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Effect of *Curcuma longa* supplementation in post-weaning lambs ration on performance, carcass and meat quality

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ABSTRACT. The current study aimed to examine the effects of *Curcuma longa* (CL) addition to the post-weaning lambs ration on production efficiency and carcass quality. Twenty-eight post-weaning (12–14 week old) Awassi male lambs were randomly divided into four groups of seven lambs each, with the first (T1) group fed a standard ration, and the second (T2), third (T3), and fourth (T4) group fed standard rations supplemented with 100, 200, and 300 mg/kg CL powder, respectively. Treatment lasted 12 weeks. Data analysis revealed that CL supplementation improved ($P \leq 0.05$) overall body weight gain, daily body weight gain, slaughter weight, and hot and cold carcass weight compared to control. In addition, CL-treated (200 and 300 mg/kg doses) animals showed significantly increased empty body weight, dressing %, broad tail fat, and rib eye area in comparison to the control group. Regarding the physical dissection of three ribs, CL significantly enhanced three rib weight and lean % in T3 and T4 compared to other treatments. Bone percentage decreased significantly ($P \leq 0.05$) in T2 and T3, while fat percentage increased significantly in T2 and T3 compared to other treatments. In conclusion, supplementation of post-weaning lamb ration with 300 mg CL improved production traits and meat quality, as well as increased carcass weight, dressing percentage, and lean %. In addition, the fat metabolic pathway in the animal's body was diverted towards the broad tail, leading to the production of carcasses with a minimal amount of fat desired by consumers.

Introduction

Sheep are one of the most important animals for breeders in Iraq, and the main source of meat production as they are the most suitable livestock in Iraq's arid and semiarid climate. Due to their short production cycle, sheep are a source of livelihood for the rural population (Hashem et al., 2013). Awassi lambs are a major breed in Iraq, where they are known for producing high-quality meat as their carcasses contain a large amount of fat that accumulates in the broad tail area (Galal et al., 2008). Commercialization of sheep herd has increased in recent years, as well as the number of sheep farms. Due to these factors, technology should be introduced into this production sector in order to boost output by producing additional animals in less time, especially healthy animals with lower feed conversion rates. Early fattening lambs were shown to improve growth traits and reduce meat fat deposition (Boas et al., 2003). Some factors of meat quality, including cholesterol, lipid and fatty acid levels, softness, moistness, pH, test odour and colour, are considered by breeders to increase customer acceptance (Slukwa, 2014). Lambs have better growth traits as a result of low feed conversion rates and fat deposition; nonetheless, they develop quickly and have high daily weight gains. Feed additives have been utilized to increase animal ration efficiency and improve production quality (Flachowsky and Meyer, 2015). In folk medicine, medicinal plants are used to treat many diseases in various parts of the world. Products of certain plants, fungi, bacteria, and other species are still being used as pure chemicals or in the form of extracts (Araujo and Leon, 2001). Many of these compounds, such as curcumin, are extracted and refined from plants.

Curcumin, the main yellow bioactive component of turmeric, has a wide range of biological activities, including anti-inflammatory properties, as reviewed in the literature (Motterlini et al., 2000; Jurenka, 2009). Curcumin, a substance isolated from *Curcuma longa* L. (CL) plant, is one of the feed supplements that has shown promise in sheep husbandry (Jaguezeski et al., 2018a). It was demonstrated to exert positive effects on animal welfare and productivity (Jaguezeski et al., 2018b; Wang et al., 2018). According to the literature data, curcuminoids are active components of CL that are able to modulate the antioxidant and immune system (Yarru et al., 2009). Sueth-Santiago et al. (2015) concluded that the antioxidant capacity of curcumin was due to its phenol moieties that capture free radicals, thereby reducing cell damage. Molosse et al. (2019) found that adding curcumin to the ration of breastfeeding lambs increased weight gain, while inducing anti-inflammatory and antioxidant effects; both of these phenomena have biological advantages that are desirable to for enhancing performance. The antibacterial properties of curcumin are also noteworthy. Jaguezeski et al. (2018a) observed that feeding curcumin to milking sheep with chronic subclinical mastitis treated the condition in most cases. According to Noori and Sultan (2020), curcumin supplementation of lamb feed resulted in increased body weight and gain, as well as improved immunity in Awassi lambs. Curcumin dietary supplementation has been shown to minimize lipid peroxidation, increase antioxidant levels, and thus promote redox stability in meat (Salah et al., 2019; Galli et al., 2020). Our hypothesis was that similar outcomes could be achieved in ruminant meat, but this needed to be investigated because the digestion process in ruminants is different compared to other farmed animals. The aim of this study was to evaluate the effect of CL supplementation to the post-weaning lamb ration on performance, carcass and meat quality.

Material and methods

Experimental design and animals

Ethical approval

All procedures were approved by the University of Mosul, College of Veterinary Medicine, Institutional Animal Care and Use Committee, ethical approval No. UM.VET.2021.15. The research was carried out in a private field in the village of Baibukht, northeast of the city of Mosul/Iraq. Twenty-eight Awassi male lambs (20.99 ± 0.12 kg body weight, 12–14 weeks of age) were randomly assigned to 4 pens (n = 7/pen) in semi-open barns and fed concentrate rations (Table 1) (Al-Khawaja et al., 1978). The study lambs (28) were randomly divided into four groups (7 lamb/group): T1 – the control group, received standard ration; T2, T3, T4 – the experimental groups, were administered standard ration supplemented with 100, 200 and 300 mg/kg *Curcuma longa* powder. *Curcuma longa* was added and mixed with the ration daily. The study lasted 12 weeks.

Table 1. Chemical composition of standard ration, calculated on a dry matter basis (Al-Khawaja et al., 1978)

DM Ingredients, %		Chemical composition, %	
Crushed barley	78	DM	92.58
Soybean meal	10	Organic matter	94.78
Wheat bran	9	Crude protein	13.82
Wheat straw	2	Ether extract	1.65
Common salt	0.5	Crude fiber	7.31
$CaCo_3$	0.5	Ash	5.22
Ca	0.41	ME, kcal/kg/DM	2602
P	0.35		

DM – dry matter; ME – metabolic energy

Curcuma longa L.

CL was purchased from the local market, curcumin was present in 74.8% of the commercial product (Tabarak, Mosul, Iraq). Demethoxycurcumin and bisdemethoxycurcumin, two additional curcuminoid components, were also found in low concentrations (1.62 and 0.98%, respectively) when analysed using high-performance liquid chromatography, following the method of Coradini et al., (2014) described in detail by Jaguezeski et al. (2018a).

Productive traits

The lambs were weighed at the beginning of the experiment, and subsequently every two weeks until the end of the trial to determine body weight (BW) and daily body weight gain (DBWG). Weighing was carried out using a special scale with a detection limit up to150 kg at 0.5-kg increments; the difference in weight gains was calculated according to the following equation: daily weight gain (within a period), kg = (next weight − previous weight) / 14 days.

Carcass measurements

At the end of the study, three lambs from each group were fasted for 12 h, weighed, and slaughtered.

Hot carcass and empty body weight were promptly determined. Carcasses were kept at −4 °C overnight, and then cold carcass weight was measured; broad tail fat, kidney and pelvic fat, abdominal fat, heart fat, and back fat thickness were measured, and the dressing ratio was calculated based on the cold carcass weight relative to the final live weight × 100. The rib eye area was measured using a placom digital planimeter at rib 12 according to Duckett et al. (2007).

Physical dissection of three ribs

Carcasses were divided into two equal parts to physically dissect the ribs, and ribs 9, 10, and 11 were collected from the left halfs (Duckett et al., 2007); they were subsequently weighed and frozen at −20 °C in preparation for physical dissection. Muscle, fat, and bone tissues were separated with a sharp knife after thawing the frozen sections at room temperature one at a time. The three tissues were then weighed separately on a scale with a sensitivity of 5 g, and the fractions of the three tissues were calculated based on the weight of three rib pieces. The thickness of subcutaneous fat between ribs 12 and 14, as well as the rib eye area muscle were also measured.

Statistical analysis

The results of the study were analysed and presented as means (SEM). The data were analysed using the SAS software (version 9.1; SAS Institute, 2003), and the Duncan test was used to detect differences between means (Steel and Torrie, 1984).

Results

Table 2 shows that curcuma treatments improved lamb body weights throughout the treatment period, and it was significantly higher ($P \leq 0.05$) in CL groups T2, T3, and T4 (39.43, 40.49, and 41.76 kg, respectively) compared to control (T1: 38.47 kg). It was also found that BW increased linearly ($P \leq 0.05$) with increasing supplementation. Body weight gains (Table 3) demonstrated that total DBWG was significantly ($P \leq 0.05$) increased in T3 at week 6 (335.57 g) compared to T1 and T2 (165.29 and 240.00 g, respectively), and in T4 at weeks 4, 10, 12 of the study (209.14, 360.86, and 344.57 g, respectively). For carcass traits, CL treatment caused a significant increase in slaughter weight for T2, T3, and T4 (39.43, 40.49, and 41.76 kg, respectively) compared to control (T1: 32.47) at $P \leq 0.05$ (Table 4). Empty body weight, cold and hot carcass weight, and dressing percentage improved significantly in the CL groups in comparison to control. Table 5 shows that CL treatment increased broad tail fat in T3 and T4 (3.18 and 3.10 kg, respectively) and fat in the rib eye area (14.18 and 14.75 cm^2, respectively) when compared to control (2.60 kg and 13.33 cm^2, respectively) at a significance level of $P < 0.05$. CL supplementation, on the other hand, had no effect on kidney, pelvic, abdominal or heart fat. Compared to the high level of supplementation (T4: 300 mg/kg ration), in which back fat thickness reached 0.94 cm, the low level of CL (T: 100 mg/kg ration) resulted in a significant increase in this parameter (1.20 cm).

Table 2. Effect of *Curcuma longa* (CL) supplementation on body weight (kg) of Awassi lambs

Groups	Weeks						
	Initial BW	2	4	6	8	10	Final weight
T1	21.20 ± 0.23^a	22.44 ± 0.25^a	24.27 ± 0.15^b	26.58 ± 0.24^c	31.01 ± 0.33^b	35.20 ± 0.24^b	38.47 ± 0.27^d
T2	20.83 ± 0.36^a	22.02 ± 0.33^a	24.24 ± 0.29^b	27.60 ± 0.42^{bc}	32.25 ± 0.38^b	35.97 ± 0.20^b	39.43 ± 0.19^c
T3	20.90 ± 0.16^a	22.16 ± 0.15^a	24.85 ± 0.26^{ab}	29.55 ± 0.54^a	34.11 ± 0.48^a	37.04 ± 0.39^a	40.49 ± 0.17^b
T4	21.05 ± 0.24^a	22.41 ± 0.20^a	25.34 ± 0.14^a	28.72 ± 0.28^{ab}	31.89 ± 0.43^b	36.94 ± 0.39^a	41.76 ± 0.12^a

BW – body weight, T_1 – control, T_2 – CL 100 mg/kg ration, T_3 – CL 200 mg/kg ration, T_4 – CL 300 mg/kg ration; data are presented as mean values ± SEM (standard error of the mean); $^{a-d}$ – means within a column with different superscripts are significantly different at $P < 0.05$

Table 3. Effect of *Curcuma longa* (CL) supplementation on daily body weight gain (g) of Awassi lambs

Weeks	T1	T2	T3	T4
2	86.28 ± 2.94^a	85.42 ± 4.63^a	90.28 ± 7.36^a	97.42 ± 3.96^a
4	132.71 ± 10.33^c	158.14 ± 14^{bc}	192.29 ± 16.16^{ab}	209.14 ± 15.87^a
6	165.29 ± 16.16^c	240.00 ± 16.30^b	335.57 ± 26.21	244.29 ± 16.27^{ab}
8	216.29 ± 20.01^a	332.71 ± 10.71^a	329.71 ± 12.09^a	225.86 ± 14.49^b
10	299.29 ± 11.38^b	265.43 ± 18.84^b	209.14 ± 27.22^c	360.86 ± 8.94^a
12	233.86 ± 19.95^b	247.43 ± 17.68^b	246.29 ± 24.83^b	344.57 ± 23.54^a
Total BWG	17.27 ± 0.26^d	18.60 ± 0.43^c	19.59 ± 0.24^b	20.71 ± 0.16^a

BWG – body weight gain, T1 – control, T2 – CL 100 mg/kg ration, T3 – CL 200 mg/kg ration, T4 – CL 300 mg/kg ration; data are presented as mean values ± SEM (standard error of the mean); $^{a–d}$ – means within a column with different superscripts are significantly different at $P < 0.05$

Table 4. Effect of *Curcuma longa* (CL) supplementation on different carcass weights (kg) and dressing percentage of Awassi lambs

Groups	Carcass parameters*				
	SW	EBW	HCW	CCW	Dressing, %
T1	32.47 ± 0.27^{d}	33.69 ± 0.39^{c}	18.97 ± 0.20^{c}	18.63 ± 0.20^{c}	55 ± 0.06^{b}
T2	39.43 ± 0.19^{c}	34.35 ± 0.26^{bc}	19.97 ± 0.23^{b}	19.63 ± 0.22^{b}	57 ± 0.09^{ab}
T3	40.49 ± 0.17^{b}	35.24 ± 0.16^{b}	21.05 ± 0.39^{a}	21.12 ± 0.33^{a}	59 ± 0.01^{a}
T4	41.76 ± 0.12^{a}	36.17 ± 0.34^{a}	21.44 ± 0.33^{a}	21.44 ± 0.33^{a}	59 ± 0.06^{a}

* Based on empty body weight; SW – slaughter weight, EBW – empty body weight, HCW – hot carcass weight, CCW –cold carcass weight, T1 – control, T2 – CL 100 mg/kg ration, T3 – CL 200 mg/kg ration, T4 – CL 300 mg/kg ration; data are presented as mean values ± SEM (standard error of the mean); $^{a–d}$ – means within a column with different superscripts are significantly different at $P < 0.05$

Table 5. Effect of *Curcuma longa* (CL) supplementation on fat weight in the carcass offal, rib eye area and back fat thickness in Awassi lambs

Groups	Parameters					
	WTF, kg	KPF, kg	AF, kg	HF, kg	REA, cm^2	BFT, cm
T1	2.60 ± 0.14^{b}	0.16 ± 0.05^{a}	0.50 ± 0.04^{a}	0.38 ± 0.01^{a}	13.33 ± 0.16^{b}	1.06 ± 0.14^{ab}
T2	2.92 ± 0.11^{ab}	0.26 ± 0.09^{a}	0.41 ± 0.04^{ab}	0.34 ± 0.01^{a}	13.79 ± 0.07^{ab}	1.20 ± 0.02^{a}
T3	3.18 ± 0.17^{a}	0.16 ± 0.02^{a}	0.37 ± 0.02^{b}	0.30 ± 0.02^{a}	14.75 ± 0.13^{a}	1.10 ± 0.02^{ab}
T4	3.10 ± 0.13^{a}	0.17 ± 0.03^{a}	0.45 ± 0.02^{ab}	0.29 ± 0.02^{a}	14.18 ± 0.23^{a}	0.94 ± 0.03^{b}

WTF – broad tail fat, KPF – kidney and pelvic fat, AF – abdominal fat, HF – heart fat, REA – rib eye area, BFT – back fat thickness, T1 – control, T2 – CL 100 mg/kg ration, T3 – CL 200 mg/kg ration, T4 – CL 300 mg/kg ration; data are presented as mean value ± SEM (standard error of the mean); ^{abc} – means within a column with different superscripts are significantly different at $P < 0.05$

Table 6. Effect of *Curcuma longa* (CL) supplementation on physical dissection component of three ribs of Awassi lam

Groups	Three ribs parameters			
	Weight, kg	Bone, %	Fat, %	Lean, %
T1	0.38 ± 0.02^{c}	44.42 ± 0.23^{a}	34.07 ± 0.32^{a}	21.12 ± 0.46^{c}
T2	0.39 ± 0.03^{c}	44.25 ± 0.32^{a}	33.05 ± 0.47^{b}	22.30 ± 0.24^{b}
T3	0.40 ± 0.04^{b}	42.07 ± 0.30^{b}	34.16 ± 0.15^{a}	23.16 ± 0.15^{a}
T4	0.42 ± 0.03^{a}	41.76 ± 0.35^{c}	35.07 ± 0.32^{a}	23.08 ± 0.32^{a}

T1 – control, T2 – CL 100 mg/kg ration, T3 – CL 200 mg/kg ration, T4 – CL 300 mg/kg ration; data are presented as mean values ± SEM (standard error of the mean); ^{abc} – means within a column with different superscripts are significantly different at $P < 0.05$

Statistical analysis of the data obtained from the physical dissection of three ribs (Table 6) demonstrated an increase by 0.40 and 0.42 kg in T3 and T4 (200 and 300 mg/kg ration), respectively, in comparison to control (0.38 kg) at $P \leq 0.05$. T3 and T4 significantly reduced bone percentage (41.76 and 42.07%) when compared to control.

Discussion

Statically analysed data obtained in this study showed a significant increase in BW and BWG in group 3 and 4 of treated lambs (200 and 300 mg/kg CL ration), which was consistent with findings of Molosse et al. (2019), who fed 64 Lacaune lambs rations containing 100 and 200 mg/kg CL diet. Moreover, Al-Zabaie and Sultan (2020) conducted a study in Awassi male lambs reared on standard ration containing 100 and 200 mg/kg CL ration, and observed a significant increase in BW and BWG and improved immunity. In a study on 32 male Lacaune lambs fed a ration containing 100, 200, and 300 mg/kg CL, Marcon et al. (2021a) reported a significant increase in BW and BWG. Habeeb and El-Tarabany (2012), in their study on Zaraibi goats (4–5 months old) fed a ration containing 2 g/kg CL, observed a significant increase in BW and BWG during all months of the study. According to Cervantes-Valencia et al. (2016), CL improved body immunity by increasing plasma levels of IgG, IgM, and IgA. CL also improved the activity of digestive enzymes, such as trypsin, lipase, and creatine kinase (Jiang et al., 2016). Jaguezeski et al. (2019) argued that BW and BWG improvement could be related to the overall increase in antioxidant capacity and the reduction in lipid peroxidation; the latter authors also reported that CL showed antiparasitic potential that improved lamb performance. Many researchers concluded that CL effect on BW and BWG could be due to its anti-inflammatory and antibacterial properties (Jungbauer and Medjakovic, 2012; Fu et al., 2014) or a higher number of intestinal villi (Rahmani et al., 2018), increased fibre digestibility (Jaguezeski et al., 2018a), and stimulation of energy metabolism or antioxidant system (Jaguezeski et al., 2018b). Molosse et al. (2019), attributed the increase in BW and daily BWG to the stimulation of serum creatine kinase activity, which enhances energy metabolism. CL was also shown to increase quail performance due to its high antioxidant capacity (Marchiori et al., 2019). Macron et al. (2020) reported that curcumin could act as a growth enhancer improving lamb performance. Moreover, many authors (Jungbauer and Medjakovic, 2012; Fu et al., 2014; de Almeida et al., 2018; Molosse et al., 2019) concluded that CL was a potent anti-inflammatory agent.

In the current study, CL reduced carcass fat thickness in group T3 of lambs. According to the studies of Ejaz et al. (2009) and Lee et al. (2013), CL decreased adiposity by activating protein kinase – an energy regulator that inhibits adipocyte lipid synthesis. The increase in lean percentage and REA in three ribs of CL-fed lambs was reflected in carcass weight and dressing ratio. Carcass characteristics corresponded to those described by Al-Zabaie and Sultan (2020), who reported an increase in lean weight and REA when CL was introduced into the diet. It enhanced feed utilisation efficiency, resulting in an increase in the weight of individual carcass cuts. It is possible that medicinal plants or herbs have the ability to destroy or prevent the proliferation of harmful germs in the animal's stomach. According to Jiang et al. (2016), CL supplementation increased growth performance, metabolism, and inflammatory response. In addition, Jaguezeski et al. (2018a) also reported that curcumin improved digestibility, which could affect milk production and composition in terms of digestibility and carbohydrate, lipid, and protein metabolism parameters. CL was found to prevent and regulate inflammation, reduce oxidative stress and coccidian infections. When added to the ration, CL improved weight gain in calves of different ages due to its beneficial effects on feed digestion (Glombowsky et al., 2020). Moreover, Marcon et al. (2020) noted that CL supplementation improved the fatty acid profile in lamb meat by reducing SFA and increasing PUFA levels.

Powder formulations in microcapsules containing CL, when added to lamb rations, improved health and minimized oxidative stress (Marcon et al., 2021b), as well as provided anti-inflammatory benefits, which could indirectly increase BW. In the current study, turmeric caused a redirection of the fat storage pathway in Awassi lambs from the body parts to the broad tail. This could be due to a change in the carbohydrate conversion and storage metabolic pathways in the body of Awassi lambs.

Conclusions

Curcuma longa supplementation (300 mg/kg) increased body weight and body weight gain in Awassi lambs, and improved meat quality, as demonstrated by increased carcass weight, dressing percentage and lean %. In addition, directing the fat metabolic pathway in the animal's body towards the broad tail resulted in the production of carcasses desirable to consumers because they contained lower fat percentage.

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Conflict to interest

The Authors declare that there is no conflict of interest.

Data availability statement

The corresponding author will make the data used and analysed available upon reasonable request.

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