Research Article

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Carryover effect of direct-fed microbial supplementation and early weaning on the growth performance and carcass characteristics of growing Najdi lambs

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Abstract: Growing Najdi lambs were randomly selected from lambs weaned at 30, 45, and 60 days old which were treated with 3 doses of direct-fed microbial (DFM) at 5, 10, and 15 days old to investigate the carryover effect of early weaning and DFM supplementation on their growth performance and carcass characteristics. Ten lambs from each group were transferred to individual pens for a feeding trial using the total mixed ration (Wafi). Lambs treated with DFM and weaned at 60 days old showed numerically higher body weight and average daily gains compared to other groups. Concerning the carcass and meat quality, there were significant differences between all groups in all carcass and tissue measurements, except for the back-fat and body wall thickness. In conclusion, treatment did not have any significant negative effect on body weight, feed intake, and conversion ratio compared with the control, but positively affected Zn and Cu absorption. DFM also played an important role in fat metabolism, which affects fat deposits in carcasses. The most important finding was that early weaning can be performed using DFM supplementation without any negative effect on the lambs’ performance during growth.

Keywords: direct-fed microbial, Najdi lambs, growing period, performance, meat quality

1 Introduction

Increasing the survival rate of newborn lambs from birth up to weaning and the growth rate during growth periods is the most significant factor that affects the profit of sheep farms. The main cause of high mortality rates of newborn lambs is the management system followed by farmers [1]. Proper vaccination, feeding, and other management practices using feed additives also play an important role in newborn health and productivity [2]. Many feed additives have therefore been introduced in the market, such as direct-fed microbial (DFM) supplementation, to improve newborn lambs’ health and performance by accelerating rumen and reticulum development, improving the rumen environment, and altering the metabolic activities of rumen microorganisms [3,4].

DFM differs from probiotics in that DFM involves the utilization of naturally available living microbes [5,6]. DFM is a combination of single or mixed cultures of living microbes, primarily lactic acid-producing bacteria, that produce beneficial effects on health by enhancing the gastrointestinal complex microbial balance and keeping a healthy system inside the intestinal tract, making it unsuitable for most of the harmful bacteria [7–10]. The DFM improves animal performance by promoting digestion, increasing feed intake, reducing ruminal problems, and improving animal performance [9]. In addition to boosting ruminant performance, it detoxifies unwanted chemical compounds, strengthens the immune system, preserves stomach peristalsis, and promotes the integrity of intestinal mucus [6,11–14].

Several studies have reported the effect of feeding microbial supplementation, especially yeast, on adult ruminants, and their effects on productivity and general performance [15–18]. However, limited studies with inconsistent findings applied DFM in preruminant
animals [11,19,20]. According to our pilot study, feeding DFM to newborn lambs increased their growth rate, health status, and general performance, due to the acceleration of forestomach growth and development. Thus, lambs can be weaned early at 30 and 45 days old using DFM supplementation without major negative effects on their performance compared with weaning at 60 days old [21], which eventually will improve the profitability of sheep owners by shortening the lambing interval. As a continuation of the aforementioned work, this study aimed to investigate the carryover effect of early weaning with or without DFM on growth performance, blood metabolites, and carcass characteristics of Najdi lambs during their growth period.

2 Materials and methods

2.1 Animals and management

This experiment was carried out at the Department of Animal Production Farm Al-Amari, King Saud University, Riyadh region, Saudi Arabia (24°47’57.3”N and 46°33’52.4”E). Ten lambs from each group were randomly selected from lambs weaned at different ages and treated with DFM as follows: control (C) (weaning at 60 days old); T1, DFM (weaning at 30 days old); T2, DFM (weaning at 45 days old); and T3, DFM (weaning at 60 days old). Through the oral route, 3 doses of DFM (5 mL each) were administered to each lamb from the treated groups at 5, 10, and 15 days old. The lambs were then transferred to individual separate pens for the feeding trial, which began in July 2013. A 1-month adaptation period to the new dietary and management system was also performed. Then, Wafi total mixed ration was formulated in the trial phase to feed the growing lambs (Table 1). Lambs were then individually fed the recommended amount of Wafi diet and alfalfa hay as a pellet to cover their nutrient requirements for 12 weeks. Feed intake and refusal were recorded daily and samples from the total mixed ration diet and the refusals were then taken for laboratory analysis [22].

2.2 Sample collection

Body weight (BW) and blood samples of all experimental lambs were taken at the beginning of the study and every 4 weeks until the end of the feeding trial. The blood serum samples were analyzed for glucose, total protein, cholesterol, creatinine, urea-N, and triglycerides as well as concentrations of calcium, phosphorus, zinc, and copper using UDICHEM-310 spectrophotometer (semi-automated, United Diagnostic Industry, Dammam, KSA) and commercial kits (Randox Laboratories Ltd, BT, United Kingdom).

At the end of the feeding trial, six lambs from each group were randomly selected and BWs were recorded before slaughtering by severing the jugular vein and carotid artery after a 16 h fast. Empty body and hot and cold carcasses were weighed as well as samples from the head, skin, four feet, lungs, trachea, heart, liver, spleen, kidneys, genital organs, and tail were taken. The Longissimus dorsi (LD) muscle was similarly collected from each slaughtered lamb for quality control measurements. The thickness of the back and kidney fat was also measured. In addition, the fat distribution between 9 and 13 ribs was evaluated.

For the chemical analyses, muscle from LD was ground 3 times through a 3 mm screen and mixed after
each grinding. The samples were stored frozen for subsequent chemical analyses according to the Association of Official Analytical Chemists [22].

2.3 Color

The colored values of the CIELAB Color System (1976), \(L^*\) (lightness), \(a^*\) (redness), and \(b^*\) (yellowness), were determined on the LD muscle 20 min after slaughter using a chromameter (Konica Minolta, CR-400-Japan).

2.4 Temperature and pH

The pH and temperature were also measured directly in the muscle immediately after slaughter using a microprocessor pH meter (model pH 211, Hanna Instruments). Two readings were taken and the mean value was calculated for each carcass.

2.5 Cooking loss

The frozen LD muscles were thawed overnight at 4°C. Then, they were placed on a commercial indoor countertop grill and cooked to an internal temperature of 70°C. The temperature was monitored by inserting a thermocouple thermometer probe (Ecocan Temp JKT, Eutech Instruments) into the geometric center of the muscle. The muscles were then weighed before and after cooking to determine cooking loss as the difference between the initial and final weights.

2.6 Shear force

The cooked samples used to determine cooking loss were used to evaluate the shear force according to the protocol of Wheeler et al. [23]. They were cooled to room temperature (21°C), and then 5 round cores each with diameter of 1.27 cm were removed from each muscle sample parallel to the longitudinal orientation of the muscle fibers. The cores were then obtained using a handheld coring device. Shear force was determined as the maximum force (kg) perpendicular to the fibers using a Texture Analyzer (TA-HD-Stable MicroSystems, England) equipped with a Warner-Bratzler attachment. The crosshead speed was set at 200 mm/min.

2.7 Fat thickness

Fat thickness (rib fat or back fat) was measured (in mm) at a point 75% of the length of the LD muscle from the split chine bone using a digital Vernier caliper.

2.8 Body wall thickness

The body wall thickness measurement (in mm) was taken from the outside of the rib to the outside fat at 4–5 in. below the rib-eye using a digital Vernier caliper.

2.9 Carcass composition

The rack cut (four ribs) was taken and physically dissected into four components: lean, bone, fat, and trimmings (blood vessels, nerves, and connective tissue). These components were estimated as a percentage based on the cut weight.

2.10 Rib-eye area (REA)

The REA was measured in the LD muscle between the 12th and 13th ribs. An acetate sheet was then rubbed over the rib-eye and then peeled off. The rib-eye muscle wetted a certain area of the sheet that was traced with a pen. Then, the area was colored black and scanned (150 dpi Res.), after which it was saved as a monochrome bitmap image for later analysis using the analyzing digital imaging software (AreaScan 2 MFC Application 2000).

2.11 Water-holding capacity (WHC)

The WHC was determined based on the technique described by Wilhelm et al. [24]. Two replicates of around 2 g were collected from the LD muscle of each sample and cut into cubes. Then, the sample was placed between 2 filter papers and two plexiglasses and left under a 10 kg weight for 5 min. Subsequently, the sample was weighed and the WHC was determined as the difference between the initial and final weights.

2.12 Carcass liner measurements

The linear measurements of the carcass were taken after being chilled at 4°C for 24 h before cutting. Measurements were made with a measuring plastic tape (to the nearest
0.5 cm) as follows: carcass length (CL), the distance between the front edge of the pubic bone and the front edge of the first rib at its midpoint; carcass width (CW), the distance between the sternum and the withers; rump width (RW), the maximum width between the trochanters of the femurs; and hind leg length (HLL), the measurement from the inner edge of the proximal end of the medial malleolus of the tibian to the anterior tip of the symphysis pubis.

### 2.13 Drip loss (DL)

The DL was determined in the LD muscles by weighing the samples 20 min after slaughtering and then kept in plastic bag and left in a cooler (4°C) for 24 and 48 h. Thereafter, the samples were re-weighed to determine the DL values as a percentage based on the initial sample weight.

### 2.14 Carcass compactness (CC)

CC was determined as a ratio of cold carcass weight to CL as described by Bonvillani et al. [25].

### 2.15 Statistical analysis

Data were subjected to analysis of variance using the General Linear Model procedure of Statistical Analysis System Institute, Inc. (SAS, [26]) for a completely randomized design, according to the following model:

\[ Y_{ij} = \mu + C_i + e_{ij}, \]

where \( Y_{ij} \) = measurement of the variables, \( \mu \) = overall mean, \( C_i \) = effect of the \( i \)th treatment (C and 3 treatments), and \( e_{ij} \) = residual error.

BW, bodyweight gain (BWG), daily gain (DG), daily feed intake (DFI), feed conversion, biochemical parameters, and mineral concentrations of blood serum, carcass characteristics, and stomach development were dependent variables. The effects of blood sampling time, treatment, and interaction were considered for the biochemical parameters and mineral concentrations of blood serum. Differences among treatment means were detected using the protected least significant difference procedure (PLSD), with \( P < 0.05 \) considered statistically significant unless otherwise noted.

## 3 Results

### 3.1 Growth performance and feed efficiency

Table 2 shows the growth performance and feed efficiency of lambs from the same treated groups during the growing trial to detect the carryover effect of treatment and early weaning. There was no significant effect of DFM treatment of growing lambs on BW, BWG, FI, and feed conversion ratio (FCR) compared to the control. However, lambs from T3 reported a numerically higher final BW, body weight gain, and average daily gain than the other groups.

### 3.2 Blood serum metabolites and mineral levels

The effect of treatment on the levels of different metabolites in blood serum at different periods of growing lambs is reported in Table 3. There was no significant effect of treatment at different sampling times on glucose, total protein, and creatinine levels at different measured periods, but a significant effect was reported on cholesterol (56 days), urea-N (56 and 84 days), and triglyceride (84 days). Treatment caused a significant increase in cholesterol and triglyceride levels compared to the control group. The same trend was also reported for the urea-N levels.

At the end of the feeding trial, treatment, time, and interaction, only triglyceride levels in the blood serum were affected as a general trend (Table 4). Significantly lower glucose and urea-N levels were detected in the blood serum of lambs from T2 and higher triglyceride levels of lambs from T3 than the other groups (Table 4).

Furthermore, the phosphorus concentration in the blood serum of the control group lambs was significantly lower than those of the lambs in the treated groups (T1, T2, and T3; Table 5) during the growth trial. The same trend was also reported for Zn and Cu. Zinc was significantly lower \((P < 0.0004)\) for lambs in the control group than for those in T1 and T3, but not different compared with lambs in T2. A significantly \((P < 0.0003)\) higher Cu concentration was also reported in lambs from the treated groups compared to the control lambs. Moreover, the effect of treatment and time of sampling is reported in Table 6. A significant effect of treatment, time, and interaction was observed on Cu and Zn levels in blood serum, which was high compared to lambs from the treated groups (T1, T2, and T3; Table 6).
Table 2: Growth and feed efficiency of growing Najdi lambs during the feeding trial (mean value ± SE)

| Item                        | Treatment | P-value |
|-----------------------------|-----------|---------|
| BW (kg)                     |           |         |
| BW 1                        | 22.78 ± 1.59 | 21.86 ± 1.56 | 24.09 ± 0.99 | 21.78 ± 1.15 | 0.52 |
| BW 28                       | 29.00 ± 2.04 | 28.78 ± 2.41 | 30.32 ± 1.49 | 29.80 ± 1.39 | 0.92 |
| BW 56                       | 37.96 ± 2.46 | 37.02 ± 3.13 | 39.30 ± 1.96 | 39.09 ± 1.72 | 0.89 |
| BW 84                       | 45.11 ± 2.35 | 45.49 ± 2.94 | 45.86 ± 2.24 | 46.67 ± 2.08 | 0.97 |
| BWG (kg)                    |           |         |
| 1–28                        | 6.21 ± 0.86 | 6.69 ± 1.11 | 6.84 ± 0.48 | 8.02 ± 0.48 | 0.34 |
| 28–56                       | 8.96 ± 0.64 | 9.55 ± 0.85 | 9.39 ± 0.38 | 9.30 ± 0.79 | 0.94 |
| 56–84                       | 7.15 ± 0.50 | 7.11 ± 0.31 | 6.61 ± 0.64 | 7.58 ± 0.88 | 0.75 |
| 1–84                        | 22.33 ± 1.26 | 23.35 ± 1.85 | 22.84 ± 1.09 | 24.89 ± 1.52 | 0.59 |
| Fi (kg)                     |           |         |
| 1–28                        | 31.75 ± 2.16 | 31.25 ± 3.19 | 34.44 ± 0.85 | 32.91 ± 1.26 | 0.59 |
| 28–56                       | 43.96 ± 2.05 | 44.95 ± 2.68 | 47.77 ± 0.36 | 45.14 ± 1.77 | 0.38 |
| 56–84                       | 50.91 ± 1.22 | 51.02 ± 1.75 | 52.83 ± 0.33 | 51.59 ± 0.91 | 0.49 |
| 1–84                        | 126.63 ± 5.24 | 127.22 ± 7.57 | 135.04 ± 1.25 | 129.64 ± 3.82 | 0.47 |
| DFI (kg)                    |           |         |
| 1–28                        | 1.13 ± 0.08 | 1.12 ± 0.11 | 1.23 ± 0.03 | 1.18 ± 0.04 | 0.58 |
| 28–56                       | 1.57 ± 0.07 | 1.61 ± 0.10 | 1.71 ± 0.01 | 1.61 ± 0.06 | 0.38 |
| 56–84                       | 1.82 ± 0.04 | 1.82 ± 0.06 | 1.89 ± 0.01 | 1.84 ± 0.03 | 0.48 |
| ADFI (1–84)                 | 1.51 ± 0.06 | 1.52 ± 0.09 | 1.61 ± 0.01 | 1.54 ± 0.05 | 0.46 |
| Daily gain (kg)             |           |         |
| 1–28                        | 0.22 ± 0.03 | 0.24 ± 0.04 | 0.25 ± 0.02 | 0.29 ± 0.02 | 0.31 |
| 28–56                       | 0.32 ± 0.02 | 0.34 ± 0.03 | 0.34 ± 0.01 | 0.33 ± 0.03 | 0.91 |
| 56–84                       | 0.26 ± 0.02 | 0.25 ± 0.01 | 0.24 ± 0.02 | 0.27 ± 0.03 | 0.79 |
| ADG (1–84)                  | 0.27 ± 0.01 | 0.28 ± 0.02 | 0.27 ± 0.01 | 0.30 ± 0.02 | 0.51 |
| FCR (intake: gain ratio)    |           |         |
| 1–28                        | 6.01 ± 1.03 | 5.14 ± 0.56 | 5.20 ± 0.27 | 4.17 ± 0.22 | 0.21 |
| 28–56                       | 5.01 ± 0.29 | 4.79 ± 0.30 | 5.16 ± 0.20 | 5.00 ± 0.26 | 0.81 |
| 56–84                       | 7.42 ± 0.64 | 7.25 ± 0.43 | 9.17 ± 1.45 | 7.62 ± 1.05 | 0.56 |
| 1–84                        | 5.72 ± 0.18 | 5.51 ± 0.25 | 6.02 ± 0.25 | 5.29 ± 0.20 | 0.13 |

C – Control (weaning at 60 days old). T1 – Weaning at 30 days old with 3 doses of DFM (5, 10, and 15 days old). T2 – Weaning at 45 days old with 3 doses of DFM (5, 10, and 15 days old). T3 – Weaning at 60 days old with 3 doses of DFM (5, 10, and 15 days old). BW, body weight; BWG, body weight gain; ADG, average daily gain; ADFI, average daily feed intake; Fi, feed intake; FCR, feed conversion ratio; SE, standard error.

3.3 Carcass characteristics and stomach development

Slaughter components are presented in Table 7. All parameters were not significantly (P > 0.05) different between the treatments. However, T2 achieved the highest weight (kg) values for slaughter (53.07), empty body (47.97), hot carcass (26.48), and cold (26.10) carcass. This result was also true regarding the weight (kg) values of the head (2.66), four feet (1.45), lungs and trachea (0.47), liver (0.81), kidneys (0.13), and genital organs (0.65). The control group (C) followed the T2 group in achieving the second-best weight (kg) values for slaughter (52.62) and empty body (47.37) measurements. The results of the size of the digestive system and the final pH of the rumen fluid are presented in Table 8. All treatment groups did not show significant differences for the parameters tested. The weight of empty stomach and full stomach (full stomach – empty stomach) increased in treated groups compared to the control group. This trend was also noticed in rumen fluid pH, where the C group showed the lowest rumen fluid value (5.69) followed by T3 (5.77), then T2 (5.79), and finally T1 with the highest value (5.85). The results of the intestine measurement showed inconsistencies in their values. The results of temperature, pH, and color of the LD muscle of growing Najdi lambs are shown in Table 9. Treatment did not show significant differences
with 3 doses of DFM

Mean values followed by a common letter are not significantly different by the PLSD test at 95% level of significance.

Table 3: Blood serum metabolites of growing Najdi lambs during the feeding trial (mean value ± SE)

| Parameters       | Treatment | P-value |
|------------------|-----------|---------|
|                  | C         | T1      | T2      | T3      |         |
| Glucose (mg/dL)  | 61.13 ± 4.53 | 73.68 ± 5.79 | 70.73 ± 4.73 | 64.35 ± 6.33 | 0.36   |
|                  | 64.98 ± 4.50 | 66.70 ± 2.22 | 74.92 ± 6.58 | 67.46 ± 7.28 | 0.60   |
|                  | 86.56 ± 2.66 | 88.38 ± 4.01 | 73.00 ± 4.99 | 83.70 ± 3.49 | 0.05   |
| Total protein (g/dL) | 6.21 ± 0.79 | 6.46 ± 1.00 | 7.03 ± 0.60 | 6.50 ± 0.88 | 0.91   |
| Cholesterol (mg/dL) | 36.30 ± 4.06 | 49.54 ± 3.34 | 48.54 ± 5.07 | 43.92 ± 3.65 | 0.12   |
| Creatinine (mg/dL) | 0.90 ± 0.10 | 0.80 ± 0.08 | 0.79 ± 0.05 | 0.64 ± 0.07 | 0.18   |
| Urea nitrogen (mg/dL) | 28.18 ± 3.54 | 35.62 ± 3.50 | 27.02 ± 3.59 | 26.82 ± 5.56 | 0.40   |
| Triglycerides (mg/dL) | 45.53 ± 2.40 | 40.72 ± 3.33 | 40.13 ± 2.02 | 39.53 ± 2.70 | 0.38   |

C – Control (weaning at 60 days old). T1 – Weaning at 30 days old with 3 doses of DFM (5, 10, and 15 days old). T2 – Weaning at 45 days old with 3 doses of DFM (5, 10, and 15 days old). T3 – Weaning at 60 days old with 3 doses of DFM (5, 10, and 15 days old). SE, standard error. Mean values followed by a common letter are not significantly different by the PLSD test at 95% level of significance.

Table 4: Effect of DFM supplementation on Najdi newborn lambs, sampling time, and interaction with blood serum during the feeding trial

| Parameters       | Treatment | SEM | Trt | Time | Trt * time |
|------------------|-----------|-----|-----|------|------------|
|                  | C         | T1  | T2  | T3   |            |
| Glucose (mg/dL)  | 70.89     | 76.25 | 72.88 | 71.84 | 2.88 | 0.58 | 0.0001 | 0.14   |
| Total protein (g/dL) | 5.67     | 6.18  | 5.96  | 5.97  | 0.36 | 0.80 | 0.04  | 0.35   |
| Cholesterol (mg/dL) | 42.03    | 53.52  | 55.30  | 50.32  | 2.49 | 0.002 | 0.005 | 0.35   |
| Creatinine (mg/dL) | 0.86     | 0.75   | 0.80   | 0.75   | 0.03 | 0.08 | 0.92  | 0.22   |
| Urea nitrogen (mg/dL) | 39.70   | 39.43  | 38.72  | 46.99  | 1.60 | 0.001 | 0.03  | 0.001  |
| Triglycerides (mg/dL) | 33.31   | 35.31  | 34.71  | 36.68  | 1.84 | 0.63 | 0.0001 | 0.004  |

C – Control (weaning at 60 days old). T1 – Weaning at 30 days old with 3 doses of DFM (5, 10, and 15 days old). T2 – Weaning at 45 days old with 3 doses of DFM (5, 10, and 15 days old). T3 – Weaning at 60 days old with 3 doses of DFM (5, 10, and 15 days old). SEM, standard error of mean values. Trt, treatment.

(P > 0.05) between the tested groups with respect to the mentioned parameters. The initial (pHₐ) and ultimate (pHₜₐ) pH values were within the normal range. Moreover, the three-color components were increased in the final time (24 h postmortem). T3 attained the highest lightness (L* value (39.83) at the initial time (1 h postmortem) followed by the control group (39.82). In contrast to the results mentioned above, the control group reached the highest value for the L* component (42.64) at the final time, while T3 reached the lowest value (40.86) for the same period.

The carcass measurement data are displayed in Table 10. These include REA, CC, and carcass linear measurements (CLM).
Table 5: Mineral concentration in blood serum of lambs during growth at different sampling times (mean value ± SE)

| Parameters | Treatment | C | T1 | T2 | T3 | P-value |
|------------|-----------|---|----|----|----|---------|
| Calcium (mg/dL) | | | | | | |
| 1          | 7.89 ± 0.79 | 9.01 ± 0.95 | 8.98 ± 0.73 | 8.02 ± 0.65 | 0.63 |
| 56         | 8.57 ± 0.66 | 6.64 ± 0.38 | 8.29 ± 0.81 | 8.14 ± 1.07 | 0.32 |
| 84         | 7.24 ± 0.55 | 7.89 ± 0.56 | 7.07 ± 0.17 | 8.53 ± 0.25 | 0.09 |
| Phosphorus (mg/dL) | | | | | | |
| 1          | 5.75 ± 0.32 | 6.28 ± 0.38 | 6.46 ± 0.88 | 5.69 ± 0.57 | 0.73 |
| 56         | 5.28 ± 0.24 | 5.69 ± 0.33 | 5.91 ± 0.64 | 5.28 ± 0.42 | 0.67 |
| 84         | 4.18 ± 0.59 | 5.44 ± 0.50 | 6.11 ± 0.38 | 6.71 ± 0.30 | 0.01 |
| Zinc (µg/dL) | | | | | | |
| 1          | 69.78 ± 4.82 | 147.68 ± 13.29 | 120.86 ± 7.79 | 133.79 ± 15.31 | 0.001 |
| 56         | 140.08 ± 10.79 | 146.27 ± 6.61 | 157.78 ± 11.18 | 130.35 ± 18.77 | 0.69 |
| 84         | 110.83 ± 9.33 | 154.14 ± 10.82 | 124.67 ± 3.06 | 167.58 ± 8.16 | 0.0004 |
| Copper (µg/dL) | | | | | | |
| 1          | 161.36 ± 9.85 | 156.34 ± 4.22 | 166.96 ± 7.64 | 162.3 ± 2.85 | 0.74 |
| 56         | 156.42 ± 4.11 | 142.07 ± 5.26 | 172.15 ± 4.35 | 150.16 ± 5.47 | 0.002 |
| 84         | 155.90 ± 5.99 | 198.25 ± 6.68 | 173.39 ± 4.19 | 179.20 ± 4.74 | 0.0003 |

C – Control (weaning at 60 days old). T1 – Weaning at 30 days old with 3 doses of DFM (5, 10, and 15 days old). T2 – Weaning at 45 days old with 3 doses of DFM (5, 10, and 15 days old). T3 – Weaning at 60 days old with 3 doses of DFM (5, 10, and 15 days old). SE, standard error. Mean values followed by a common letter are not significantly different between the treatments in these parameters. How- ever, the WHC of the meat was improved compared to the control group (C) as weaning days increased. The best WHC was achieved by group T3 (38.72%), followed by T2 (33.94%), followed by T1 (30.39%). The tenderness was enhanced in T1 and T2 compared to the C group and T3. Contrary to the expected result based on the WHC results, the cooking loss of T3 was the highest (33.94%), followed by T2 > T1 > C. The DL of T2 was the lowest in all treatment groups for both the 24 h (7.78) and 48 h (9.35) periods. Alternatively, the highest values in 24 h were attained by T1 (8.63) and in 48 h by the C group (10.15).

Table 6: Effect of DFM supplementation to Najdi newborn lambs, time of sampling, and interaction with blood serum minerals during the feeding trial

| Parameters | Treatment | C | T1 | T2 | T3 | SEM | Trt | Time | Trt*time |
|------------|-----------|---|----|----|----|-----|-----|------|----------|
| Calcium (mg/dL) | | | | | | | | | |
| 1          | 7.90 | 7.85 | 8.11 | 8.23 | 0.39 | 0.89 | 0.25 | 0.17 |
| 56         | 5.07 | 5.80 | 6.16 | 5.89 | 0.29 | 0.06 | 0.30 | 0.17 |
| 84         | 106.90 | 149.36 | 134.44 | 143.91 | 6.26 | 0.0001 | 0.003 | 0.003 |
| Phosphorus (mg/dL) | | | | | | | | | |
| 1          | 157.90 | 165.52 | 170.83 | 163.89 | 3.33 | 0.05 | 0.0001 | 0.0001 |
| Zinc (µg/dL) | | | | | | | | | |
| 1          | 106.90 | 149.36 | 134.44 | 143.91 | 6.26 | 0.0001 | 0.003 | 0.003 |
| 56         | 156.42 ± 4.11 | 142.07 ± 5.26 | 172.15 ± 4.35 | 150.16 ± 5.47 | 0.002 |
| 84         | 155.90 ± 5.99 | 198.25 ± 6.68 | 173.39 ± 4.19 | 179.20 ± 4.74 | 0.0003 |

C – Control (weaning at 60 days old). T1 – Weaning at 30 days old with 3 doses of DFM (5, 10, and 15 days old). T2 – Weaning at 45 days old with 3 doses of DFM (5, 10, and 15 days old). T3 – Weaning at 60 days old with 3 doses of DFM (5, 10, and 15 days old). SEM, standard error of mean values. Trt, treatment.
the carcass fat deposits of the treatment groups. The treatment groups revealed significant (\(P < 0.05\)) differences in back-fat and body wall contents. Other fat deposits such as omental, mesentery, pericardial, and kidney knob channel fats did not differ significantly (\(P > 0.05\)) between the groups. The T2 attained the highest back-fat thickness of 8.72 mm, while the T1 attained the lowest amount of 4.73 mm. The C and T3 groups had got 5.05 and 4.91 mm, respectively. The body wall fat deposit (mm) was as follows: C (5.70) > T2 (5.49) > T1 (4.50) > T3 (2.65).

Alternatively, the chemical composition of the LD muscles is reported in Table 14, which shows only a significantly higher intramuscular fat content of lambs in the T3 group than in the other groups.

| Parameter (kg)          | Treatment | P-value |
|-------------------------|-----------|---------|
| Slaughter wt            | C         | T1      | T2      | T3      |
| 52.62 ± 1.26            | 49.18 ± 1.62 | 53.07 ± 2.38 | 48.13 ± 1.90 | 0.21 |
| Empty body wt*          | 47.37 ± 1.57 | 44.57 ± 1.33 | 47.97 ± 2.05 | 43.68 ± 1.75 | 0.25 |
| Hot carcass wt          | 24.05 ± 1.45 | 25.22 ± 0.88 | 26.48 ± 1.16 | 25.70 ± 0.89 | 0.75 |
| Cold carcass wt         | 23.68 ± 1.44 | 24.83 ± 0.87 | 26.10 ± 1.16 | 25.30 ± 0.89 | 0.50 |
| Head wt                 | 2.50 ± 0.12  | 2.51 ± 0.08  | 2.66 ± 0.09  | 2.52 ± 0.11  | 0.64 |
| Skin wt                 | 4.95 ± 0.58  | 4.82 ± 0.27  | 4.98 ± 0.33  | 5.15 ± 0.33  | 0.95 |
| Four feet wt            | 1.29 ± 0.08  | 1.28 ± 0.04  | 1.45 ± 0.10  | 1.43 ± 0.07  | 0.28 |
| Lung and trachea wt     | 0.43 ± 0.02  | 0.45 ± 0.03  | 0.47 ± 0.02  | 0.45 ± 0.03  | 0.76 |
| Heart wt                | 0.20 ± 0.01  | 0.18 ± 0.01  | 0.20 ± 0.01  | 0.18 ± 0.01  | 0.49 |
| Liver wt                | 0.72 ± 0.04  | 0.76 ± 0.04  | 0.81 ± 0.06  | 0.70 ± 0.03  | 0.36 |
| Spleen wt               | 0.07 ± 0.01  | 0.06 ± 0.002 | 0.07 ± 0.01  | 0.07 ± 0.004 | 0.60 |
| Kidneys wt              | 0.12 ± 0.01  | 0.12 ± 0.01  | 0.13 ± 0.01  | 0.12 ± 0.01  | 0.51 |
| Genital organs wt       | 0.52 ± 0.06  | 0.53 ± 0.04  | 0.65 ± 0.08  | 0.48 ± 0.05  | 0.24 |
| Tail wt                 | 1.85 ± 0.19  | 2.27 ± 0.16  | 2.27 ± 0.25  | 2.88 ± 0.37  | 0.18 |

*Empty body wt = (full stomach – empty stomach) + (full intestine – empty intestine) – slaughter/1,000. C – Control (weaning at 60 days old). T1 – Weaning at 30 days old with 3 doses of DFM (5, 10, and 15 days old). T2 – Weaning at 45 days old with 3 doses of DFM (5, 10, and 15 days old). T3 – Weaning at 60 days old with 3 doses of DFM (5, 10, and 15 days old). SE, standard error.

**Table 8:** Digestive system and final rumen fluid pH of DFM-offered growing Najdi lambs weaned at different ages

| Parameter                  | Treatment | SEM | P-value |
|----------------------------|-----------|-----|---------|
| Full stomach (g)           | C         | T1  | T2      | T3      |
| 4185.33                    | 4531.33   | 5154.17 | 4393.83 | 404.47  | 0.39 |
| Empty intestine (g)        | 1223.67   | 1265.67 | 1463.17 | 1340.83 | 93.77  | 0.32 |
| Full intestine (g)         | 2500.50   | 2338.67 | 2686.67 | 2436.17 | 149.90 | 0.31 |
| Empty intestine (g)        | 1157.17   | 1099.50 | 1277.00 | 1178.70 | 77.69  | 0.46 |
| Rumen fluid pH             | 5.69      | 5.85 | 5.79    | 5.77    | 0.09   | 0.66 |

C – Control (weaning at 60 days old). T1 – Weaning at 30 days old with 3 doses of DFM (5, 10, and 15 days old). T2 – Weaning at 45 days old with 3 doses of DFM (5, 10, and 15 days old). T3 – Weaning at 60 days old with 3 doses of DFM (5, 10, and 15 days old). SEM, standard error of mean values.

**Table 7:** Slaughter components of DFM-offered growing Najdi lambs weaned at different ages (mean value ± SE)

**4 Discussion**

Microbial feed additives have several objectives, which differ from those reported for non-ruminants. During the preruminant stage of newborn life, commercial benefits of feeding DFM feeds can be achieved by enhancing the rate of beneficial microbial growth in the rumen and reticulum. This feeding method accelerates the onset of weaning without any negative effect on the lamb growth, performance, and health [19]. The main finding of the pilot part of this study was that feeding DFM to newborn...
Several studies have discussed the effect of DFM supplementation on ruminant animal performance. There was no improvement in daily gain due to feeding *Lactobacilli* and other bacteria as a DFM to animals [27–31]. This lack of effect was also observed when growing goat kids were supplemented with probiotics [20,32,33]. These findings completely agree with our results reported in this study. On the contrary, an improvement in the rate of gain (17%) was obtained when 2.5 × 1,011 cfu/day of *L. acidophilus* species was added to milk or as a milk replacement [34]. Similarly, an increase in body weight and an improvement in FCR of growing lambs were detected when probiotics were fed [35]. Moreover, these findings agreed with Theodorou et al. [31] who reported that feeding microbial supplementation based on anaerobic fungi to animals increased feed intake and live-weight gain in calves following weaning. Furthermore, the introduction of yeast culture through stomach tubes to newborn lambs increased

### Table 9: Temperature, pH, and color values of LD muscle from DFM-offered growing Najdi lambs weaned at different ages (mean value ± SE)

| Parameter               | Treatment | P-value |
|-------------------------|-----------|---------|
|                         | C         | T1      | T2      | T3      |         |
| Temperature (°C)        | 25.08 ± 0.24 | 25.70 ± 0.37 | 25.33 ± 0.14 | 25.46 ± 0.31 | 0.48     |
| pH<sub>1</sub>          | 6.62 ± 0.09 | 6.51 ± 0.09 | 6.73 ± 0.11 | 6.36 ± 0.11 | 0.12     |
| pH<sub>2</sub>          | 5.79 ± 0.04 | 5.85 ± 0.05 | 5.73 ± 0.02 | 5.82 ± 0.06 | 0.27     |
| Color at 1 h postmortem |           |         |         |         |         |
| L*                     | 39.82 ± 0.98 | 38.80 ± 1.10 | 39.54 ± 1.17 | 39.83 ± 0.81 | 0.88     |
| a**                    | 17.02 ± 0.53 | 16.95 ± 1.28 | 17.37 ± 0.68 | 17.23 ± 0.71 | 0.98     |
| b***                   | 4.86 ± 0.29 | 5.08 ± 0.50 | 5.23 ± 0.17 | 5.27 ± 0.30 | 0.82     |
| Color at 24 h postmortem|           |         |         |         |         |
| L*                     | 42.64 ± 0.81 | 41.74 ± 1.42 | 41.39 ± 0.95 | 40.86 ± 0.44 | 0.62     |
| a**                    | 20.56 ± 0.60 | 19.79 ± 0.72 | 21.06 ± 0.28 | 20.97 ± 0.92 | 0.53     |
| b***                   | 10.49 ± 0.63 | 10.80 ± 0.54 | 12.39 ± 0.68 | 11.04 ± 0.77 | 0.22     |

C – Control (weaning at 60 days old). T1 – Weaning at 30 days old with 3 doses of DFM (5, 10, and 15 days old). T2 – Weaning at 45 days old with 3 doses of DFM (5, 10, and 15 days old). T3 – Weaning at 60 days old with 3 doses of DFM (5, 10, and 15 days old). SE, standard error. pH<sub>1</sub> – Initial pH and pH<sub>2</sub> – Ultimate pH. L* for lightness, a** for redness, and b*** for yellowness.

### Table 10: REA, CC, and CLM of DFM-offered growing Najdi lambs weaned at different ages (mean value ± SE)

| Parameter | Treatment | P-value |
|-----------|-----------|---------|
|           | C         | T1      | T2      | T3      |         |
| REA (cm<sup>2</sup>) | 15.39 ± 0.93 | 16.45 ± 0.42 | 14.93 ± 0.75 | 17.12 ± 0.42 | 0.12     |
| CC        | 0.35 ± 0.02 | 0.37 ± 0.01 | 0.38 ± 0.01 | 0.39 ± 0.02 | 0.33     |
| CLM (cm)  |           |         |         |         |         |
| CL        | 67.50 ± 1.38 | 68.17 ± 1.78 | 69.33 ± 1.17 | 66.00 ± 1.24 | 0.43     |
| CW        | 30.67 ± 0.67<sup>b</sup> | 29.33 ± 0.33<sup>b</sup> | 32.33 ± 0.56<sup>a</sup> | 30.33 ± 0.33<sup>b</sup> | 0.003    |
| RW        | 43.00 ± 0.68 | 42.67 ± 1.90 | 45.17 ± 0.91 | 43.33 ± 0.95 | 0.48     |
| HLL       | 43.00 ± 0.63 | 43.50 ± 0.76 | 45.17 ± 0.87 | 43.33 ± 0.92 | 0.26     |

C – Control (weaning at 60 days old). T1 – Weaning at 30 days old with 3 doses of DFM (5, 10, and 15 days old). T2 – Weaning at 45 days old with 3 doses of DFM (5, 10, and 15 days old). T3 – Weaning at 60 days old with 3 doses of DFM (5, 10, and 15 days old). SE, standard error. Mean values followed by a common letter are not significantly different by the PLSD test at 95% level of significance.
Table 11: Shear force, cooking loss, WHC, and DL of LD muscle of DFM-offered growing Najdi lambs weaned at different ages (mean value ± SE)

| Parameter               | Treatment     | P-value |
|-------------------------|---------------|---------|
|                         | C             | T1      | T2      | T3      |         |
| Shear force (kg)        | 4.45 ± 0.75   | 4.26 ± 0.49 | 3.84 ± 0.25 | 4.54 ± 0.49 | 0.79    |
| WHC (%)                 | 37.57 ± 0.51  | 37.42 ± 1.74 | 38.37 ± 1.67 | 38.72 ± 1.15 | 0.89    |
| Cooking loss (%)        | 30.28 ± 1.16  | 30.46 ± 1.49 | 30.64 ± 1.16 | 33.94 ± 0.61 | 0.13    |
| DL in 24 h              | 8.48 ± 2.93   | 8.63 ± 1.42 | 7.78 ± 1.57 | 8.15 ± 2.87 | 0.94    |
| DL in 48 h              | 10.15 ± 2.43  | 9.72 ± 2.02 | 9.35 ± 1.41 | 9.75 ± 2.03 | 0.94    |

C – Control (weaning at 60 days old). T1 – Weaning at 30 days old with 3 doses of DFM (5, 10, and 15 days old). T2 – Weaning at 45 days old with 3 doses of DFM (5, 10, and 15 days old). T3 – Weaning at 60 days old with 3 doses of DFM (5, 10, and 15 days old). SE, standard error.

Table 12: Carcass composition (%) of DFM-offered growing Najdi lambs weaned at different ages (mean value ± SE)

| Parameter (%)          | Treatment     | P-value |
|------------------------|---------------|---------|
|                        | C             | T1      | T2      | T3      |         |
| Cut                    | 3.83 ± 0.17   | 3.50 ± 0.22 | 3.50 ± 0.22 | 3.50 ± 0.34 | 0.47    |
| Meat                   | 40.17 ± 1.94  | 39.17 ± 2.80 | 41.67 ± 1.52 | 43.67 ± 1.56 | 0.61    |
| Bone                   | 29.17 ± 2.17  | 26.33 ± 2.06 | 29.17 ± 1.56 | 25.17 ± 2.41 | 0.35    |
| Fat                    | 22.00 ± 2.59  | 23.17 ± 2.73 | 18.33 ± 2.04 | 22.17 ± 2.47 | 0.57    |
| Trimmings              | 7.67 ± 0.88   | 8.83 ± 0.60 | 9.83 ± 0.75 | 8.17 ± 0.70 | 0.17    |

C – Control (weaning at 60 days old). T1 – Weaning at 30 days old with 3 doses of DFM (5, 10, and 15 days old). T2 – Weaning at 45 days old with 3 doses of DFM (5, 10, and 15 days old). T3 – Weaning at 60 days old with 3 doses of DFM (5, 10, and 15 days old). SE, standard error.

Table 13: Carcass fat deposits of DFM-offered growing Najdi lambs weaned at different ages (mean value ± SE)

| Parameter (%)          | Treatment     | P-value |
|------------------------|---------------|---------|
|                        | C             | T1      | T2      | T3      |         |
| Back-fat thickness (mm) | 5.05 ± 0.94^b | 4.73 ± 0.51^b | 8.72 ± 0.56^a | 4.91 ± 0.80^b | 0.002   |
| Body wall (mm)         | 5.70 ± 1.03^a | 4.50 ± 0.36^a | 5.49 ± 0.54^a | 2.65 ± 0.13^b | 0.004   |
| Omental fat (g)        | 1,121.17 ± 173.77 | 964.00 ± 100.68 | 1,102.33 ± 159.61 | 880.00 ± 118.29 | 0.61    |
| Mesentery fat (g)      | 551.00 ± 72.16 | 507.17 ± 59.74 | 467.67 ± 66.38 | 536.00 ± 92.33 | 0.86    |
| Pericardial fat (g)    | 105.00 ± 6.45  | 86.83 ± 16.39 | 107.33 ± 14.05 | 116.00 ± 9.40 | 0.41    |
| KKCf^* (g)             | 805.17 ± 112.63 | 754.17 ± 118.57 | 743.67 ± 121.85 | 714.50 ± 77.07 | 0.95    |

C – Control (weaning at 60 days old). T1 – Weaning at 30 days old with 3 doses of DFM (5, 10, and 15 days old). T2 – Weaning at 45 days old with 3 doses of DFM (5, 10, and 15 days old). T3 – Weaning at 60 days old with 3 doses of DFM (5, 10, and 15 days old). *Kidney knob and channel fat. SE, standard error. Mean values followed by a common letter are not significantly different by the PLSD test at 95% level of significance.
Table 14: Effect of treatment on the meat chemical composition of growing Najdi lambs

| Measurements (%) | Treatment | SEM | P-value |
|------------------|-----------|-----|---------|
|                  | C         | T1  | T2    | T3    |
| Moisture         | 66.13     | 63.01| 60.64 | 63.06 | 1.30 | 0.583 |
| Crude protein    | 20.91     | 20.07| 20.98 | 21.83 | 0.31 | 0.669 |
| Ether extract    | 0.977     | 1.047| 1.247 | 1.32  | 0.06 | 0.073 |
| Ash              | 1.34      | 1.40 | 1.50  | 1.54  | 0.06 | 0.073 |
| Moisture         | 11.79c    | 17.33b| 13.10c| 19.79a| 1.00 | 0.0001|

C – Control (weaning at 60 days old). T1 – Weaning at 30 days old with 3 doses of DFM (5, 10, and 15 days old). T2 – Weaning at 45 days old with 3 doses of DFM (5, 10, and 15 days old). T3 – Weaning at 60 days old with 3 doses of DFM (5, 10, and 15 days old). SEM, standard error of mean values. Mean values followed by a common letter are not significantly different by the PLSD test at 95% level of significance.

The change in metabolite levels in blood serum reflects the effect of DFM supplementation on nutrient digestibility and absorption. There was no significant effect of treatment at different sampling times on glucose, total protein, and creatinine levels, but a significant effect was reported on cholesterol (56 days), urea N (56 and 84 days), and triglycerides (84 days). The treatment caused a significant increase in cholesterol and triglyceride levels compared to the control group. This finding disagreed with that of Lubbadeh et al. [37] who reported a reduction in cholesterol levels of blood serum and meat of growing lambs as a result of Lactobacillus acidophilus supplementation. An increase in urea N was also noticed due to DFM supplementation. This result disagrees with several reports, which suggested an improvement in rumen nitrogen use by supplemented probiotics [38–40].

At the end of the feeding trial, treatment, time, and interaction, only triglyceride levels in the blood serum were affected as a general trend (Table 4). Significantly lower glucose and urea-N levels were also detected in the blood serum of lambs from T2 and higher triglyceride levels of lambs from T3 than others (Table 4). As a general trend, metabolite levels also fell within the recommended levels [41].

Furthermore, the phosphorus concentration in the blood serum of lambs from the control group was significantly lower than lambs from all treated groups (T1, T2, and T3; Table 5) during the growing trial. The same trend was also reported for Zn and Cu levels. Zinc was significantly lower (P < 0.0004) for the lambs in the control group than for those in T1 and T3, but not different for the lambs in the T2 group. Alternatively, significantly (P < 0.0003) higher Cu concentrations were also reported in lambs from the treated groups compared to control lambs. Moreover, the effect of treatment and time of sampling is reported in Table 6. A significant effect of treatment, time, and interaction on Cu and Zn levels in blood serum was also found to be high for lambs from the treated groups (T1, T2, and T3; Table 6). A similar observation was reported on the growth of lambs under DFM supplementation and their mineral absorption status, especially Zn [19] as well as with Lactobacillus bacterial supplementation [42]. The efficiency of absorption and bioavailability of many minerals affected by many factors is mainly related to diet, rumen, and reticulum fermentation process. The ruminant diet is usually high in fiber, and considerable fiber digestion occurs through the microbial fermentation in the rumen. However, the association of minerals with fiber in feedstuffs [43] or binding of minerals to undigested fractions in the gastrointestinal tract negatively affects the bioavailability of minerals [44]. Furthermore, rumen pH affects the solubility of some mineral complexes formed in the rumen [45]. Due to that, the mineral concentration and other metabolites in the blood are crucial to be determined after using the DFM supplementation because of their effect on nutrient digestibility, availability, and absorbability via the digestive tract [46,47]. These results will help avoid nutrient deficiencies or toxicity. As a general trend, all mineral levels in the blood serum of this study dropped within the normal range [48].

One of the important hypotheses of using DFM is to improve the rate of rumen microbial growth and forestomach development, thus accelerating the onset of weaning, without any negative impact on performance and health. A numerically general improvement in the forestomach capacity was also observed, especially in lambs fed with DFM and weaned at 45 days old when slaughtered after the feeding trial. Results are shown in Table 8. Improvements in the digestive system capacity and development of lambs fed with DFM explain the better performance of animals during these feeding trials as a carryover effect.

There were no significant differences between the groups in all measurements of carcass components, including those of the hot and cold carcass weights, as shown in Table 7.
Furthermore, only a numerically higher weight of the liver, kidney, and genital organs was found in slaughtered lambs from T2 compared with lambs from the other groups. The liver and kidney also play an important role in animal metabolism. The tail weights in lambs from T3 were numerically higher compared to control, T1, and T2, which reflect a higher accumulation of fat in this group. Similarly, no significant effect was detected by taking probiotics in the lungs, heart, and kidney on the weight of growing lambs [49]. In contrast, several studies noticed a significantly higher dressing percentage of growing lambs and kids when fed with probiotics [50,51].

Concerning meat quality, shear force, cooking loss, WHC, and DL of LD muscles did not indicate any significant differences between all groups in the above measurements of meat quality. A numerically higher value for some LD measurements such as cooking loss for lambs from T3 (33.94 ± 0.61%), DL in 24 h for lambs’ meat from T1 (8.63 ± 1.42%), and DL in 48 h for lambs’ meat from C (10.15 ± 2.43%; Table 11) was observed. Alternatively, the chemical compositions of the LD muscles were significantly higher for the intramuscular fat contents of lambs from the T3 group compared to the other groups. On the contrary, no change in LD muscle fat content was observed as a result of the DFM supplement in growing lambs [19].

The component of rack meat cut (meat, bone, fat, and trimmings) did not show significant differences between all groups, except for a numerically higher percentage of rack cut meat for lambs from the T3 group (43.67%) compared with the control, T1, and T2 (40.17, 39.17, and 41.67%, respectively; Table 12).

The REA (cm²) for T3 lambs showed numerically higher values than the other groups. No significant differences were reported between the groups in terms of CC, CL, width, and HLL as well (Table 10). Alternatively, the CW (cm) was significantly ($P < 0.003$) wider in lambs from T2 compared with the other groups (Table 10). Unfortunately, no solid research regarding these results was cited to compare with or to justify some of these findings in this experiment, especially the change in fat deposits and intramuscular measurements. Therefore, more studies should be conducted to identify the mechanism of DFM in fermentation and the negative or positive effect on the quality of meat of newborn lambs and the general performance considering many factors that affect the results.

For carcass fat deposits, back-fat thickness (mm) and body wall fat (mm) were the only deposits that significantly differed between the experimental groups (Table 13). The thickness of the back-fat was also significantly ($P < 0.002$) higher in T2 lambs. Significantly lower body wall fat (mm) for lambs in the T3 group was also observed when compared to others. However, the intramuscular fat content in the meat of lambs from T3 was significantly higher ($P < 0.0001$; 19.79%), followed by the meat of T1 lambs (17.33%) compared to the lambs of control and T2 (11.79 and 13.10%, respectively) as shown in Table 14. Generally, many studies have reported a relationship between probiotic supplementation in ruminants and fat metabolism. An increase in the back-fat thickness in response to probiotic supplementation compared to that of the control groups was noticed [33] and an increase in total body fat percentage due to probiotic supplementation to animals [52] was noticed. One of the most reasonable explanations for this finding is a shift in the rumen fermentation pattern, which changed the concentration and ratios of volatile fatty acids and consequently increased the lipogenesis and distribution of fat within animal tissues [53].

5 Conclusion

At the end of the trial, feeding DFM to the three groups did not have any negative effect on the final BW, BWG, FI, and FCRs compared to the control, only triglyceride levels in the blood serum were affected as a general trend. All mineral levels in the blood serum of this study dropped within the normal range improving the digestive system capacity and development of lambs. Concerning the carcass and meat quality, DFM played an important role in fat metabolism, which affected fat deposits in carcasses. Since a considerable variation in the magnitude of different animal performance responses to commercial feed (DFM) was observed, additional knowledge is required regarding the mechanism of action through which these performance improvements are mediated. Furthermore, identifying and characterizing existing commercial probiotic strains, optimal doses, and needed combinations for a certain animal physiological status are vital to assess and justify their stability throughout feed processing and digestion processes.

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