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Contents lists available at ScienceDirect

# Animal Feed Science and Technology

journal homepage: [www.elsevier.com/locate/anifeedsci](http://www.elsevier.com/locate/anifeedsci)

## Effects of feeding broiler litter on performance of Awassi lambs fed finishing diets

B.S. Obeidat<sup>a,\*</sup>, M.S. Awawdeh<sup>b</sup>, A.Y. Abdullah<sup>a</sup>, M.M. Muwalla<sup>a</sup>, M.A. Abu Ishmais<sup>a</sup>, B.T. Telfah<sup>a</sup>, A.J. Ayrout<sup>a</sup>, S.K. Matarneh<sup>a</sup>, H.S. Subih<sup>c</sup>, T.O. Osaili<sup>d</sup>

<sup>a</sup> Department of Animal Production, Faculty of Agriculture, Jordan University of Science and Technology, Irbid 22110, Jordan

<sup>b</sup> Department of Pathology and Animal Health, Faculty of Veterinary Medicine, Jordan University of Science and Technology, Irbid 22110, Jordan

<sup>c</sup> Department of Nutrition and Food Sciences, Wayne State University, Detroit, MI 48202, USA

<sup>d</sup> Department of Nutrition and Food Technology, Faculty of Agriculture, Jordan University of Science and Technology, Irbid 22110, Jordan

### ARTICLE INFO

#### Article history:

Received 15 September 2010

Received in revised form 28 January 2011

Accepted 4 February 2011

#### Keywords:

Awassi lambs

Broiler litter

Carcass characteristics

### ABSTRACT

A 70-d experiment was conducted to evaluate the effect of feeding poultry broiler litter (BL) at levels 0 (BL0;  $n = 10$ ), 100 (BL100;  $n = 10$ ), and 200 g/kg (BL200;  $n = 10$ ) on performance and carcass characteristics Awassi lambs. Nutrient intakes [*i.e.*, dry matter (DM), organic matter (OM), crude protein (CP), neutral detergent fiber (aNDF), acid detergent fiber (ADF), and copper] were similar ( $P > 0.05$ ) between all diets except for ether extract (EE) intake which tended to be lower ( $P \leq 0.10$ ) for the BL20 diet than the BL0 diet whereas BL100 not different from the other two diets. Dry matter, OM, CP, aNDF, and ADF digestibility was lower ( $P < 0.05$ ) for the BL200 diet than BL00 and BL100 diets. A linear decrease in nutrient digestibility was observed among diets. Feeding BL diets did not affect ( $P > 0.05$ ) average daily gain (ADG) and dry matter intake (DMI):ADG. For dissected loin, intermuscular fat content was lower ( $P < 0.05$ ) for the BL200 diet than BL0 diet. Subcutaneous fat and total fat content were lower ( $P < 0.05$ ) for the BL200 than the BL0 and BL100 diets. Similarly, intermuscular, subcutaneous and total fat decreased linearly ( $P < 0.05$ ) among diets. Meat to fat ratio was greater ( $P < 0.05$ ) for the BL200 diet than the BL0 and BL100 diets. For the dissected leg, contents of subcutaneous fat and total fat were lower ( $P < 0.05$ ) for the BL200 diet than for BL0 and BL100 diets. Meat to fat ratio was greater ( $P < 0.05$ ) for the BL200 diet when compared to the BL0 and BL100 diets. Rib fat depth was lower ( $P < 0.05$ ) for the BL200 diet when compared to the BL0 and BL100 diets. The whiteness ( $L^*$ ) was greater ( $P < 0.05$ ) for the BL200 than the BL0 and BL100 diets. However, redness ( $a^*$ ) was lower ( $P < 0.05$ ) for the BL200 diet than the BL0. Whiteness and redness was affected linearly while no quadratic was detected among diets. Results of the current study showed that inclusion of the broiler litter at level 200 g/kg did not affect feed intake while it reduced the digestibility. However, inclusion of the broiler litter enhanced the meat quality.

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**Abbreviations:** ADF, acid detergent fiber; ADG, average daily gain; aNDF, neutral detergent fiber; BL, broiler litter; CP, crude protein; DM, dry matter; DMI, dry matter intake; EE, ether extract; JUST, Jordan University of Science and Technology; OM, organic matter; WHC, water holding capacity.

\* Corresponding author at: Department of Animal Production, Faculty of Agriculture, Jordan University of Science and Technology, P.O. BOX 3030, Irbid 22110, Jordan. Tel.: +962 2 7201000x22214; fax: +962 2 7201078.

E-mail address: [bobeidat@just.edu.jo](mailto:bobeidat@just.edu.jo) (B.S. Obeidat).

## 1. Introduction

Feed represents a major proportion of the overall production cost for livestock industry in worldwide. On the other hand, availability of good quality and unadulterated conventional feed all year round is a major constraint in livestock production. Thus, proper use of inexpensive agricultural by-products is important to beneficial livestock production (Negesse et al., 2007).

Recently, sheep-feeding industry in Jordan starts using by-products and other materials that can be digested by ruminants (Abdullah and Abdelhafes, 2004; Obeidat et al., 2008, 2009; Obeidat and Aloqaily, 2010). One of such by-product is broiler litter (BL). Approximately, there is about 2300 poultry houses in Jordan that produce large quantities of poultry wastes annually. More than 85% of these are broiler houses that produce a waste product consisting of manure, sawdust or wood shavings, feed, and feathers that are appropriate for use as an animal feed. Usually, broiler litter is cheap to purchase with shipping and drying are the most important added cost when used in feeding livestock. Using BL as a feedstuff for sheep is an alternative mean to dispose the waste product. The chemical composition of broiler litter is variable and influenced by factors such as the composition of diets fed to poultry, method of processing before feeding and bedding material used (Wang and Goetsch, 1998; Al-Marsi and Zarkawi, 1999). According to Goetsch and Aiken (2000), the content of crude protein (CP) in broiler litter is ranged between 150 and 350 g/kg of dry matter. Mekasha et al. (2004) reported that CP (on DM basis) content in broiler litter was 298 g/kg. Inclusion of poultry litter in ruminant diets did not affect nutrient intakes, digestibility, average daily gain (ADG), or feed efficiency (Murthy et al., 1995; Anmut et al., 2002; Jackson et al., 2006; Negesse et al., 2007). However, Elemam et al. (2009) reported a greatest final live weight, ADG, and total gain for lambs fed diet containing 450 g/kg BL. Mavimbela et al. (2000) found that dressing%, lean%, fat%, bone%, and subcutaneous fat% were not different between lambs fed diets with different levels of BL. Also, Jeremiah and Gibson (2003) reported no differences in meat composition, cooking properties, and shear force values for Holstein steers fed diet containing poultry litter when compared to steers fed the control diet. Few research studies were done on the use of BL in Awassi lambs feeding. Therefore, the objective of this experiment was to study the effect of feeding different levels of BL on growth performance, digestibility, and carcass characteristics of Awassi lambs fed finishing diets.

## 2. Materials and methods

This experiment was conducted at the Agriculture Center for Research and Production at Jordan University of Science and Technology. All procedures used in this study were approved by the Jordan University of Science and Technology Institutional Animal Care and Use Committee.

### 2.1. Fattening and digestibility study procedures

Thirty Awassi lambs ( $65 \pm 2.35$  days of age;  $17.1 \pm 1.19$  kg initial body weight) were allocated randomly into one of three diets in completely randomized design experiment. Diets were: BL included in the diets at 0 (BL0), 100 (BL100), and 200 g/kg (BL200) of dietary dry matter. Broiler litter was obtained from the campus vicinity. Wood shavings were used as the bedding material that was comprised around 25% of the broiler litter. Before mixing the diets, BL was placed in autoclavable plastic bags and autoclaved ( $121^\circ\text{C}$  for 15 min) to kill litter background microflora. After autoclaving, BL was grinded to pass 3 mm screen to ease the mixing with the other ingredients (Table 1). The broiler litter contained 886, 842, 272, 334, 215, and 22 g/kg dry matter (DM), organic matter (OM), crude protein (CP), neutral detergent fiber (aNDF), acid detergent fiber (ADF), and ether extract (EE) (on dry matter basis), respectively. Also, BL was analyzed for copper content and found to be  $20.3 \mu\text{g/g}$ . All diets were formulated to be similar in CP content (163 g/kg CP; DM basis) and to meet the requirements for fattening Awassi lambs (NRC, 2007). Lambs were housed individually in shaded pens ( $1.5 \text{ m} \times 0.75 \text{ m}$ ), and fed twice daily (two equal meals at 0900 and 1600 h). An adaptation period of one-week was allowed prior to the experimental period. The study lasted for 70 days.

The experimental diet was offered *ad libitum* intake as a total mixed ration. The water was offered with free access throughout the experiment. Feed refusals were weighed daily throughout the study and stored at  $-20^\circ\text{C}$  for chemical analysis. Lambs were weighed at the beginning of the experiment and subsequent weights were measured weekly during the entire of the experiment.

On day 50 of the fattening period, six animals from each group were selected randomly and housed individually in metabolism crates ( $1.05 \text{ m} \times 0.80 \text{ m}$ ) to evaluate nutrient digestibility. Animals were allowed a period of five days to adapt the crates followed by collection period of five days; where feed intake and refusals were recorded and sampled for further analysis. Daily fecal output was collected, weighed, and recorded, and then 100 g/kg was kept for subsequent analyses. Fecal samples were dried at  $55^\circ\text{C}$  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.

### 2.2. Laboratory analysis

Composited diets and refusal samples were dried at  $55^\circ\text{C}$  in a forced-air oven to reach a constant weight, air equilibrated, ground to pass through 1 mm sieve (Brabender, Duisburg, Germany) and kept for further analysis. Broiler litter, diets, refusals,

**Table 1**  
Ingredients and chemical composition of diets fed to Awassi lambs.

Item	Diets <sup>a</sup>		
	BL0	BL100	BL200
Ingredients (g/kg DM)			
Barley	614	554	489
Soybean meal	160	120	85
Broiler litter	0	100	200
Wheat hay	200	200	200
Vegetable oil	10	10	10
Salt	10	10	10
Limestone	5	5	5
Mineral and vitamins <sup>b</sup>	1	1	1
Nutrients			
Dry matter (g/kg)	90.1	89.5	89.0
Organic matter (g/kg)	89.2	89.7	87.1
Crude protein (g/kg)	16.4	16.3	16.3
Neutral detergent fiber (g/kg)	35.3	37.7	38.3
Acid detergent fiber (g/kg)	17.5	18.1	20.0
Ether extract (g/kg)	5.3	4.6	4.7
Copper ( $\mu\text{g/g}$ )	3.15	4.10	4.50

<sup>a</sup> Diets were: broiler litter (BL) included in the diets at 0 (BL0), 100 (BL100), and 200 g/kg (BL200) of dietary dry matter.

<sup>b</sup> Composition per 1 kg contained (vitamin A, 450,000 IU; vitamin D<sub>3</sub>, 1,100,000 IU; vitamin E, 3.18 g, Mn, 10.9 g; I, 1.09 g; Zn, 22.73 g; Fe, 22.73 g; Cu, 2.73 g; Co, 0.635; Mg, 100 g; Se, 0.1 g).

and feces were analyzed following AOAC (1990) procedures for DM (100 °C in air-forced oven for 24 h; method 967.03), OM (550 °C in ashing furnace for 6 h; method 942.05), CP (Kjeldahl procedure; method 976.06) and EE (Soxtec procedure, Soxtec System HT 1043 Extraction Unit, Tecator, Box 70, Hoganäs, Sweden; method 920.29). Also, samples were analyzed for neutral detergent fiber (aNDF) and acid detergent fiber (ADF) according to the procedure described by Van Soest et al. (1991) with modifications for use in the Ankom<sup>2000</sup> fiber analyzer apparatus (Ankom Technology Cooperation, Fairport, NY, USA). Neutral detergent fiber analysis was performed using sodium sulfite and alpha amylase (heat stable) and expressed with residual ash content. According to procedure described by AOAC (1990), copper content was analyzed for all diets and BL (method number 975.05).

### 2.3. Slaughtering procedures and meat quality evaluation

At the end of the fattening period, all lambs were slaughtered at the Center for Agriculture and Production facilities at Jordan University of Science and Technology. Fasted body weight was recorded after 18 h after the last meal was offered. Then, all lambs were slaughtered at 0900 h by trained personnel following procedures described by Abdullah et al. (1998). Hot carcass weight was recorded immediately after slaughter. Cold carcass weight was recorded after carcasses were chilled at 4 °C for 24 h. Dressing percentage was calculated as the percentages of cold carcass weight/fasted live weight. Non-carcass components (i.e., lungs and trachea, heart, liver, spleen, kidneys, kidney fat, and mesenteric fat) were removed and weighed directly after slaughter. On the next day, the following linear dimensions were taken on the chilled carcasses and *longissimus* muscle: tissue depth (GR), rib fat depth (J), *Musculus longissimus* (*M. longissimus*) width (A), *M. longissimus* depth (B), *M. longissimus* area, and fat depth (C) following the procedure described by Abdullah et al. (1998). Carcasses were then cut into four parts (shoulder, rack, loin and leg cuts). Upon cutting, loin cut was dissected and *longissimus* muscle excised from the loin cut and vacuum-packed immediately and stored at –20 °C for 2 weeks until the time of meat quality assessment.

Meat quality variables measured were pH, color (CIE  $L^*a^*b^*$  coordinates), cooking loss, water holding capacity (WHC), and shear force values. Frozen *longissimus* muscles were thawed in a chiller at 4 °C over night while still in plastic bags. Each muscle was divided into slices of specific thickness and each slice was used for specified meat quality measurement as described by Abdullah and Musallam (2007) and Obeidat et al. (2008). Color was measured on slices of 15 mm thick, all slices were placed on a polystyrene tray and covered with permeable film and allowed to oxygenate for 2 h at 4 °C using a colorimeter device (12MM Aperture U 59730-30, Cole-Parameter International, Accuracy Microsensors Inc., Pittsford, NY, USA). Cooking loss was measured on duplicate-slices of 25 mm thickness, slices were weighed before cooking, placed in plastic bags and cooked in water bath at 75 °C for 90 min and re-weighed after cooking to calculate the percentage of water lost on cooking. The cooked slices were stored at 4 °C over night, then 6 cores, with the size of 1-mm<sup>3</sup> were cut from the slices to measure shear force values. Cooked meat cores were sheared in a perpendicular direction of muscle fiber using Warner–Bratzler (WB) shear blade with the triangular slot cutting edge mounted on Salter Model 235 (Warner–Bratzler meat shear, G-R Manufacturing Co. 1317 Collins LN, Manhattan, KS, USA) to determine the peak force (kg) required to shear the cores. The muscle pH was measured after thawing by homogenizing 2 g of raw meat in 10 ml of neutralized 5-mM iodoacetate reagent, pH of the homogenate was measured using pH spear (pH Spear, Large screen, waterproof pH/Temperature Tester, double injection, model 35634-40, Eurotech instruments, Selangor Darul Ehsan, Malaysia). Water holding capacity was measured using the procedure described by Grau and Hamm (1953). Approximately 5 g of raw meat was cut into small pieces and

placed between 2 filter paper and two quartz plates, and pressed with a weight of 2500 g for 5 min, then meat was removed and weighed, WHC was calculated as a percent of the initial weight  $WHC\ g/kg = (initial\ weight - final\ weight) \times 100 / initial\ weight$ .

#### 2.4. Statistical analysis

All data were analyzed using the MIXED procedure of SAS (version 8.1, 2000, SAS Inst. Inc., Cary, NC, USA) where lamb was the random variable. For all data, the fixed effects included only treatment. Initial body weight was used as a covariate for analyzing differences in body weight gain. For loin and leg measurements, loin and leg weight were included as covariates, respectively. Least square means of the MIXED procedures of SAS was used to further identify significant differences among means. Additionally, the main effect was tested for linear and quadratic effect. Significant differences were considered at ( $P \leq 0.05$ ).

### 3. Results

#### 3.1. Nutrient intake, digestibility and growth performance

The effects of BL inclusion on nutrient intakes, digestibility and growth performance are presented in Table 2. No differences ( $P > 0.05$ ) were observed on DM, OM, CP, aNDF, ADF, and copper intakes. Ether extract intake tended to be lower ( $P \leq 0.10$ ) for the BL200 diet than the BL0 diet whereas BL100 was not different from the other two diets. Additionally, there were no linear ( $P > 0.05$ ) or quadratic ( $P > 0.05$ ) differences between treatment diets for the nutrient intakes except for EE and copper intake. There was a tendency ( $P = 0.08$ ) or a linear decrease in EE intake among diets. However, copper intake tended to linearly increase ( $P = 0.09$ ) as the level of BL increased.

Digestibility of DM, OM, CP, NDF and ADF was lower ( $P < 0.05$ ) in lambs fed the BL200 diet than in those fed the BL0 and BL100 diets (Table 2). Similarly, the digestibility of EE was lower for the BL200 than the BL0 diet while BL100 diet was not different from the other two diets. A linear decrease ( $P < 0.05$ ) was noted for the nutrient digestibility among treatments. However, quadratic effect was not detected ( $P > 0.05$ ) for the nutrient digestibility among treatment diets.

Final body weight, average daily gain (ADG) and DMI:ADG were not affected by the inclusion of the BL (Table 2). Additionally, there were no linear ( $P > 0.05$ ) or quadratic ( $P > 0.05$ ) differences between treatment diets for same parameters.

#### 3.2. Carcass characteristics and meat quality

No differences ( $P > 0.05$ ) in fasting live weight, hot carcass weight, cold carcass weight, dressing, non-carcass components, and carcass cut weights were detected between diets (Table 3). For dissected loin *longissimus* muscle weight, total meat

**Table 2**  
Nutrient intake, digestibility and growth performance of Awassi lambs fed diets containing broiler litter.

Item	Diets <sup>a</sup>			SEM	p <sup>b</sup>		
	BL0	BL100	BL200		1	2	3
<b>Nutrient intake</b>							
Dry matter (g/d)	1086	1035	965	82.6	0.59	0.31	0.93
Organic matter (g/d)	1071	1045	947	81.1	0.53	0.29	0.72
Crude protein (g/d)	171	165	146	13.8	0.41	0.21	0.70
Neutral detergent fiber (g/d)	438	444	433	32.0	0.97	0.90	0.84
Acid detergent fiber (g/d)	213	211	224	16.7	0.84	0.65	0.72
Ether extract (g/d)	63	53	50	5.1	0.18	0.08	0.54
Copper (mg/d)	3.4	4.2	4.3	0.37	0.18	0.09	0.43
<b>Digestibility coefficients</b>							
Dry matter	0.81b	0.793b	0.68a	0.039	0.05	0.03	0.31
Organic matter	0.84b	0.83b	0.73a	0.031	0.04	0.02	0.28
Crude protein	0.84b	0.86b	0.68a	0.043	0.02	0.02	0.08
Neutral detergent fiber	0.76b	0.73b	0.59a	0.047	0.05	0.02	0.38
Acid detergent fiber	0.75b	0.71b	0.59a	0.047	0.07	0.03	0.51
Ether extract	0.89b	0.83ab	0.78a	0.032	0.08	0.03	0.80
Initial body weight (kg)	17.4	16.8	17.0	1.19	0.94	0.82	0.78
Final body weight (kg)	32.3	32.5	33.1	0.96	0.82	0.55	0.86
Average daily gain (g)	217.5	220.5	229.4	13.75	0.82	0.55	0.86
Feed efficiency (DMI:ADG) <sup>c</sup>	5.1	4.9	4.3	0.43	0.44	0.22	0.73

<sup>ab</sup> Within a row, means without a common letters (a and b) differ ( $P \leq 0.05$ ).

<sup>a</sup> Diets were: broiler litter (BL) included in the diets at 0 (BL0), 100 (BL100), and 200 g/kg (BL200) of dietary dry matter.

<sup>b</sup> Probability for the main effect of feeding broiler litter. 2 = Probability for the linear effect of feeding broiler litter. 3 = Probability for the quadratic effect of feeding broiler litter.

<sup>c</sup> DMI:ADG (dry matter intake:average daily intake).

**Table 3**

Carcass, non-carcass components, dissected loin and leg carcass cut weights and percentages of Awassi lambs fed diets containing broiler litter.

Item	Diets <sup>a</sup>			SEM	p <sup>d</sup>		
	BL0	BL100	BL200		1	2	3
Fasting live weight (kg)	32.0	31.3	31.9	1.54	0.94	0.96	0.73
Hot carcass weight (kg)	15.7	15.1	15.3	0.94	0.90	0.77	0.73
Cold carcass weight (kg)	15.1	14.7	14.7	0.93	0.93	0.75	0.85
Dressing percentage	47.1	46.7	45.7	0.82	0.35	0.16	0.76
Non-carcass components (kg) <sup>b</sup>	2.88	2.80	2.76	0.230	0.93	0.71	0.93
Carcass cut weights (kg) <sup>c</sup>	13.3	12.9	13.1	0.74	0.93	0.81	0.78
Loin weight (g)	705	670	694	62.10	0.90	0.89	0.66
Longissimus muscle (g)	199.9	178.1	195.8	15.20	0.52	0.84	0.26
Intermuscular fat (g/100 g)	6.8b	6.0ab	5.0a	0.44	0.03	0.01	0.96
Subcutaneous fat (g/100 g)	12.9b	13.2b	9.5a	1.10	0.01	0.01	0.96
Total fat (g/100 g)	19.7b	19.1b	14.5a	1.58	0.02	0.01	0.21
Total meat (g/100 g)	52.7	51.5	54.9	1.62	0.29	0.30	0.24
Total bone (g/100 g)	19.3	18.6	20.6	1.19	0.50	0.44	0.38
Meat to bone ratio	2.8	2.9	2.8	0.22	0.92	0.92	0.70
Meat to fat ratio	3.0a	2.8a	4.3b	0.41	0.02	0.03	0.08
Leg weight (g)	2487	2419	2426	127.0	0.91	0.73	0.80
Intermuscular fat (g/100 g)	3.6	3.3	3.3	0.33	0.80	0.59	0.71
Subcutaneous fat (g/100 g)	11.0b	11.5b	8.5a	0.76	0.03	0.04	0.08
Total fat (g/100 g)	14.5b	14.8b	11.8a	1.75	0.02	0.02	0.11
Total meat (g/100 g)	60.4	59.5	62.2	0.96	0.16	0.21	0.14
Total bone (g/100 g)	20.2	20.5	21.1	0.63	0.56	0.30	0.81
Meat to bone ratio	3.0	3.0	3.0	0.13	0.97	0.81	0.99
Meat to fat ratio	4.4a	4.1a	5.5b	0.32	0.02	0.03	0.05

<sup>ab</sup>Within a row, means without a common letters (a and b) differ ( $P \leq 0.05$ ).<sup>a</sup> Diets were: broiler litter (BL) included in the diets at 0 (BL0), 100 (BL100), and 200 g/kg (BL200) of dietary dry matter.<sup>b</sup> Non-carcass components (Heart, liver, spleen, kidney, and lungs and trachea).<sup>c</sup> Carcass cut (shoulder, racks, loins, and legs).<sup>d</sup> Probability for the main effect of feeding broiler litter. 2 = Probability for the linear effect of feeding broiler litter. 3 = Probability for the quadratic effect of feeding broiler litter.

content, total bone content, and meat to bone ratio were similar ( $P > 0.05$ ) among all diets. Intermuscular fat content was lower ( $P < 0.05$ ) for the BL200 diet than the BL0 diet; while the BL100 diet was not different from the other two diets. However, contents of subcutaneous fat and total fat were lower ( $P < 0.05$ ) for the BL200 diet than the BL0 and the BL100 diets. Meat to fat ratio was greater ( $P < 0.05$ ) for the BL200 diet than for the BL0 and BL100 diets. There was a linear decrease ( $P < 0.05$ ) in intermuscular, subcutaneous, and total fat for the dissected loin. For the dissected leg, subcutaneous fat and total fat contents were lower ( $P < 0.05$ ) in lambs fed the BL200 diet than in those fed the BL0 and BL100 diets. In addition to the main effect, subcutaneous and total fat decreased linearly ( $P < 0.05$ ) among diets. Total meat content tended to be greater ( $P < 0.10$ ) for the BL200 diet than the BL100 diet whereas both diets were similar to the BL0 diet. Meat to bone ration was higher ( $P < 0.05$ ) for the BL200 diet than the BL0 and BL100 diets. A linear and quadratic effect ( $P \leq 0.05$ ) was observed for the meat to fat ratio among diets.

Carcass and *M. longissimus* linear dimensions and fat measurements are presented in Table 4. No differences ( $P > 0.05$ ) were observed on GR, B, and *M. longissimus* area between all diets. Similarly, no linear or quadratic effect was detected for

**Table 4**Carcass and *M. longissimus* linear dimensions and fat measurements of Awassi lambs fed diets containing broiler litter.

Item	Diets <sup>a</sup>			SEM	p <sup>b</sup>		
	BL0	BL100	BL200		1	2	3
Tissue depth (GR) (mm)	11.6	10.9	10.2	0.71	0.28	0.11	1.00
Rib fat depth (J) (mm)	5.4b	5.1ab	3.7a	0.47	0.04	0.02	0.35
<i>M. longissimus</i> width (A) (mm)	25.4	24.6	27.1	0.92	0.18	0.21	0.16
<i>M. longissimus</i> depth (B) (mm)	56.6	55.7	56.9	1.55	0.82	0.88	0.55
<i>M. longissimus</i> area (cm <sup>2</sup> )	13.7	14.5	14.9	0.80	0.58	0.32	0.86
Fat depth (C) (mm)	3.2	1.9	2.1	0.47	0.14	0.12	0.21
Fat tail (g)	1260.4	1298.3	1325.0	189.46	0.97	0.81	0.98
Mesenteric fat (g)	264.4b	206.1ab	158.3a	22.57	0.01	0.01	0.85
Kidney fat (g)	175.0	163.3	127.8	23.65	0.33	0.16	0.67

<sup>ab</sup>Within a row, means without a common letters (a and b) differ ( $P \leq 0.05$ ).<sup>a</sup> Diets were: broiler litter (BL) included in the diets at 0 (BL0), 100 (BL100), and 200 g/kg (BL200) of dietary dry matter.<sup>b</sup> Probability for the main effect of feeding broiler litter. 2 = Probability for the linear effect of feeding broiler litter. 3 = Probability for the quadratic effect of feeding broiler litter.

**Table 5**  
Meat quality characteristics of Awassi lambs fed finishing diets containing broiler litter.

Item	Diets <sup>a</sup>			SEM	P <sup>c</sup>		
	BL0	BL100	BL200		1	2	3
pH <sup>b</sup>	5.6	5.6	5.6	0.02	0.87	0.93	0.61
Cooking loss (g/100g)	46.6	43.7	46.4	1.36	0.21	0.88	0.08
Water holding capacity (g/100g)	31.3	29.5	30.7	1.25	0.48	0.72	0.25
Shear force (kg/cm <sup>2</sup> )	4.7	5.0	5.8	0.41	0.15	0.06	0.59
Color coordinates							
L* (whiteness)	38.8a	39.4a	41.3b	0.65	0.03	0.01	0.41
a* (redness)	4.2b	3.4ab	2.9a	0.33	0.04	0.01	0.80
b* (yellowness)	19.5	19.2	21.2	1.00	0.33	0.25	0.34

<sup>ab</sup>Within a row, means without a common letters (a and b) differ (P<0.05).

<sup>a</sup> Diets were: broiler litter (BL) included in the diets at 0 (BL0), 100 (BL100), and 200 g/kg (BL200) of dietary dry matter.

<sup>b</sup> pH measured after thawing.

<sup>c</sup> Probability for the main effect of feeding broiler litter. 2 = Probability for the linear effect of feeding broiler litter. 3 = Probability for the quadratic effect of feeding broiler litter.

the previous parameters. Rib fat depth was lower (P<0.05) in lambs fed the BL200 diet than in those fed the BL0 diet, while the BL100 diet was intermediate. A linear decrease (P<0.05) in rib fat depth was observed among diets. A tendency was detected (P<0.10) for *M. longissimus* width to be greater for BL200 diet than the BL100, while the BL0 diet was not different from the other two diets. Fat depth tended to be lower (P<0.10) in the BL100 diet than BL0 diet while the BL200 was similar to the BL100 and BL0 diets. No differences (P>0.05) were observed in fat tail and kidney fat weight among diets. However, mesenteric fat weight was lower (P<0.05) for the BL200 diet than the BL0 diet, whereas the BL100 diet was not different from the other two diets. Mesenteric fat decreased linearly (P<0.05) with increasing the level of BL in the diets.

The effects of BL inclusion on meat quality characteristics of lambs *M. longissimus* muscle are presented in Table 5. No differences (P>0.05) were detected for ultimate pH, cooking loss, water holding capacity, and redness between all diets. However, shear force values tended to be greater for BL200 diet than the BL0 diet while the BL100 was similar to the BL0 and BL200 diets. Lambs fed BL200 diet had the highest whiteness values for *M. longissimus* muscle than those fed BL0 and BL100 diet. Redness values of *M. longissimus* muscle was lower (P<0.05) for lambs fed BL200 diet when compared to the BL0 whereas both diets were similar to the BL100 diet. Similarly, there was a linear effect (P<0.05) on whiteness and redness among diets while no quadratic effect was observed.

## 4. Discussion

### 4.1. Growth performance

Consistent with our results, Rossi et al. (1999) reported no differences in DM intake of pregnant Simmental × Angus beef cows when soybean meal-based protein supplement was replaced by caged layer litter. Conversely, in a recent study, Elemam et al. (2009) observed that DM intake increased for lambs fed 450 g/kg broiler litter compared with lambs fed 0, 150, 300 g/kg broiler litter. Abebe et al. (2004) reported that OM intake increased when BL fed to Spanish goats wethers fed wheat-straw based diet. In another study, when broiler litter was included at different levels (0, 200, 400, or 600 g/kg of DM concentrate) in diets for Spanish and Boar × Spanish doelings goats, Negesse et al. (2007) observed no major difference between the experimental and control diets in term of nutrient intakes and concluded that intake would not be impacted negatively when the including rate of BL is less than 400 g/kg. Concurrent with the previous research studies, results of the current study indicated the possibility of inclusion of broiler litter in diets of lambs at levels up to 200 g/kg of the DM.

In agreement to the results obtained in the current study, Abebe et al. (2004) found that OM digestibility decrease when BL increase in Spanish goat diets. Similarly, Negesse et al. (2007) reported that CP, aNDF and ADF digestibility was lower for Alpine doelings fed 200 g/kg BL diet than those fed diet free of BL. Negesse et al. (2007) assumed that the reduction in aNDF and ADF digestibility may be due to low ruminal pH that was associated in the BL diets. Likewise, Elemam et al. (2009) reported that DM and crude fiber digestibility were lower in lambs from 9 to 12 months old when fed diet 300 g/kg BL when compared to lambs fed control diet. Furthermore, DM, OM and CP digestibility were lower when BL replaced the soybean meal in Alpine doelings diets (Negesse et al., 2007). However, same study found that aNDF digestibility was not affected by the inclusion of the BL. In the current study, the reduction in the digestibility in BL200 diet is caused by the litter material. This is because the litter contained wood shavings (approximately 25%) which are almost completely indigestible.

In spite of the reduction of nutrient digestion of diets containing 200 g/kg BL, all animals had similar growth rate and total gain. These results are consistent with Elemam et al. (2009) who found that inclusion of BL in lamb diets up to 300 g/kg did not affect final live weight, ADG and total gain. Similarly, Animut et al. (2002) found similar growth performance in Alpine doelings consuming wheat straw supplemented with either BL or soybean meal at set rates. Also, these results agree with results of Mavimbela et al. (2000) where the ADG did not differ between sheep fed diet containing 0, 280, or 560 g/kg BL. Furthermore, growth rate was similar when poultry litter pellets fed to meat goat kids at levels 0, 200, or 400 g/kg (Jackson et al., 2006).

In the current study, replacement of part of barley and soybean meal with BL had no significant effect on feed efficiency (*i.e.*, DMI:ADG). Similarly, no effect of diets that contained BL at levels 0 or 200 g/kg on feed efficiency was observed by [Negesse et al. \(2007\)](#) when fed to Spanish and Boar × Spanish doelings. In contrast, same authors reported that the feed efficiency decreased at higher levels of BL (*i.e.*, 400 or 600 g/kg). In another study, similar trend was noted in feed efficiency when BL included at different levels (*i.e.*, 0, 150, 300, or 450 g/kg) ([Elemam et al., 2009](#)). Similarly, including BL at 0 or 150 g/kg in diets for lambs did not affect feed efficiency ([Elemam et al., 2009](#)); whereas, when BL fed at levels 300 or 450 g/kg, feed efficiency decreased; authors attributed that the lower feed efficiency could be related to the lower energy density when BL included at higher levels. According to the conditions of the current study, nutrient intake and growth performance data derived herein showed the possibility of using BL to replace soybean meal and barley grains with enhancing the profitability when used at moderate levels (100 or 200 g/kg).

#### 4.2. Carcass characteristics and meat quality

[Mavimbela et al. \(2000\)](#) reported that dressing%, carcass mass, lean%, fat%, bone%, subcutaneous fat and fat thickness were not differ when BL included in sheep diets. According to [Mavimbela et al. \(2000\)](#), and [Negesse et al. \(2007\)](#) the difference in fat and meat percentages in leg and loin cuts may be due to the fact that feeding BL may alter volatile fatty acid percentages specially propionate and acetate which may affect lipogenesis process. Additionally, the dietary fiber also influences the fatty acid composition of subcutaneous fat, the fat intake in the present study was lower for the BL200 and BL100. Similarly, according to the digestibility data ([Table 2](#)), the lower digestibility of aNDF and ADF for the BL200 diet might have depressed ruminal acetate production. Therefore, the low fat content that was observed in most tissues in BL200 most likely due in part to the low acetate production due to the fact that acetate can be used to synthesize subcutaneous fat as indicated by [Smith and Crouse \(1984\)](#). Also, it is well known that there is a relationship between the accumulation of fat in different body tissue and the energy consumption. Under the condition of the current study, the consumption of the energy was low in the BL200 diet and therefore, the accumulation of the fat was low when compared to the other diets. All results observed in the current study, mainly in the BL200 diet, assure that the use of the BL improved the meat quality throughout decreasing the level of the fat.

[Jeremiah and Gibson \(2003\)](#) found that meat shear force, chemical composition, and cooking time were not significantly differ between animals fed BL containing diet and diet free of BL in Holstein steers. Tenderness improved when sheep fed diets containing BL at levels up to 400 g/kg when compared to the control diet ([Ilian et al., 1988](#)). The tendency of increasing shear force values in the current study may be due to reduction of intermuscular fat content in lambs fed 200 g/kg BL diet. However, the shear force value reported in the current study were similar to results obtained recently by [Obeidat and Aaloqaily \(2010\)](#).

## 5. Conclusion

Current data suggests that the use of the broiler litter in feeding Awassi lambs fed finishing diets did not affect the growth performance while reducing the cost of gain. However, feeding broiler litter at level 200 g/kg reduced the digestibility. At the same time, the use of broiler litter improved the meat quality and it did not affect the health status of the lambs. Using broiler litter in feeding sheep is an effective and environmentally beneficial technique. More research is necessary to evaluate the rumen ecosystem and performance of sheep when using greater levels of broiler litter during different stages of production.

## Acknowledgements

Authors wish to thank the Deanship of Research at Jordan University of Science and Technology (JUST) for the financial support of this project (72/2008). In addition, thanks to the staff of the Center for Agricultural and Production at JUST for their help.

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