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RESEARCH ARTICLE

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Effects of distillated myrtle (*Myrtus communis* L.) leaves' intake on cull ewes' body weight gain, carcass composition and meat quality

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Abstract

Aim of study: Cull ewes are characterized by poor body condition, low body weights and tough meat texture. This work aimed to investigate the effect of distillated myrtle leaves (MDL) intake on body weight (BW) gain; carcass characteristics and meat quality of Barbarine cull ewes.

Area of study: Northwest of Tunisia

Material and methods: 27 Barbarine ewes were assigned into 3 groups receiving 500 g of oat hay and 750 g of concentrate control group (C), while they were given concentrate and pellets, containing 87% MDL, as substitute to hay in MHay group; for MConc group, they were fed hay, concentrate and pellets containing 30% MDL in partial substitution to concentrate. At the end of the fattening period (90 days), ewes were slaughtered.

Main Results: The dry matter intake was higher (p<0.05) for MConc and C groups. The average daily gain was significantly higher for C and MConc than MHay groups (113 and 107 *vs.* 87 g, respectively). Ewes fed MHay and MConc had a significantly lower feed conversion rate than Control group (12.5 *vs.* 15.4). Dietary treatment had no significant effect on carcass joint's weight and proportions. The dressing percentage and carcass tissue composition were similar for all groups. The ultimate pH, water cooking loss and color parameters values were unaffected by the type of diet.

Research highlights: These findings revealed that MDL could substitute, in ewes feeding, up to 87% to hay or up to 30% to concentrate without negative effects on body weight, carcass characteristics and meat quality.

Additional key words: feedstuffs; performance; diet; by-products

Abbreviations used: ADG (average daily gain); BW (body weight); C (control group); CCW (cold carcass weight); CDP (commercial dressing percentage); CP (crude protein); DM (dry matter); EBW (empty body weight); HCW (hot carcass weight); LTL (Longissimus Thoracis and Lumborum); MAT (total azote matter); MConc (group receiving pellets containing 30% distillate myrtle leaves, concentrate and hay); MDL (distillated myrtle leaves); MHay (group receiving pellets containing 87% distillate myrtle leaves and concentrate); OMF (omental and mesenteric fat); SBW (slaughter body weight).

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Ethics statement: All procedures employed in this study (transport and slaughtering) meet ethical guidelines, animal welfare adhere to humanitarian practices and Tunisian legal requirements (The Livestock Law No. 2005-95 of 18 October 2005).

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Introduction

The consumption of sheep meat is a part of gastronomic traditions for a large part of the world, representing a strategic component in diets for events and ceremonies (Krajnc *et al.*, 2020). However, its consumption was still low mainly related to its high price and high cost of production, particularly the feedstuff. In fact, feeding system represents a major part of the production costs in sheep farms; as well as a defining factor that affects the quality of its product (Majdoub-Mathlouthi *et al.*, 2015; Hajji *et al.*, 2016). Although young lamb meat represents the majority of sheep meat production, cull ewes may also have an important contribution in meat production system. Bhatt *et al.* (2012) reported that about 40% of sheep slaughtered in many developing countries fall under the category of cull animals. These ewes, older than 5-6 years, are generally characterized by poor body conditions and low body weights (Atti *et al.*, 2001; Bhatt *et al.*, 2012). Meat of cull ewes is tough due to an increased content of insoluble collagen (Kopp & Bonnet, 1987). However, Muir *et al.* (2001) have shown that increasing the level of ingestion before slaughter improves the potential of production and tenderness of the meat; thus, a suitable finishing system is required in order to increase body weight (BW) at slaughter which improves the financial incomes of farmers and provides better quality of meat to consumers. Several studies have showed that a short- term of high feeding level resulted in satisfactory BW gain (Atti & Mahouachi, 2011; Bhatt *et al.*, 2012). In terms of animal feeding, sheep husbandry in West Asia and North Africa region suffers from insufficient feeding resources because of rangeland's degradation and forage crop' surface reduction that lead to an excessive use of the concentrate and expensive feed supplies. In order to reduce production loads, and considering the highly increasing demand for safer and healthier products by consumers, many researchers studied the possibilities of using fodder shrubs and agro-industrial by-products as alternatives feed resources. However, by-products of aromatic and medicinal plants have not been commonly used in livestock feeding. The distillation industry of aromatic and medicinal plants generates substantial quantities of phenolic-rich by-products, which could be valuable natural sources of antioxidants. Some of these by-products, such as rosemary and thyme distillate leaves, have been the subject of investigations when included in animal's diet. They have proven to be effective sources of antioxidants, and permitted a body weight gain without undesirable effects on carcass characteristics and meat quality (Nieto *et al.*, 2010; Yagoubi *et al.*, 2018; Ben Abdelmalek *et al.*, 2019). However, the myrtle (*Myrtus communis* L.), which is an aromatic plant shrub distributed throughout the Mediterranean area, has not been used in animal feeding, despite it is widely used in folk medicinal practices as antimicrobial and antioxidant. It spreads over 22000 ha in Tunisia. Several studies have focused on the use of myrtle essential oil in the poultry diet (Birick *et al.*, 2012; Mahmoudi *et al.*, 2014). Myrtle distilled leaves (MDL) are discarded after extraction of the oils whereas these leaves can constitute an interesting alternative feed for ruminants given their protein and energy content and their richness on bioactive compounds (Mebirouk-Boudechiche *et al.*, 2014). Therefore, the present experiment aimed to optimize animal's feeding by incorporating different levels of MDL into the diet of Barbarine cull ewes in order to study its effect on BW gain, carcass characteristics and some meat traits.

Material and methods

Diets, animals and experimental design

The experiment was conducted at the National Institute of Agricultural Research of Tunisia (INRAT). All procedures employed in this study (transport and slaughtering) meet ethical guidelines and adhere to Tunisian legal requirements (The Livestock Law No. 2005-95 of 18 October 2005, Chapter II; Section 1 and Section 2 relative to the slaughter of animals) and the Halal slaughtering procedure. The MDL were collected from a Heno-Bio Company distillation placed in the Northwest of Tunisia (Nefza), and then air-dried in the shade for one week to ensure complete dehydration. Dried MDL were then ground and mixed in the manufactory with other ingredients in order to formulate two types of pellets with two MDL levels. The first (M87) was composed from 87% MDL and 13% wheat-bran to have a feed similar to oat hay. The second (M30) contains 30% MDL, 12% soya-bean and 58% barley; it is equivalent to the concentrate given its energy and proteins content (Table 1). Twenty-seven culled ewes (5-6 years old, BW= 35 ± 0.91 kg) were divided into three groups of 9 animals individually fed with a diet consisting of 1.250 kg feed per animal and day. The Control (C) group was fed 500 g of hay and 750 g of concentrate, the MHay group received 750 g of concentrate and 500 g of M87 pellets as substitute to hay. For the third group (MConc), the concentrate was partially substituted by M30; ewes received 500 g of oat-hay with 350 g of concentrate and 400 g of M30. The chemical composition of the feed is shown in Table 1. Feed was offered twice a day (9 h and 15 h) with free access to water; feed intake was daily recorded, and BW of ewes was recorded weekly in order to determine BW gain. At the end of the fattening period (90 days), all ewes were slaughtered.

Slaughter procedure and carcass trait measurements

At the end of the experiment, ewe's BW at slaughter (SBW) was recorded after a fasting period of 12 h. After slaughter, the bodies were skinned; the head and feet were removed and weighed. The weights of all body components such as internal organs, liver, lungs, omental and mesenteric fat, full and empty gut, were recorded. The digestive content was calculated as the difference between full and empty gut. Carcasses were weighed immediately after slaughter (hot carcass weight (HCW)) and after 24 h at 4°C to obtain the cold carcass weight (CCW).

Table 1. Chemical composition (%) of feedstuff for cull ewes with two type of pellets M87 (pellets containing 87% of distillated myrtle leaves (MDL)) and M30 (pellets containing 30% of MDL)

	Oat hay	Concentrate[1]	MDL	M87	M30
Dry matter	90.10	92.60	91.80	93	92.10
Organic matter	93.80	97.40	-	95	91.50
Crude protein	5.10	12.90	-	10.60	14.90
Total ash	6.20	2.60	-	5	8.50
Crude cellulose	31.80	6.20	-	14.40	8.50
Tannins (mg TAE/g)	6.88	3.07	153.43	72.41	25.17
NDF	63.80	44.98	33.56	37.59	30.85
ADF	36.39	10.21	24.11	20.69	11.29
ADL	3.49	1.25	8.78	5.99	2.91
Energy value (kcal)	1156	1870	-	1615	1717

[1] Concentrate composition: 76% barley, 12% soybean, 9% wheat bran and 3% mineral vitamin-supplement; NDF: neutral detergent fibre; ADF: acid detergent fibre; ADL: acid detergent lignin; TAE: tannic acid equivalents, expressed in mg g^{-1} dried sample.

The carcass joints were obtained following the procedures of Colomer-Rocher *et al.* (1988). The tail, kidneys and renal fat were removed and weighed and the carcasses were split lengthwise down the spine into two halves. The left side of the carcass was separated in leg, shoulder, neck, racks and breast (RB). First, the Longissimus thoracis and lumborum (LTL) muscles were separated to determine meat quality in the same day (24 h after slaughtering). The leg and the racks and breast, from which the LTL was removed, were covered by film and reserved at -20°C and then dissected into lean meat, bone, and fat (subcutaneous, intermuscular and pelvic) according to Colomer-Rocher *et al.* (1988). Each tissue was weighed separately in order to determine the carcass tissue composition. The empty BW (EBW) was determined by differences between SBW and gut content. The commercial dressing percentage (CDP) and the real dressing percentages (RDP) were determined.

Meat analysis

Meat qualitative parameters were measured on the left LTL muscles. Initial and ultimate pH (1 hour and 24 h after slaughter, respectively) were measured with penetrating electrode connected to a calibrated pH meter (HI99163; Hanna Instruments, Romania). To evaluate meat's color parameters, a Minolta spectrophotometer (CM-2006 d; Konica Minolta Holdings, Inc., Osaka, Japan) was used directly on the LTL muscle surface with a measured area of 8 mm, standard illuminant D65 and an observer angle 10° and zero, after blooming time of 30 min. Results were expressed according to CIE L*a*b* values (CIE, 1986): lightness (L*), redness (a*) and yellowness (b*), as the average of three measurements performed on cut surface area. In the aim to measure the cooking loss (WCL), about 30 g of each LTL meat sample was first weighed (initial weight, Wi), held in plastic bags, immersed in a water-bath at 80°C and heated for 30 min until the internal temperature reached 70°C, which was monitored with thermocouple. Then, the bags were cooled under running tap water and blotted dry with paper towels, the cooked meat was weighed again (final weight, Wf). The percentage of cooking losses were calculated as the difference between the weights and expressed as 100 × (Wi − Wf) / Wi.

Statistical analyses

The effect of MDL supplementation on productive performances, carcass and meat quality traits were assessed by ANOVA using the General Linear Model (GLM) procedure of SAS (2004) with Student's multiple range test and the statistical significance was defined at $p<0.05$. The model was: $Yij = \mu + Ri + eij$, where Y_{ij} represents the dependent variable, μ the mean, R_i the ration effect and eij the aleatory error. Mean squared errors (MSE) were determined for all analysis.

Results

Feedstuff composition and diet intake

Feed's chemical composition is shown in Table 1. Dry matter content ranged between 90 and 93%, while organic matter content ranged between 91.5 and 97.4%.

Crude protein (CP) content recorded for M30 pellets, containing 30% of distillate myrtle leaves, was higher (15%) than other feedstuffs. In fact, CP content found in concentrate presented 12.9%, M87 pellets (Pellets containing 87% of distillate myrtle leaves) contain about 10% of CP content while oat-hay contain only 5% of CP content. The tannins content was significantly higher in M87 and M30 pellets and in MDL. The average daily intake of feeds and components for all groups and diets' nutritional values are presented in Table 2. The diets provided an energetic value ranging from 1751 kcal d^{-1} ewe^{-1} to 1921 kcal d^{-1} ewe^{-1}. The DM intake was significantly higher for C and MConc than MHay group in relationship with the low intake of M87 in the last group (1139, 1143 and 1085 g DM day^{-1}, respectively). The CP intake was higher ($p<0.05$) for MHay and MConc than for the C group (130, 120 and 112 g day^{-1}, respectively).

Productive traits

MDL incorporation in the diet had a significant effect on ewes' productive traits. Final live weight (BW) was improved in all groups, the BW gain represented 17.3% of initial BW for MHay group; it was 21% for C and MConc groups; so the highest total weight gain was observed in C and MConc groups (Fig. 1). ADG values had the same tendency, being significantly higher for C than MHay group (113 *vs.* 87 g day^{-1}) (Table 2). ADG values of the three groups were fluctuating during the fattening period with a decreasing trend towards the end of the experiment. Ewes fed MHay or MConc had significantly better feed conversion rate than the C group (12.5 *vs.* 15.4; Table 2).

Carcass weight, dressing yield and carcass joints

Carcass weight and dressing yields are summarized in Table 2. The use of MDL pellets for MHay and MConc groups had no significant effect on EBW, HCW, CCW as well as commercial and true yields. For all groups, the commercial and true yields averaged 50.6% and 56.7%, respectively. The weight of different carcass joint is shown in Table 3. Among all groups, no significant differences were recorded between the percentages of leg, a first grade joint. Also, the shoulder also a first grade joint had similar proportion for all dietary treatments (17%). The mean weight of both leg and shoulder, first grade joints, was similar to that of thoracic region and tail, pieces containing most of the fat.

Carcass tissue composition

Feeding cull ewes diets supplemented with MDL did affect neither the thoracic region nor leg's tissue composition (Table 4). The thoracic region tissue composition averaged 46%, 25% and 29% of muscle, bone and fat,

Table 2. Average daily intake, body gain (ADG) and carcass traits of cull ewes and nutritional values of diets (g/ kg DM) for control group (C), MHay (group receiving pellets containing 87%) and MConc (group receiving pellets containing 30% MDL)

	Treatment			Statistics	
	C	**MHay**	**MConc**	**MSE**	***p*-value**
Intake (g/day day^{-1})					
Dry matter	1139^{a}	1085^{b}	1143^{a}	5.70	0.005
Organic matter	1093^{a}	1047^{b}	1075^{a}	5.46	0.008
Crude protein	112^{c}	131^{a}	120^{b}	0.63	0.001
Crude cellulose	186^{b}	99^{c}	195^{a}	0,82	0,001
Energy (kcal /kg kg^{-1})	1802^{b}	1921^{a}	1751^{c}	0.01	0.001
ADG (g)	113^{a}	87^{b}	107^{ab}	8.79	0.01
Feed efficiency (kg DM intake /kg kg^{-1} BW gain)	15.4^{a}	12.2^{b}	12.7^{b}	1.14	0.01
Slaughter body weight (kg)	42.8	40.7	41.9	0.98	0.07
Empty body weight (kg)	36.6	34.6	35.8	0.78	0.6
Hot carcass weight (kg)	21.1	20.6	21.2	0.59	0.9
Cold carcass weight (kg)	20.7	20.1	20.6	0.59	0.92
CDP (%)	50.0	51.0	51.0	0.54	0.65
RDP (%)	56.0	56.0	58.0	0.53	0.56

C: control group receiving oat hay and concentrate; CDP: carcass weight divided by slaughter body weight (SBW); RDP: carcass weight divided by empty body weight (EBW); MSE: mean squared error;

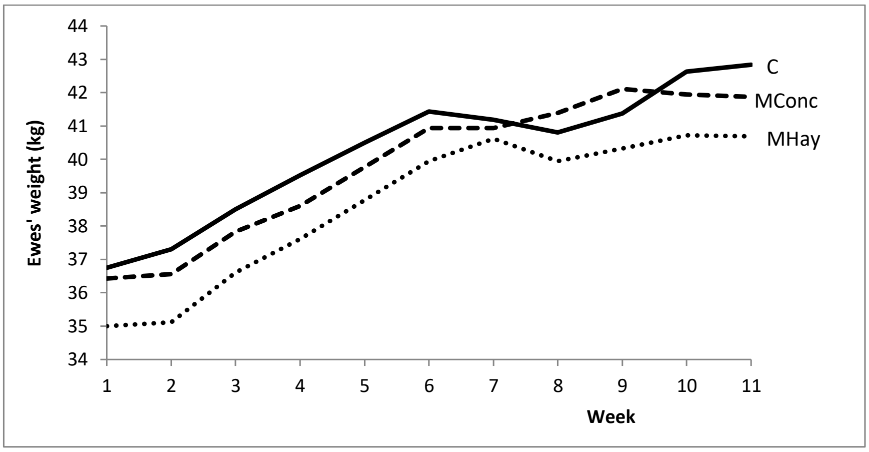

Figure 1. Cull ewe's body weight evolution for the control (C), MHay and MConc groups

respectively, while the leg composition averaged 59%, 20% and 21% of muscle, bone and fat, respectively.

Non-carcass components

The weights of non-carcass component and their proportions in EBW were not affected by the dietary treatment (Table 5). Weights of liver, feet, head and skin were similar among the three groups with average values of 0.6, 1, 2 and 4 kg, respectively. The same tendency was observed for their proportions relative to EBW. Digestive tract weights had an average value of 3 kg, and its proportions varied between 8.11% for MConc and 9.05% for MHay. The omental and mesenteric fat (OMF) proportions were not significantly affected by the diet; they ranged between 1.67% for MHay and 2.38% for MConc. The sum of weights of non-carcass component did not differ between the groups where we recorded values of 13 kg for C and 14 kg for MHay and MConc.

Meat pH, cooking loss and color parameters

The dietary treatment did not affect the pH, cooking loss and color parameters values (Table 6). The initial pH ranged between 6.16 and 6.25 in all groups. The water cooking loss values ranged between 21 and 25%. The meat's mean value for lightness (L*) recorded was around 35.5 and the redness was overall above 16.

Table 3. Regional carcass composition of cull ewes from control group (C) and two experimental groups MHay (group receiving pellets containing 87%) and MConc (group receiving pellets containing 30% MDL

	Treatment			Statistics	
	C	**MHay**	**MConc**	**MSE**	***p*-value**
Joints' weight					
Leg (kg)	3.02	3.05	3.31	0.09	0.38
Shoulder (kg)	1.71	1.55	1.76	0.05	0.28
Thoracic region (kg)	3.70	3.39	3.62	0.14	0.66
Neck (kg)	0.72	0.77	0.66	0.05	0.69
Fat tail (kg)	0.93	0.67	0.81	0.07	0.46
Joints' proportion					
Leg (%)	29.97	32.23	32.77	0.66	0.20
Shoulder (%)	17.19	16.50	17.44	0.51	0.73
Thoracic region (%)	36.64	35.52	35.50	0.87	0.83
Neck (%)	7.03	7.89	6.39	0.39	0.30
Tail (%)	9.17	7.86	7.90	0.50	0.48

MSE: mean squared error

Table 4. Tissue composition of leg and thoracic region of cull ewes from control group (C) and two experimental groups MHay (group receiving pellets containing 87%) and MConc (group receiving pellets containing 30% MDL)

	Treatment			Statistics	
	C	MHay	MConc	MSE	*p*-value
Thoracic region total weight (g)	3944	3506	3544	171.80	0.50
Tissue composition (g)					
Muscle	1722	1624	1568	62.70	0.60
Bone	1054	843	917	63.20	0.40
Fat	1168	1039	1059	81.60	0.78
Tissue composition (%)					
Muscle	45.05	47.35	44.82	1.38	0.71
Bone	26.65	24.43	25.08	1.05	0.68
Fat	28.29	28.21	30.08	1.49	0.84
Leg total weight (g)	2846	2965	3111	146.80	0.76
Tissue composition (g)					
Muscle	1717	1740	1789	67.80	0.9
Bone	558	565	579	31.10	0.96
Fat	571	660	744	90.60	0.74
Tissue composition (%)					
Muscle	61	59	58	1.48	0.64
Bone	20	20	19	1.49	0.92
Fat	19	21	23	2.27	0.69

MSE: mean squared error; g: tissue composition of leg and thoracic region expressed in grams; %: tissue composition leg and thoracic region expressed in percentage

Discussion

Feedstuff composition and diet intake

The energy level provided by the diet was sufficient to cover the energy requirements of ewes weighed 35 kg that is necessary to improve their growth rate. The difference in DM intake between diets may be explained by the high tannin content of MDL pellets (M87) (6.88 *vs* 72.41 mg TAE/g) contained in MHay diet. Ben Abdelmalek *et al.* (2019) reported that the lack of effect of rosemary residues on DM intake by cull ewes may be due to its high level of polyphenols; the phenolics and tannins are known for their anti-nutrient effect which affect negatively animal's feed intake when consumed at high level (Chriaa *et al.*, 1997). The substitution of oat hay by MDL pellets probably requires a longer adaptation period for ewes to accept the new feed. This result was confirmed by Rihani (1991), who showed that the incorporation of citrus by-products in animal diet requires a period of adaptation to avoid the decrease in the feed ingestion. These results are also in agreement with those reported by Ben Abdelmalek *et al.* (2019) for re-alimented cull ewes (1165 g day^{-1}). Yagoubi *et al.* (2018) found that total DM intake was higher for lambs fed two levels of rosemary distillation residues compared to control group. Higher CP intake in both dietary treatments was associated to the higher CP content in both MDL' pellets (14.9 and 10.6%). For the energy content, the MConc diet (where M30 pellets partially substituted the concentrate) resulted in the same value as the diet with 100% concentrate (Control). These results are in agreement with those of Mebirouk-Boudechiche *et al.* (2008), who showed that date scraps and barley have the same energy value so their association could be considered as a concentrate in lamb's diet.

Productive traits

Ewes of all groups, which initial BW was low, performed a cert body weight gain. It is important to point this phenomenon, which concretized the accomplishment of our main objective on body condition improvement and sheep meat production augmentation.

Table 5. Non-carcass components' weights and percentages in empty body weight (EBW) for cull ewes in two experimental groups MHay (group receiving pellets containing 87%) and MConc (group receiving pellets containing 30% MDL)

	Treatment			Statistics	
	C	MHay	MConc	MSE	*p*-value
Organs' weight (kg)					
Skin	4.36	3.90	3.94	0.12	0.22
Head	1.99	2.05	2.09	0.08	0.89
Feet	0.81	0.82	0.79	0.02	0.84
Liver	0.58	0.65	0.55	0.02	0.27
Red organs	1.58	1.77	1.54	0.04	0.11
Digestive tube (DT)	3.15	3.11	2.92	0.09	0.56
Mesenteric fat	0.70	0.51	0.74	0.07	0.43
Omental fat	0.79	0.58	0.87	0.06	0.18
Organs (%)					
Skin	11.9	11.23	11.04	3.30	0.48
Head	6.05	5.96	5.86	1.17	0.79
Feet	2.22	2.36	2.22	0.47	0.36
Liver	1.63	1.94	1.54	0.75	0.11
Red organs[1]	4.39 [ab]	5.08[a]	4.31[b]	1.35	0.07
DT	8.63	9.05	8.11	1.92	0.16
Mesenteric fat	1.89	1.44	2.00	1.81	0.43
Omental fat	2.10	1.67	2.38	1.57	0.21

[1]Red organs: heart, liver, lung and trachea. MSE: mean squared error

This result is in consistence with other results on feed restriction followed by higher energy level and the compensatory growth in young animals (Haddad & Younis, 2004; Mahouachi & Atti, 2005). The increase in BW gain percentages is comparable to that found by Bhatt *et al.* (2012) in cull ewes. However, the low average daily gain (ADG) for the MHay group, where M87 pellets were entirely substituted by the hay, could be explained by the high tannin' content of these pellets. It was shown that the high level intake of phenolics and tannins affect negatively the animal performance (Chriaa *et al.*, 1997). Guerrero *et al.* (2018) found that final BW of cull ewes was unaffected

Table 6. Meat characteristics for cull ewes in two experimental groups MHay (group receiving pellets containing 87%) and MConc (group receiving pellets containing 30% MDL

	Treatment			Statistics	
	C	MHay	MConc	MSE	*p*-value
L*	35.49	33.32	37.77	1.28	0.26
a*	17.24	16.4	16.75	0.24	0.99
b*	6.74	6.28	5.92	0.24	0.76
Cooking loss (%)	25.47	21.72	23.45	1.09	0.39
Initial pH	6.25	6.2	6.16	0.05	0.75
pH 24	5.78	5.79	5.7	0.04	0.63

L* (lightness), a* (redness), b* (yellowness); MSE: mean squared error by the level of linseed incorporation into diet; also, Ben Abdelmalak el al. (2019) recorded a comparable BW evolution among cull ewes fed diets containing rosemary residues and linseed. The ADG values variation may be related to the low energy intake (0.47 feed units for milk (UFL)) that ewes had before the experiment, which only covered the maintenance needs, as their diet were based on pasture and small amount of barley. After the first week of fattening, ADG values were high for all groups (223, 151 g day^{-1} for C and MConc, respectively, and 127 g day^{-1} for MHay), the energy intake increased (1870 kcal), and ewes fed concentrate and forage recovered their weight gain. Cabaraux *et al.* (2005) proved that the non-consistent variation of ADG in cull animals is related to the increase of maintenance needs, which result in a low energy availability to cover the needs of production thus a slow recovery of weight. Diets containing MDL did improve the feed conversion rate since they contain more energy intake and had higher protein content. Similar results were recorded by Guerrero *et al.* (2018) when culled ewes were fed linseed supplementation. Mahmoodi *et al.* (2014) also found that myrtle essential oil improves the feed conversion in broilers. Whereas, Nourozi *et al.* (2008) showed that feeding cull ewes a low energy diet resulted in a decreased feed efficiency. However, Ben Abdelmalek *et al.* (2019) found that ewes supplemented with rosemary residues tended to have the worst feeding efficiency.

Carcass weight, dressing yield and carcass joints

The similarity in EBW, HCW, and CCW as well as in commercial and true yields may be due to the similarity of the SBW among all groups (Sents *et al.*, 1982). Several studies reported that the lack of effect of dietary supplementation on carcass weight could be due to the fact that diets were isoenergetics and isonitrogenous (Urrutia *et al.*, 2015; Guerrero *et al.*, 2018). Similarly, Hajji *et al.* (2016) found that dietary protein level in lamb's diet had no effect on the slaughtering parameters. For the commercial and true yields the mean values recorded for Barbarine culled ewes in this trial were similar to those found by Bhatt *et al.* (2012) in Malpura breed ewes. In addition, Hajji *et al.* (2016) recorded similar values for CDP (49.5%) in heavy lambs of the same breed. In general, the dietary supplementation had no significant effect on carcass joint's weight and proportion. In fact, the average percentages of the leg and shoulder in the carcass are close to those previously reported for the same breed (Hajji *et al.*, 2016) and for other sheep breeds (Joy *et al.*, 2008). Similarly, Ben Abdelmalek *et al.* (2019) did not record effect of dietary supplementation of cull ewes with rosemary residues and linseed on carcass joints' weight. Hajji *et al.* (2016) explained similar results by the strong correlation between the carcass and joint's weights (Sents *et al.*, 1982). This constancy of joints proportions in carcass confirms the existence of the anatomical harmony recorded firstly by Boccard & Dumont (1960) and then confirmed by other authors for thin and fat tail sheep (Sents *et al.*, 1982; Atti & Mahouachi, 2011; Yagoubi *et al.*, 2018).

Carcass tissue composition

The similarity in bone weights can be explained by the fact that bone formation and development depends mostly on animal breed and age, not on its nutrition (Smeti *et al.*, 2014).

The leg contained more muscle (59%) and less fat (21%) than the thoracic region with 46% of muscle and 29% of fat, which approves the classification of leg as first grade joint and thoracic region as third grade joint (Hajji *et al.*, 2016). The thoracic region of animals from MHay group accumulates more muscle due to high protein in their diet. According to Roux *et al.* (1993) and Mahouachi *et al.* (2012), working on cow and goat, respectively, the proportion of the muscle is slightly higher for animals fed higher levels of protein. However, Hajji *et al.* (2016), by testing two protein levels in heavy lambs' diet, found that compared to the high diet protein level (16% MAT kg-1 DM), the low protein level (11% MAT kg-1 DM) tends to improve the proportions of muscle (36% *vs.* 34%) in carcass joints with low fat level like leg but not the third grade region. Bhatt *et al.* (2012) also recorded higher fat gain.

Non-carcass components

The non-carcass component's weights are in agreement with several authors who confirmed that head and feet, having a high bone content as well as being early maturing and low fattening organs, are less affected than the late maturing ones by food treatment in finishing period (Smeti *et al.*, 2014; Yagoubi *et al.*, 2018). The skin is characterized by a high metabolic activity and it is proportionally related to EBW, so in animals with the same EBW, the proportions of the skin are similar (Smeti *et al.*, 2014). Even though the liver's proportion did not significantly differ among groups, it was slightly higher in ewes from the MHay group with 1.94% *vs.* 1.63% and 1.54% for C and MConc, respectively; this result may be due to the higher CP content in MHay diet. It has been shown that liver weight can be affected by animals' diet (Bhatt *et al.*, 2012; Yagoubi *et al.*, 2018). It was shown that the liver and the digestive tract are organs whose energy expenditure, activity and weight increase with intake (Lindsay, 1993; Reynolds, 1995; Mahouachi & Atti, 2005), which explains the slight weight superiority of the digestive tract, associated with lower intake of the total ration in the MHay group. The mesenteric and omental fat (OMF) content was unaffected by the diet. Joy *et al.* (2008) showed that lambs with high carcass fat content had the highest OMF content; however, in the current study, fat content was similar between all groups, which may explain the results. The sum of weights of non-carcass components was similar among groups. These findings are in agreement with previous researches confirming that the weight of non-carcass components depends mostly on weight at slaughter and animal age, sex and breed (Hajji *et al.*, 2016). Ben Abdelmalek *et al.* (2019) found similar results for cull Barbarine ewes.

Meat pH, cooking loss and color parameters

After 24 h postmortem, the ultimate pH decreased to reach, for all groups, an average value of 5.75 since the glycogen reserves were exhausted. This value was within the normal range determined for ovine meat, considering a value of 5.8 as a threshold for a good microbiological and physic-chemical quality (Ben Abdelmalek *et al.*, 2019). This result is explained by the rate of glycogen breakdown in the muscle that leads to a decrease in meat pH at post mortem (Kadim *et al.*, 2006). Similarly, Guerrero *et al.* (2018) reported a lack of effect of linseed supplementation in cull ewe's diet, on its meat's ultimate pH. The water cooking loss is an indicator of water binding capacity of the meat, which is affected by moisture, protein and fat content (Choe *et al.*, 2013). In fact, normal cooking changes the composition of animal fat; reduction in mass can be from 20 to 35% of which 70-80% is lipid cookout (Karami *et al.*, 2011). The low pH values in post-mortem muscle leads to a decrease in water binding capacity of meat, due to the denaturation of muscle protein, particularly myosin (Wiklund *et al.*, 2001), thus a rapid decline of pH caused an increase in the denaturation rate. In the current study, pH values were acceptable and unaffected by the diet, which could explain the similarity in cooking loss values among groups. Ben Abdelmalek *et al.* (2019) found similar results with cull ewes fed linseed and rosemary residues, The type of diet did not have significant effect (p>0.05) on LTL muscle color parameters. The meat's mean value for lightness (L*) recorded was around 35.5, similar to the value found by Smeti *et al.* (2018). Comparable values were also recorded for yellowness (b*). Redness (a*) values were above 16 in all groups, this result is in acceptability range for good quality meat (Khliji *et al.*, 2010).

Similarly, Yagoubi *et al.* (2018) found that a dietary diet supplemented with rosemary residues did not affect meat's color parameters. Nieto *et al.* (2010), did not record effect of diet added with rosemary by-product on meat redness. Likewise, Realini *et al.* (2017) reported this lack of effect of diet on meat color. Similar results were reported by Yagoubi *et al.* (2018) and Guerrero *et al.* (2018) using linseed on heavy lambs and culls ewes, respectively.

In summary, with all dietary treatments, Barbarine cull ewes achieved a considerable BW gain, which should encourage its fattening operation. The total substitution of hay or partial of concentrate by MDL pellets, in ewe's diet improved BW gain and the conversion rate. Feeding culled ewes by MDL pellets had no significant effect on carcass joint's weight, tissue composition as well as their meat traits. Thus, MDL, a widely available and cheap by-product in Mediterranean area, could be included in animal's diet in substitution of hay or concentrate and considered as an alternative feeding strategy in order to decrease production costs and improve sheep farmers' incomes without a negative effect on sheep performances and their meat quality.

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References

Atti N, Thériez M, Abdennebi L, 2001. Relationship between ewe body condition at mating and reproductive performance in the fat-tailed Barbarine breed. Anim Res 50: 135-144. https://doi.org/10.1051/animres:2001121

Atti N, Mahouachi M, 2011. The effects of diet, slaughter weight, and docking on growth, carcass composition and meat quality of fat-tailed Barbarine lambs: A review. Trop Anim Health Prod 43: 1371-1378. https://doi.org/10.1007/s11250-011-9865-6

Ben Abdelmalek Y, Smeti S, Mekki I, Hajji H, Essid I, Atti N, 2019. Rehabilitation of Barbarine cull ewes using rosemary residues and linseed: effect on weight gain, carcass characteristics and meat quality. Animal 13: 879-887. https://doi.org/10.1017/S175173111800215X

Bhatt RS, Soren NM, Sahoo A, Karim SA, 2012. Level and period of realimentation to assess improvement in body condition and carcass quality in cull ewes. Trop Anim Health Prod 45: 167-176. https://doi.org/10.1007/s11250-012-0188-z

Birick H, Yesilbag D, Gezen SS, Bulbul T, 2012. Effects of dietary myrtle oil (*Myrtus communis* L.)

supplementation on growth performance, meat oxidative stability, meat quality and erythrocyte parameters in quails. Revue de Médecine Vétérinaire 163 (3): 131-138.

Boccard R, Dumont BL, 1960. Étude de la production de la viande chez les ovins. Variation de l'importance relative des différentes régions corporelles de l'agneau de boucherie. Annales de Zootechnie 9 (4): 385-398. https://hal.archives-ouvertes.fr/hal-00886736/document

Cabaraux JF, Dufrasne I, Roux M, Istasse L, Hornick JL, 2005. La production de viande bovine à partir de femelles de réforme. INRA Productions Animales 18 (1): 37-48. https://doi.org/10.20870/productions-animales.2005.18.1.3508

Choe JH, Kim HY, Lee JM, Kim YJ, Kim CJ, 2013. Quality of frankfurter-type sausages with added pigskin and wheat fiber mixture as fat replacers. Meat Sci 93: 849-854. https://doi.org/10.1016/j.meatsci.2012.11.054

Chriaa A, Moore KJ, Waller SS, 1997. Browse foliage and annual legume pods as supplements to wheat straw for sheep. Anim Feed Sci Technol 66: 85-96. https://doi.org/10.1016/S0377-8401(96)01132-7

CIE, 1986. Colorimetry, 2nd ed. Commission Internationale de L'Eclairage, Viena.

Colomer-Rocher F, Delfa R, Sierra I, 1988. Método normalizado para el estudio de los caracteres cuantitativos y cualitativos de las canales ovinas producidas en el área mediterránea según los sistemas de producción. Cuadernos INIA 17: 19-41. https://citarea.cita-aragon.es/citarea/handle/10532/1424

Guerrero A, Sañudo C, Campo M, Olleta J, Muela E, Macedo R, Macedo F, 2018. Consumer acceptability of dry cured meat from cull ewes reared with different linseed supplementation levels and feeding durations. Foods 7: 89. https://doi.org/10.3390/foods7060089

Haddad SG, Younis HM, 2004. The effect of adding ruminally protected fat in fattening diets on nutrient intake, digestibility and growth performance of Awassi lambs. Anim Feed Sci Technol 113: 61-69. https://doi.org/10.1016/j.anifeedsci.2003.10.015

Hajji H, Smeti S, Ben Hamouda M, Atti N, 2016. Effect of protein level on growth performance, non-carcass components and carcass characteristics of young sheep from three breeds. Anim Prod Sci 56: 2115-2121. https://doi.org/10.1071/AN14917

Joy M, Ripoll G, Delfa R, 2008. Effects of feeding system on carcass and non-carcass composition of Churra Tensina light lambs. Small Rumin Res 78: 123-133. https://doi.org/10.1016/j.smallrumres.2008.05.011

Kadim IT, Mahgoub O, Al-Kindi A, Al-Marzooqi, W, Al-Saqri NM, 2006. Effects of transportation at high ambient temperatures on physiological responses, carcass and meat quality characteristics of three breeds of Omani goats. Meat Sci 73: 626-634. https://doi.org/10.1016/j.meatsci.2006.03.003

Karami M, Alimon AR, Sazili AQ, Goh, YM, Ivan M, 2011. Effects of dietary antioxidants on the quality, fatty acid profile, and lipid oxidation of longissimus muscle in Kacang goat with aging time. Meat Sci 88: 102-108. https://doi.org/10.1016/j.meatsci.2010.12.009

Khliji S, Van de Ven R, Lamb TA, Lanza M, Hopkins DL, 2010. Relationship between consumer ranking of lamb colour and objective measures of colour. Meat Sci 85: 224-229. https://doi.org/10.1016/j.meatsci.2010.01.002

Kopp J, Bonnet M, 1987. Stress-strain and isometric tension measurement in collagen. In: Advances in meat research, collagen as food; Pearson AM, Dutson TR (eds.). pp: 163-185. van Nostr and Reinhold, NY.

Krajnc B, Bontempo L, Araus Ortega JL, Giovanetti M, Alegria C, Lauteri M, Augusti A, Atti N, Smeti S, Taous F, *et al.*, 2020. Selective methods to investigate authenticity and geographical origin of mediterranean food products. Food Rev Int 1-27. https://doi.org/10.1080/87559129.2020.1717521

Lindsay DM, 1993. Metabolism of the portal drainer viscera. In: Quantitativ aspects of ruminant digestion and metabolism; Forbes JM, France J (Eds), pp: 267-289. CAB Int, Wallingford.

Mahmoudi BM, Salehi A, Sharifi SD, 2014. Growth performance, carcass characteristics, antibody titer and blood parameters in broiler chickens fed dietary myrtle (*Myrtus communis*) essential oil as an alternative to antibiotic growth promoter. Poultry Sci J 2: 37-49.

Mahouachi M, Atti N, 2005. Effects of restricted feeding and re-feeding of barbarine lambs: intake, growth and non-carcass components. Anim Sci 81: 305-312. https://doi.org/10.1079/ASC41380305

Mahouachi M, Atti N, Hajji H, 2012. Use of spineless cactus (Opuntia ficus indica f. inermis) for dairy goats and growing kids: impacts on milk production, kid's growth and meat quality. The Scientific World Journal 2012: 321567. https://doi.org/10.1100/2012/321567

Majdoub-Mathlouthi L, Saïd B, Kraiem K, 2015. Carcass traits and meat fatty acid composition of Barbarine lambs reared on rangelands or indoors on hay and concentrate. Animal 9: 1-7. https://doi.org/10.1017/S1751731115001731

Mebirouk-Boudechiche L, Araba A Ouzrout R, 2008. Influence du type de complément énergétique (rebuts de dattes *vs.* orge) sur les performances d'engraissement et caractéristiques des carcasses d'agneaux berbères à l'engraissement. Revue Élev Méd Vét Pays Trop 61: 209-214. https://doi.org/10.19182/remvt.9991

Mebirouk-Boudechiche L, Cherif M, Boudechiche L, Sammar F, 2014. Teneurs en composés primaires et secondaires des feuilles d'arbustes fourragers de la région humide d'Algérie. Revue Méd Vét 165: 344-352

Muir PD, Smith NB, Dobbie PM, Smith DR, Bown MD, 2001. Effects of growth path on beef quality in 18-month-old Angus and South Devon*Angus pasture fed steers. Anim Sci 72: 297-308. https://doi.org/10.1017/S135772980005579X

Nieto G, Díaz P, Bañón S, Garrido MD, 2010. Dietary administration of ewe diets with a distillate from rosemary leaves (Rosmarinus officinalis L.): Influence on lamb meat quality. Meat Sci 84: 23-29. https://doi.org/10.1016/j.meatsci.2009.08.001

Nourozi M, Abazari M, Raisianzadeh M, Mohammadi M, ZareShahne A, 2008. Effect of terbutaline and metaproterenol (two beta-adrenergic agonists) on performance and carcass composition of culled Moghani ewes. Small Rumin Res 74: 72-77. https://doi.org/10.1016/j.smallrumres.2007.03.009

Realini CE, Bianchi G, Betancur O, Garibotto G, 2017. Effect of supplementation with linseed or a blend of aromatic spices and time on feed on fatty acid composition, meat quality and consumer liking of meat from lambs fed dehydrated alfalfa or corn. Meat Sci 127: 21-29. https://doi.org/10.1016/j.meatsci.2016.12.013

Reynolds CK, 1995. Quantitative aspects of liver metabolism in ruminants. In: Ruminant physiology: digestion, metabolism, growth and reproduction; Engelhardt WV *et al.* (Eds), pp: 351-371. Ferdinand Enke Verlag, Stuttgart, Germany.

Rihani N, 1991. Valeur alimentaire et utilisation des sous-produits des agrumes en alimentation animale. Opt Méditerr 16: 113-117.

Roux M, Dumont R, Agabriel J, Bonnemaire J, Micol D, 1993. Engraissement des vaches de réforme de race Charolaise. Effet d'une suralimentation protéique sur les performances d'engraissement et les caractéristiques physicochimiques musculaires. INRA Prod Anim 6: 237-248. https://doi.org/10.20870/productions-animales.1993.6.3.4204

SAS, 2004. The SAS version 8.2. SAS Inst. Inc., Cary, NC, USA.

Sents AE, Walters LE, Whiteman JV, 1982. Performance and carcass characteristics of ram lambs slaughtered at different weights. J Anim Sci 55: 1360-1369. https://doi.org/10.2527/jas1982.5561360x

Smeti S, Atti N, Mahouachi M, 2014. Effects of finishing lambs in rich aromatic plant pasture or in feedlot on lamb growth and meat quality. J Appl Anim Res 42: 297-303. https://doi.org/10.1080/09712119.2013.845102

Smeti S, Hajji H, Mekki I, Mahouachi M, Atti N, 2018. Effects of dose and administration form of rosemary essential oils on meat quality and fatty acid profile of lamb. Small Rumin Res 158: 62-68 . https://doi.org/10.1016/j.smallrumres.2017.10.007

Urrutia O, Soret B, Insausti K, Mendizabal JA, Purroy A, Arana A, 2015. The effects of linseed or chia seed dietary supplementation on adipose tissue development, fatty acid composition, and lipogenic gene expression in lambs. Small Rumin Res 123: 204-2011. https://doi.org/10.1016/j.smallrumres.2014.12.008

Wiklund E, Stevenson-Barry JM, Duncan SJ, Littlejohn RP, 2001. Electrical stimulation of red deer (Cervus elaphus) carcasses: effects on rate of pH-decline, meat tenderness, colour stability and water-holding capacity. Meat Sci 59: 211-220. https://doi.org/10.1016/S0309-1740(01)00077-8

Yagoubi Y, Hajji H, Smeti S, Mahouachi M, Kamoun M, Atti N, 2018. Growth performance, carcass and non-carcass traits and meat quality of Barbarine lambs fed rosemary distillation residues. Animal 12: 2407-2414. https://doi.org/10.1017/S1751731118000071