet. Results indicate DDGS has the potential to be included up to 300 g kg⁻¹ of dietary DM of DDGS in Awassi ewes’ diets with no negative effects on production parameters whilst being cost effective.

**Highlights**

- Cost of feed and milk production decreased in DDGS diets.
- Milk production increased in DDGS diets.
- Milk composition was similar among diets.

**Introduction**

In Middle Eastern countries like Jordan, pastures are a primary source of nutrients for small ruminant producers. However, because available pastures are insufficient and often inferior in quality (Obeidat et al. 2014), animals are supplemented with grains and other concentrates to enable them to meet their nutrient requirements, especially during the high-producing phase, such as milk production. The early stages of milk production are critical as they affect the lactation outcome and, hence, lamb pre-weaning growth. Rearing livestock on non-by-product grains and protein sources is usually very costly, as the price of feeds is the greatest variable expense in the sheep industry, affecting productivity and reducing profitability (Obeidat and Shdaifat 2013; Obeidat 2018). Thus, by-products such as corn dried distillers grains with solubles (DDGS) are great feed alternatives that can be fed to livestock to decrease the cost of production, thereby improving profitability (Obeidat 2018).

Dried distillers grains with solubles are ethanol byproducts that are expected to remain abundant during the next few decades (Benchaar et al. 2013; Omer et al. 2015; RFA 2016). As feeds become more expensive and unavailable, and ethanol becomes more abundant and cheap, the use of DDGS as an alternative feed becomes more popular because of price. Dried distillers grains with solubles are rich in fibre, protein and fat and can be fed as a protein source (Gaillard et al. 2017; Böttger and Südekum 2018) when...
and N partitioning of Awassi ewe lambs (Exp. 2). To test would have no negative impact on nutrient digestibility lambs). The second hypothesis is that feeding DDGS of Awassi ewes and pre-weaning growth of their suckling (i.e. milk production and composition, ewes body weight (Exp. 1) with no negative effects on nursing performance and protein and fibre that will contribute to reducing dietary cost DDGS in the diets of lactating Awassi ewes supplies pro-

essional feed components for animals (Pecka-



4Calculated based on the prices of diet ingredients of the year 2018.

fed at <150 g kg\(^{-1}\) DM or as an energy source when included at levels greater than 150 g kg\(^{-1}\) DM in ruminant diets (Klopfenstein et al. 2008). It contains high levels of energy (3.67–4.34 Mcal/kg of DM) and fat (Engel et al. 2008) in addition to being highly digestible, making it the most economical feed components for animals (Pecka-Kielb et al. 2015). Kleinschmit et al. (2006) found that milk yield and feed efficiency were the same in cows fed diets containing DDGS (experimental group) and those in the control group. Similarly, Mjoun et al. (2010) reported that whether dairy cows were fed with DDGS diets or not, DM intake, milk production and milk fat content remained the same. Moreover, dairy cows fed diets containing DDGS had more milk production and composition (i.e. milk fat and energy-corrected milk) than those fed the basal diet (Abdelgaleed and Oba 2012). Until now, no data are available on feeding Awassi ewes diets containing different levels of DDGS, especially during the early lactation period. The first hypothesis of this study is that using DDGS in the diets of lactating Awassi ewes supplies protein and fibre that will contribute to reducing dietary cost (Exp. 1) with no negative effects on nursing performance (i.e. milk production and composition, ewes body weight of Awassi ewes and pre-weaning growth of their suckling lambs). The second hypothesis is that feeding DDGS would have no negative impact on nutrient digestibility and N partitioning of Awassi ewe lambs (Exp. 2). To test the research hypotheses, our objectives were to determine the effect of replacing part of barley grain, soybean meal and wheat straw with DDGS on lactating Awassi ewe feed intake, BW change, milk production and composition and pre-weaning ADG of their offsprings (Exp. 1) and nutrient digestibility and N partitioning of Awassi ewe lamb (Exp. 2).

Materials and methods

The influence of corn DDGS on nutrient digestibility milk yield, milk composition and body weight (BW) of lactating Awassi ewes and their lambs was assessed using two experiments. Tests were conducted using the same treatment diets; lactating experiment (Exp. 1) and digestibility and N partitioning experiment in Awassi ewe lambs (Exp. 2). Dietary treatments were (1) no DDGS (CON), (2) 200 g kg\(^{-1}\) DDGS (DDGS200) or 300 g kg\(^{-1}\) DDGS (DDGS300) of dietary dry matter (DM) in partial substitution of soybean meal, barley grain and wheat straw. Dried distillers grains with solubles were purchased locally. Table 1 shows the ingredients used and chemical composition of the experimental diets. Both experiments were conducted at Jordan University of Science and Technology (JUST) facilities. All experimental procedures received the approval of JUST Institutional Animal Care and Use Committee. All experimental animals were inspected by the farm veterinarian to evaluate health and udder status (of the mature ewes) before and during the experiment.

**Exp. 1. Nursing experiment**

**Ewes, milk yield and composition**

Intravaginal sponges were used to estrually synchronise 50 ewes for lambing consistency amongst the experimental animals. Of those synchronised, 30 Awassi ewes (initial BW = 49.7±2.06 kg; age = 3±0.13 years) nursing single lambs were selected for the experiment (based on lambing dates) and randomly assigned to one of the three dietary treatments above (10 ewes/diet). Ewes were fed isonitrogenous diets and housed individually with their lamb in shaded pens (0.75 x 1.5 m). The shaded pens were equipped with plastic feed and water troughs that allow ad libitum access to feed and water. Feed intake was measured daily throughout the experiment. The study lasted for 8 weeks, of which the first was used as an adaptation period for the diets and pens, followed by a 7-week period for data collection. Ewes were fed their experimental diets ad libitum at 8:00 h and given free access to water throughout the study.

| Table 1. Ingredients and chemical composition of diets “fed to lactating Awassi ewes” containing increasing concentrations of dried distillers grains with solubles (DDGS), replacing barley grain, soybean meal and wheat straw. |
|-------------------------|-----------|-----------|
| Item                    | CON       | DDGS200   | DDGS300   |
| Ingredients, g kg\(^{-1}\) DM |           |           |           |
| Barley grain            | 540       | 490       | 470       |
| Soybean meal, 440 g kg\(^{-1}\) CP (solvent) | 170       | 70        | 20        |
| Dried distillers grains with solubles | 0         | 200       | 300       |
| Wheat straw             | 270       | 220       | 190       |
| Salt                    | 10        | 10        | 10        |
| Limestone               | 10        | 10        | 10        |
| Mineral vitamin premix\(^b\) | +         | +         | +         |
| Feed cost/ton (US$)\(^c\) | 1415     | 360       | 332       |
| Nutrients, g kg\(^{-1}\) DM |           |           |           |
| Dry matter              | 912       | 905       | 909       |
| Crude protein           | 160       | 160       | 160       |
| Neutral detergent fibre | 292       | 298       | 298       |
| Acid detergent fibre    | 189       | 172       | 161       |
| Ether extract           | 19        | 24        | 27        |
| Sulphur\(^d\)           | 1.7       | 3.1       | 3.8       |

\(^a\)Diets contained (1) no DDGS (CON), (2) 200 g kg\(^{-1}\) DDGS (DDGS200) or 300 g kg\(^{-1}\) DDGS (DDGS300) of dietary dry matter (DM).

\(^b\)Mineral vitamin premix contained per kg (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 g/100 g; ß2-methionine, 0.15 g/100 g; 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 of the year 2018.

\(^d\)Sulphur was calculated based on tabular values of NRC (2007).
Experimental diets contained 160 g kg\(^{-1}\) CP, which is adequate for lactating ewes (NRC 2007). Feed buckets were managed to provide 110% of daily voluntary feed intake. Feed refusals were weighed, recorded and sampled daily to correct nutrient intakes. Body weights of ewes and nursing lambs were measured on days 0, 28 and 56 of the study. Trained personnel performed the recording of milk yield on days 18, 36 and 54 during the collection period at 08:00 h by hand milking. Lambs were separated from their dams 12 h before the hand milking. Then, milk yield was adjusted over a 24 h period. A 125 mL sample was collected from each ewe and was analysed directly for total solids (in air-forced oven at 55 °C), fat (Gerber method, Gerber Instruments, K. Schneider and Co. AG; 8307 Langhag, Effretikon) and CP (Kjeldahl procedure; N × 6.25).

**Laboratory procedures**

For chemical analysis, diets and feed refusal samples were dried in a forced air oven at 105 °C overnight to determine final DM (AOAC 1990). Crude protein (N × 6.25) was measured using Kjeldahl procedure (AOAC 1990). The analysis of neutral detergent fibre and acid detergent fibre was done using an ANKOM\(^{2000}\) fibre analyser (ANKOM technology Corp., Fairport, NY). Ether extract was evaluated using Soxtec procedure (SXTEC SYSTEM HT 1043 Extraction Unit, TECATOR, Box 70, Hoganas, Sweden). Dry matter and other nutrient intakes were determined by subtracting the feed refusal from the offered feed.

**Statistical analyses**

Data were analysed as a completely randomised design using the MIXED procedure of SAS (version 8.1, 2000, SAS Inst. Inc., Cary, NC). Milk production and ewe and lamb BW were analysed by analysis of variance for repeated measures in a model including treatment, day and the treatment × day interaction (i.e. ewe and lamb BW = 0, 28 or 56 d; milk production = 18, 36 or 54 d). Because no treatment × day interaction was detected, only the main effects are discussed. For diets, milk composition and yield, nutrient intakes, ewe and lamb BW, the only fixed effect was the treatment. A probability of \(p<.05\) was considered as a significant difference.

**Exp.2. Digestibility and N partitioning**

**Lambs, housing and nutrition**

Eighteen Awassi lambs (BW = 35.5 ± 0.69 kg; age = 7–8 months) were randomly assigned to one of the three dietary treatments above (six ewe lambs/diet) to evaluate the effect of replacing part of soybean meal, barley grain and wheat straw with the DDGS on nutrient digestibility and N partitioning. The experiment lasted for 21 days [adaptation period; 14 days housed individually in shaded pens (0.75 × 1.5 m) and collection period; 7 days in metabolic cages (0.8 × 1.05 mL)]. The shaded pens were equipped with plastic feed and water troughs that allowed ad libitum access to feed and water. Diets were prepared immediately before feeding period.

Feed buckets were managed to provide 110% of daily voluntary feed intake to reduce feed waste. Feed refusals were weighed, recorded and sampled to measure nutrient intakes correctly. Refusals were collected daily and sampled weekly and were analysed for DM, CP, NDF and ADF. From days 15 to 21, ewe lambs were placed in metabolic cages equipped with faecal trays that allow for total faecal and urinary collections. Daily faecal output was collected, weighed and recorded and then 10% was kept for subsequent analyses. Urine was collected using plastic containers, weighed and recorded and then 5% was kept (−20 °C) to determine N content. Each bottle contained 50 mL of 6 N HCl to prevent ammonia losses. At the end of the study, faecal and urinary samples were composited for each ewe lamb. Faecal samples were dried in an air-forced oven at 55 °C for few days to reach a constant weight and weighed to determine DM content. Faecal and dietary samples were then ground in a Wiley mill ((Brabender OHG Duisburg, Kulturstrasse 51–55, type 880845, Nr 958084, Germany) to pass through a 1 mm screen and stored in plastic bags at room temperature to be further analysed using procedures described by AOAC (1990). Diets and faecal samples were analysed for DM, CP, NDF and ADF as described in Exp.1.

The collected urinary samples were composited for each ewe lamb and analysed for N content using Kjeldahl procedure. Nitrogen intake was calculated by multiplying DM intake by the N content of each diet. Nitrogen lost in faeces and urine was calculated by multiplying N content in the faeces and urine by faecal and urinary output, respectively. Then, retained N (g/d) was calculated by subtracting faecal and urinary output from the N intake. Nitrogen retention (%) was calculated by dividing the retained N by N intake.

**Statistical analyses**

Data were analysed using the MIXED procedure of SAS (version 8.1, 2000, SAS Institute Inc., Cary, NC) where lamb was the random variable. For all data, treatment was the fixed effect. Least square means of the MIXED procedures of SAS was used to
Table 2. Nutrient intake in nursing Awassi ewes fed diets containing increasing concentration of dried distillers grains with solubles (DDGS), replacing barley grain, soybean meal and wheat straw.

| Item                  | CON       | DDGS200   | DDGS300   | SEM        |
|-----------------------|-----------|-----------|-----------|------------|
| Intake, g/d           |           |           |           |            |
| Dry matter            | 2678<sup>a</sup> | 2424<sup>b</sup> | 2423<sup>b</sup> | 113.6      |
| Crude protein         | 428<sup>a</sup> | 387<sup>b</sup> | 388<sup>b</sup> | 18.2       |
| Neutral detergent fibre| 782       | 721       | 722       | 33.7       |
| Acid detergent fibre  | 507<sup>b</sup> | 417<sup>b</sup> | 390<sup>b</sup> | 19.4       |
| Ether extract         | 51<sup>b</sup> | 58<sup>b</sup> | 64<sup>b</sup> | 2.8        |

<sup>a</sup>Within a row, means without a common superscript differ (p < .05).<br>
<sup>b</sup>Diet was (1) no DDGS (CON), (2) 200 g kg<sup>1</sup> DDGS (DDGS200) or 300 g kg<sup>1</sup> DDGS (DDGS300) of dietary dry matter (DM).

Table 3. Body weight change in lactating Awassi ewes and their lamb fed diets containing increasing concentrations of dried distillers grains with solubles (DDGS) replacing barley grain, soybean meal and wheat straw.

| Item                  | CON       | DDGS200   | DDGS300   | SEM        |
|-----------------------|-----------|-----------|-----------|------------|
| Ewe                   |           |           |           |            |
| Initial BW, kg        | 50        | 49.20     | 49.90     | 2.06       |
| Final BW, kg          | 53.20     | 53.30     | 54.50     | 2.33       |
| BW change, kg         | 3.20      | 4.08      | 4.60      | 2.05       |
| Lambs                 |           |           |           |            |
| Initial BW, kg        | 5.30      | 4.90      | 4.80      | 0.37       |
| Final BW, kg          | 18.20     | 18.10     | 18.40     | 0.94       |
| Total gain, kg        | 12.90     | 13.20     | 13.50     | 0.85       |
| ADG, g                | 231       | 237       | 242       | 15.20      |

<sup>a</sup>Within a row, means without a common superscript differ (p < .05).<br>
<sup>b</sup>Diet was (1) no DDGS (CON), (2) 200 g kg<sup>1</sup> DDGS (DDGS200) or 300 g kg<sup>1</sup> DDGS (DDGS300) of dietary dry matter (DM).

Table 4. Milk yield and composition in nursing Awassi ewes fed diets containing increasing concentrations of dried distillers grains with solubles (DDGS) replacing barley grain, soybean meal and wheat straw.

| Item                  | CON       | DDGS200   | DDGS300   | SEM        |
|-----------------------|-----------|-----------|-----------|------------|
| Milk yield, g/d       | 953<sup>b</sup> | 1167<sup>a</sup> | 1189<sup>a</sup> | 74         |
| Milk composition, g kg<sup>1</sup> |           |           |           |            |
| Fat                   | 50        | 50.30     | 50        | 0.63       |
| Protein               | 57.40     | 57.60     | 58.80     | 1.68       |
| Total solids          | 159       | 159       | 163       | 5.50       |
| Milk yield, g/d       |           |           |           |            |
| Fat                   | 47.70<sup>a</sup> | 58.50<sup>b</sup> | 58.70<sup>b</sup> | 3.80       |
| Protein               | 54.40<sup>a</sup> | 66.90<sup>b</sup> | 69.00<sup>b</sup> | 7.45       |
| Total solids          | 152.60<sup>a</sup> | 185.80<sup>a</sup> | 191.40<sup>b</sup> | 14.35      |
| Cost/kg milk yield (US$)<sup>c</sup> | 1.28<sup>b</sup> | 0.86<sup>a</sup> | 0.71<sup>a</sup> | 0.52       |

<sup>a</sup>Within a row, means without a common superscript differ (p < .05).<br>
<sup>b</sup>Diet was (1) no DDGS (CON), (2) 200 g kg<sup>1</sup> DDGS (DDGS200) or 300 g kg<sup>1</sup> DDGS (DDGS300) of dietary dry matter (DM).<br>
<sup>c</sup>Cost was calculated by dividing the daily feed cost by milk yield.

**Results**

Chemical analysis showed DDGS to contain 273, 272, 104 and 43 g kg<sup>1</sup> DM for CP, NDF, ADF and EE, respectively; making it a source of nutrients mainly CP. Nutrient composition of the three diets was similar except for the EE content, due to a greater level of EE in the DDGS (Table 1).

**Exp. 1**

Intake of DM, crude protein (CP) and acid detergent fibre (ADF) was greater (p ≤ .046) in the CON diet versus the DDGS-containing diets (Table 2). However, neutral detergent fibre (NDF) intake was not different (p = .29) amongst treatments. Ether extract intake was greater (p < .01) for the DDGS-containing diets than for the CON diet.

Initial BW and final BW of ewes were similar amongst dietary treatments (Table 3). As a result, BW change was unaffected (p = .89) by dietary treatments. Lamb weaning weight, total gain and pre-weaning average daily gain were similar (p ≥ .88) amongst dietary treatments.

Milk production, milk composition and milk yield are shown in Table 4. Ewes fed the CON diet had lower (p = .045) milk production yield than those fed the DDGS200 and DDGS300 diets. No significant differences (p ≥ .78) were observed amongst treatment groups in milk fat, protein and TS content. As well as, ewes fed the DDGS diets yielded more milk fat and protein (p ≤ .05) than those fed the CON diet. Daily TS output was greater (p = .05) in ewes fed the DDGS300 than in those fed the CON diet, whereas ewes receiving the DDGS200 diet not differ from other two treatments. Cost of milk yield was reduced (p = .01) in ewes fed DDGS containing diets compared with the CON diet.

**Exp. 2**

Digestibility of DM and ADF were lower (p ≤ .017) for the CON diet than for DDGS diets (Table 5). Digestibility of CP and NDF was higher (p ≤ .036) in lambs fed the DDGS200 diet than in those fed the CON diet, whereas lambs fed the DDGS300 were intermediate amongst the other two treatment diets. No significant differences (p ≥ .15) were observed in N excretion in faeces and in urine amongst dietary treatments (Table 5). However, N intake was greater (p = .047) in DDGS300 compared with the DDGS200 and the CON treatments. Nitrogen retained (g/d) and N retention were greater (p ≤ .046) in DDGS200 and DDGS300 diets than in the CON diet.
Table 5. Nutrient digestibility and N partitioning fed diets containing increasing concentrations of dried distillers grains with solubles (DDGS) replacing barley grain, soybean meal and wheat straw (Exp. 2).

| Item                     | CON  | DDGS200 | DDGS300 | SEM  |
|--------------------------|------|---------|---------|------|
| Digestibility coefficients |     |         |         |      |
| Dry matter               | 0.73<sup>b</sup> | 0.77<sup>a</sup> | 0.75<sup>a</sup> | 0.01 |
| Crude protein            | 0.74<sup>b</sup> | 0.78<sup>a</sup> | 0.76<sup>a</sup> | 0.01 |
| Neutral detergent fibre  | 0.59<sup>b</sup> | 0.65<sup>a</sup> | 0.63<sup>a</sup> | 0.02 |
| Acid detergent fibre     | 0.45<sup>b</sup> | 0.53<sup>a</sup> | 0.51<sup>a</sup> | 0.02 |
| N partitioning           |       |         |         |      |
| N intake, g/d            | 28.60<sup>b</sup> | 28.70<sup>a</sup> | 29.70<sup>a</sup> | 0.42 |
| N faeces, g/d            | 7.40  | 6.20    | 7.40    | 0.40 |
| N urine, g/d             | 9.50  | 8.50    | 8.30    | 0.68 |
| N retained, g/d          | 11.70<sup>b</sup> | 14.00<sup>a</sup> | 14.60<sup>a</sup> | 0.69 |
| N retention, %           | 40.90<sup>b</sup> | 49.10<sup>a</sup> | 49.10<sup>a</sup> | 2.58 |

<sup>a,b</sup>Within a row, means without a common superscript differ (p<.05).
<sup>c</sup>Diets contained (1) no DDGS (CON), (2) 200 g kg<sup>-1</sup> DDGS (DDGS200) or 300 g kg<sup>-1</sup> DDGS (DDGS300) of dietary dry matter (DM).

Discussion

Because it is highly abundant and affordable, DDGS is often preferred by livestock producers for feeding dairy and beef cattle. However, new studies have examined the DDGS effects on nursing performance and nutrient digestibility and N partitioning of (mainly Awassi) ewes during their early lactation period (i.e. from lambing until weaning). Due to its chemical composition, DDGS is a nutritional alternative to the high-cost ingredients for feeding sheep and other ruminants. Dried distillers grains with solubles was included at levels 0, 200, 300 g kg<sup>-1</sup> of dietary DM in this study to replace part of barley grain, soybean meal and wheat straw (Exp. 2). Similarly, other studies reported improved variable results in lambs and steers following DDGS feeding at variable concentrations (Huls et al. 2006; Buckner et al. 2008; McKeown et al. 2010; Felix et al. 2012). Inconsistencies in DM and nutrient intake results following DDGS inclusion are most likely attributed to differences in the rate of inclusion of DDGS, the type of feed ingredient of the basal diet (forage or concentrate, or both) being replaced by the distillers grains, and the form (wet or dry) of this byproduct to feed.

Results of BW changes and ADG in lambs were consistent with previous studies that were conducted in our laboratory (Obeidat and Shdaifat 2013) indicating that the used diets were palatable and the inclusion of DDGS did not affect their intake and, in turn, their BW changes.

A lactating animal requires a lot of energy for maintenance and milk production. If the requirement is not met through diet, body reserves will be catabolized, resulting in a negative energy balance. To reduce this, nutritionists balance diets to meet energy requirements. In this study, milk yield increased as the proportion of DDGS increased in the diets (Table 4). Ewes fed diets containing DDGS produced more milk than those fed the CON diet (18% or 20% more for the DDGS200 and DDGS300, respectively) corroborating the Benchaar et al. (2013) study where milk yield increased as the level of DDGS increased up to 300 g kg<sup>-1</sup> of dietary DM. Janicek et al. (2008) reported a linear increase in milk yield when dairy cows were fed 0, 100, 200 and 300 g kg<sup>-1</sup> DM DDGS. Similar results were reported where DDGS was used in different levels in diets of lactating dairy cows (Leonardi et al. 2005; Kleinschmit et al. 2006; Paz et al. 2013). This is contrary to studies by Schingoethe et al. (1999) and Uradl et al. (2006) who reported no significant difference in milk yield when DDGS was included in cow diets. Concurrent with our study, previous studies reported that milk yield either increased or at least did not change when DDGS included in diets of lactating ruminants.

One plausible explanation of the improvement in the milk yield could be due to ruminal pH, protein and fat in DDGS, although evidence suggesting that some heating might improve the efficiency of protein by ruminants (DDGS is heated during processing). Rumen undegradable protein (RUP) allows a supply of protein to escape rumen microbial degradation, and pass through to the small intestine to be digested by the animal. Schingoethe et al. (2009) suggested that DDGS has approximately 470–640 g kg<sup>-1</sup> RUP as a per cent of total CP, and Castillo-Lopez et al. (2014)
calculated RUP in the DDGS to be within the range of 465–509 g kg\(^{-1}\) DM. Total dietary requirements for RUP in lactating dairy cows according to NRC (2001) is 350–400 g kg\(^{-1}\) of total CP, suggesting that DDGS can be used to increase the consumption of RUP. The RUP in DDGS is highly digestible by ruminants and of higher quality than expected for a byproduct, thereby improving its value as a feed ingredient (Kononoff et al. 2007). Therefore, the improvement in milk yield reported in this study may be due to the availability of RUP in the DDGS diets compared with the CON diet.

Various studies showed inconsistent results regarding milk composition. We established in our study that milk composition was the same amongst diets when DDGS was included at 200 or 300 g kg\(^{-1}\) of dietary DM. According to Anderson et al. (2006), milk fat was not affected in dairy cows fed DDGS at 200 g kg\(^{-1}\) compared with the control diet, supporting our report. Tanaka et al. (2011) and Benchaar et al. (2013), on the other hand, reported that milk fat and milk protein decreased in cows fed DDGS compared with the control diet and concluded that greater level of fat in the DDGS diets, adversely affected the milk composition. This is true since reducing the fibre digestibility would decrease the released VFA mainly acetate, the precursor for fatty acid synthesis. Also, according to Schingoethe et al. (1999) and Tanaka et al. (2011), milk protein decreased in cows fed DDGS compared with the control diet. Although milk content of fat, protein and total solids did not change, the daily output of milk fat, protein and total solids increased more in diets containing DDGS than in the CON diet. This is probably due to the improvement in milk yield in DDGS200 and DDGS300 diets than in the CON diet.

Concurrent with previous studies that were reported in our lab (Obeidat et al. 2012; Obeidat et al. 2016a, 2016b; Obeidat 2018), this study proved that corn DDGS, as agro-industrial by product, is cheaper and would be more economical to feed nursing Awassi ewes compared with the other ingredients such as barley grain and soybean. Such results show the benefits of using corn DDGS in the ration. The inclusion of DDGS at 200 and 300 g kg\(^{-1}\) of dietary DM reduced the cost of feed by 13.3 and 20.2% than the CON diet. In addition, the cost of milk yield decreased in the DDGS-containing diets compared with the CON diet.

The inclusion of DDGS at either 200 or 300 g kg\(^{-1}\) of dietary DM improved the nutrient digestibility compared with the CON diet. Similar results on improving digestibility were reported by previous studies (Firkins et al. 1984; Castro-Pérez et al. 2013). The similarity in NDF or ADF digestibility may be a result of the availability of readily digestible non-forage fibre or the small particle size of DDGS. Felix et al. (2012), however, reported that DM digestibility decreased linearly when feedlot lambs were fed diets containing 200, 400 or 600 g kg\(^{-1}\) DM DDGS whereas NDF digestibility was not affected amongst dietary treatments.

In terms of N partitioning, our results are consistent with Felix et al. (2012) in that N intake and N digestibility increased, where the urinary N output increased which decreased the N retention in lambs fed diets with increasing level of DDGS. Furthermore, Gurung et al. (2012) found that daily excretion of N in urine was higher with increasing concentrates containing 0, 127, 254, 381 g kg\(^{-1}\) of DDGS fed to goats as DDGS is a good source of RUP. They also found that faecal N, urinary N, absorbed N and retained N were similar amongst all treatments, which may not be different for N intake.

Conclusions
The expansion of the ethanol industry and the simultaneous increase in prices of conventional feeds necessitated the demand for using by-products in feeding livestock. Under the conditions of the current study, inclusion of corn dried distillers grains with solubles up to 300 g kg\(^{-1}\) did not affect milk composition whilst improved milk composition yield. In addition, ewe’s body weight and lamb’s average daily gain was similar amongst the treatments; whereas, nutrient digestibility is improved in DDGS containing diets compared with the control diet. It, therefore, appears that as DDGS level in diets of lactating Awassi ewes is increased, its benefits for increased profitability and better livestock production is enhanced. Future research can address the effects of feeding DDGS at greater levels.

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