

Effect of Carob Pulp (*Ceratonia siliqua* L.) on Fattening Performance, Carcass Characteristics and Meat Quality of Moroccan Breed Deroua Lambs

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This study aimed to evaluate the effect of incorporating different levels of carob pulp (CP) on fattening performance, carcass characteristics and meat quality of the Moroccan sheep breed Deroua. Thirty-six entire male Moroccan breed Deroua lambs with an initial body weight of 23.5 ± 3.1 kg and age 120 ± 10 days, were randomly divided into three diet treatments of 12 animals: T₀ (0%CP), T₁ (10%CP) and T₂ (20%CP) containing 0, 10 and 20 % of CP, respectively. The experiment lasted 80 days, including 5 days of adaptation to different diets. Lambs were weighed every 15 days, while feed intake was determined daily. At the end of the experiment, 27 lambs (9 per treatment) were slaughtered to determine carcass characteristics and meat quality. Final body weight and average daily gain ($P < 0.05$) were affected by treatment diet. The inclusion of 10% CP led to a decrease in feed conversion ratio and feeding costs. Carcass characteristics were not affected by diets ($P > 0.05$), except, in case of mesenteric fat ($P < 0.05$) with superiority recorded in treatment diet T₁ (10%CP). Meat quality parameters were not affected by diets. The meat of lambs fed diets T₁ and T₂ tended to be lighter in color and less red than those fed diet T₀. The results of this work showed that carob pulp can be used as an alternative feedstuff from fattening lambs to reduce feeding costs without affecting fattening performance.

Keywords: Carob pulp, Deroua lambs, fattening performance, carcass characteristics, meat quality

In Morocco, small ruminant production is considered the main source of income of farmers living in arid and semi-arid areas in which small ruminants are raised mainly on the natural rangelands. The limited forage availability is the main constraint to the sustainable development of

small ruminant production in these areas. In the last decade, the climatic changes mainly the frequency of dry seasons with less rainfall are becoming structural leading to an excessive increase of the price of conventional foodstuffs and consequently an over grazing (Chebli et al. 2018 and Chebli

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al. 2020). Faced this situation, breeders are obliged to adopt new options and feeding strategies in order to ensure their income.

Non-conventional feedstuffs, including agricultural and agro-industrial by-products, present an unavoidable opportunity to maintain the production performances during critical periods, ensure the viability of livestock through reducing feed cost, improve the living conditions of farmers through the improvement of the profitability of their livestock and reduce overgrazing on pastoral and sylvan-pastoral forage resources. Many researches (Awawdeh *et al.* 2019; Vasta *et al.* 2008; Blache *et al.* 2008; Medjekal *et al.* 2018 and Karabulut *et al.* 2006) reported that alternative feed resources can be used for animal feeding without a negative effect on production performance and therefore reduce the independence of livestock from conventional feed (Grasser *et al.* 1995).

Carob pulp (CP) is one of the by-products of the agro-industry produced in large quantities in Morocco. This locally feedstuff seems to be promising as alternative feedstuff for small ruminant feeding. Scarce works were studied the effect of incorporating carob pulp in Moroccan sheep diet on fattening performance, carcass characteristics and meat quality and precisely on the Moroccan Deroua breed. Therefore, the aim of the present study is to evaluate the effect of CP incorporation in fattening lambs feed on production performances, carcass characteristics and meat quality.

MATERIAL AND METHODS

Animals, diets and experimental protocols

The experiment was carried out at the Deroua experimental station in the Tadla Regional Agricultural Research Centre (INRA-Morocco). Thirty-six entire male Moroccan breed Deroua lambs (with 23.5 ± 3.1 kg of initial body weight and 120 ± 10 days of age), previously vaccinated against enterotoxemia and treated for internal and external parasites, were divided into three homogeneous groups of 12 lambs each. Each group was assigned randomly to one of three diets: T0 (25% lucerne hay, 6% wheat straw, 22% maize grain, 40% barley grain, 0% carob pulp, 7% sunflower meal), T1 (25% lucerne hay, 6% wheat straw, 22% maize grain, 30% barley grain,

10% carob pulp, 7% sunflower meal) and T2 (25% lucerne hay, 6% wheat straw, 22% maize grain, 20% barley grain, 20% carob pulp, 7% sunflower meal). All diets were formulated to be isonitrogenous, isoenergetic, and to meet nutrient requirements of growing lambs (Agabriel, 2007). The chemical composition of the feedstuffs used to formulate treatment diets is presented in Table 1. The experiment lasted 80 days, including five days of adaptation to the tested diets.

Chemical analysis of feed stuff

The chemical composition of feedstuff used to formulate the treatment diets concerned dry matter (DM), organic matter (OM), ash, crude protein and fiber (NDF, ADF and ADL). OM was determined by ashing at 650°C for 8 hours. Proteins were determined following the Kjeldahl method using Se as a catalyst and a Buchi 335 apparatus. The NDF, ADF and ADL were measured with an ANKOM200 FiberAnalyzer according to the method described by Van Soest *et al.* (1991).

Feed intake, feed conversion ratio and feeding cost

Diets were offered twice daily (at 09:00am and 02:00pm) as a total-mixed ration (TMR) tolerates 10% refusals. The intake amounts were determined daily morning as the difference between the quantities offered the day before and the refusal. The lambs had free access to fresh water and blocks of mineral and vitamin complement (CMV) throughout the experiment. The feed conversion ratio (FCR) was calculated as the ration of feed requirement in kg dry matter and body weight gain (kg) (Wenk, 1980). The feeding cost was estimated based on the prices (Moroccan Dirham MAD) of diet ingredients during the experiment period by dividing the cost of feed intake by the average daily gain (kg BW) (Coffey and Laurent, 2014).

Fattening performance

All lambs were weighed at the beginning and at the end of the experiment and every 15 days before the morning using an electronic scale (capacity 120 ± 0.01 kg). The average daily gain (g/day) was calculated as the ratio of the difference between final body weight and initial body weight and the duration of the experiment.

Slaughtering procedure, carcass characteristics and meat quality

At the end of the experiment, nine lambs from each group were randomly selected to

evaluate carcass characteristics and meat quality. The animals were moved to the holding room (an annex of the slaughterhouse) 18 hours before slaughtering. Just before slaughtering, the animals were weighed. After slaughtering, the animals were skinned and eviscerated and mesenteric fat, the hot carcass weight and pH0 were recorded. Subsequently, the carcasses were chilled at 4°C for 24 h. The day after slaughtering, the cold carcass weight, pH24 and pelvic-renal fat were recorded and the Rectus abdominis muscle and subcutaneous fat were evaluated. In addition, the color of the meat (*Longissimus dorsi*) and the water-holding capacity were evaluated.

The color of the meat (*Longissimus dorsi*) was evaluated 24 hours post-mortem using a Chromameter CR410 (KONICA MINOLTA). The pH of *Longissimus dorsi* was measured just after slaughtering and after 24 hours post-mortem using a pH meter for food products (HANNA instrument inc. Woonsocket - USA). The water-holding capacity was evaluated according the method cited by Hamm (1986) by placing 0.3±0.05g sample of the *Longissimus dorsi* meat from the chilled carcass between two plexiglass plates to a thin film and compressed by a 2.25 kg weight for 5 min, the water squeezed out is absorbed by the filter paper.

Statistical analysis

The effect of diet on production performances, carcass characteristics and meat quality was analysed by means of a one-way analysis of variance (ANOVA) using the PROC GLM procedure of the SAS statistical package (version 9.4) according to the model:

$$Y_{ij} = \mu + a_i + e_{ij}$$

Where

μ = mean, a_i represents the effect of diet and e_{ij} the experimental error.

RESULTS AND DISCUSSION

Intake, feed conversion ratio and feeding cost

The intake, feed conversion ratio and feeding costs of lambs fed different levels of CP are shown in Table 2. The results showed that the intake (kg DM/d) increases by increasing the level of the CP in the diet. This increase in dry matter can be explained by the high content of the CP in tannins, which could reduce the availability of

nutrients to animals (Provenza 1995). These results are in agreement with those of Priolo *et al.* (1998), who reported that the inclusion of 20% of carob pulp (in substitution of barley) in a fattening diet, results in an increase of 14% of the ingested dry matter compared to the control diet. Obeidat *et al.* (2011) reported that the inclusion of carob pods up to 250 g/kg in substitution of barley grain did not affect feed intake. Similarly, Gobindram *et al.* (2016) found that dry matter intake was not significantly affected by the incorporation of 35% of the carob pulp. However, Guessous *et al.* (1988) and Silanikove *et al.* (2006) reported that the inclusion of 30% and 50% of carob pulp decreased significantly the dry matter intake. The difference between the results of the different studies could be related to the variation in the diet composition, level

Regarding the feed conversion ratio (FCR), the incorporation of carob pulp in the diet led to an improvement of CR (Table 2). The lowest value was recorded in lambs receiving the T₁(10%CP) diet followed by T₂(20%CP) and lastly the control diet. These results were consistent with those of Guessous *et al.* (1988) who reported an improvement in FCR from 7.67 to 6.95 kg DM/kg when the carob pulp percentage was reduced from 30% to 15%. In goats, Ayadi *et al.* (2014) mentioned that the use of 5% of carob pulp in the diet of kids showed an improvement in FCR. Similarly, Priolo *et al.* (1998) observed that the inclusion of 20% improved feed efficiency.

Feeding cost was lower in lambs fed the T₁(10%CP) than those fed the T₀(0%CP) and T₂(20%CP) diets (Table 2). The incorporation of CP at level 10% reduced 20% of feeding costs. The results obtained are similar to those found by Obeidat *et al.* (2012) who reported that the incorporation of 20% of carob pod in Awassiewe's diet resulted decreased the feeding cost of 18%. In addition, Obeidat *et al.* (2011) and Awawdeh *et al.* (2019) reported that the incorporation of carob pods in Awassi lamb fattening led to a significant decrease in feeding cost.

Body weight (BW) and average daily gain (ADG)

Growth performances (BW, ADG) results are shown in Table 3. The best fattening performances were obtained in the lambs receiving the T₁ (10%CP) diet followed by those fed the T₀

diet and lastly those receiving the T2 diet. Both parameters (BW and ADG) were significantly affected ($p < 0.05$) by the treatment diets indicating that incorporation of the CP at the level 10% affected positively fattening performances, however they were affected negatively by the inclusion of 20% of CP. These results were inconsistent with those obtained by Ouchkif (1988) and Guessous *et al.* (1988) who reported that incorporation of 20% CP for fattening of synthetic breed lambs "Dman*Sardi" affected positively the average daily gain. In addition, no effect on lamb performance were registered when treatment diet contained 250g/kg of CP (Awawdeh *et al.* 2019, Obeidat *et al.* 2011 and Priolo *et al.* 1998) and 350g/kg Gobindram *et al.* (2016). On the other hand, Guessous *et al.* (1988) and Silanikove *et al.* (2006)

showed that incorporation of CP at levels 30% and 50%, respectively had a negative effect on lamb growth performances. Similarly, Awawdeh *et al.* (2019) observed that at the high inclusion level (500g/kg) of CP reduced lamb performances.

Carcass characteristics

Carcass characteristics (dressing carcass, fat and color) are presented in Table 4. The results show that lambs fed T₂(20%CP) diet tended to have lower hot and cold dressing carcass percentage and pelvic-renal fat weight compared with those fed the control diet. Whereas for mesenteric fat weight, the high value was recorded in lambs fed T₁(10%CP). Hot and cold carcass dressing percentage ($p > 0.7$) and pelvic-renal fat weight ($p > 0.3$) were not affected by the treatment diet. However, there were differences among dietary treatments regarding

Table 1. Chemical composition (% DM) of feedstuffs used

	Lucerne hay	Wheat straw	Maize grain	Barley grain	Carob pulp	sunflower meal
Dry matter	89.4	90.6	91.6	91.4	93.6	89.0
Organic matter	91.8	93.1	98.1	96.4	96.3	94.1
Ash	8.2	6.9	1.9	3.6	3.7	5.95
Crud protein	15.8	4.2	7.9	9.8	4.5	28.4
Neutral detergent fiber	50.9	76.4	18.6	19.3	34.7	44.2
Acid detergent fiber	38.2	50.6	3.1	6.9	22.5	31.9
Acid detergent lignin	7.1	8.8	0.5	1.5	11.7	8.7

Table 2. Intake, feed conversion ratio and feeding cost

Parameters	Diet		
	T ₀ (0%CP)	T ₁ (10%CP)	T ₂ (20%CP)
Intake (kg DM/d)	1.28	1.41	1.48
Feed conversion ratio (kg DM/kg of gain)	6.83	5.68	7.62
Feeding cost (MAD/kg of gain)	15.10	12	15.40

T₀: Control diet; T₁: Diet containing 10% carob pulp; T₂: Diet containing 20% carob pulp; MAD: Moroccan dirham (1MAD = 0.09€)

Table 3. Body weight and average daily gain of male Deroua lambs fed different levels of CP

Parameters	Diet			SEM	P
	T ₀ (0%CP)	T ₁ (10%CP)	T ₂ (20%CP)		
Initial Body weight (kg)	23.89	24.51	23.73	-	-
Final Body weight (kg)	41.53 ^{ab}	43.18 ^a	40.74 ^b	1.06	0.0107
Average daily gain (g/day)	212.51 ^{ab}	238.16 ^a	201.8 ^b	8.29	0.0214

T₀: Control diet; T₁: Diet containing 10% carob pulp; T₂: Diet containing 20% carob pulp, ^{a, b}, means followed by the same letter are not significantly at P=0.05, SEM: Standard error of the mean

the mesenteric fat ($p < 0.05$). The obtained results are consistent with those of Priolo *et al.* (1973) who found that the inclusion of 20% CP in the diet of Comisana fattening lambs generates a decrease (-2.07%) of adressingcarcass percentage. Similarly, Awawdeh *et al.* (2019) reported that lambs fed the diet with 50% of CP tended to have a lower dressing percentage. In contrast, Obeidat *et al.* (2011) dietary inclusion of CP at 250 g/kg; Guessous *et al.* (1988) inclusion of CP at level 20% had no effects on hot and cold carcass dressing percentage of lambs. For fat deposition, Consistent with our results Awawdeh *et al.* (2019) found that the addition of 25% carob pod in the fattening diet of Awassi lambs led to higher fat deposition. The results of the carcass color, assessed through the *Rectus abdominis* muscle and the subcutaneous fat, are presented in the Table 4. No significant effect of

CP incorporation on the color of both parts of the carcass was observed. However, the results show that lambs fed T_2 (10%CP) diet tended to have a higher lightness of the *Rectus abdominis* muscle.

Meat quality

Parameters of meat quality (pH, color and water holding capacity) are presented in the Table 5. The results show that all parameters were not affected by the experimental diet. The recorded pH₂₄ (ultimate pH) values were 5.72, 5.72 and 5.74 for control diet, T_1 (10%) and T_2 (20%), respectively, indicating that the animals were not stressed during the slaughtering (Carrasco *et al.* 2009). These results are similar to those obtained by Obeidat *et al.* (2011) using carob pulp at levels 125 and 250g/kg and those obtained by Awawdeh *et al.* (2019) incorporating carob pulp at levels 250 and 500g/kg. In contrast, Priolo *et al.*

Table 4. Carcass characteristics of Deroua lambs fed different levels of carob pulp

Parameters	Diet			SEM	P
	T_0 (0%CP)	T_1 (10%CP)	T_2 (20%CP)		
Hot carcass yield (%)	51.87	51.05	49.96	0.573	0.0707
Cold carcass yield (%)	50.6	49.83	48.83	0.550	0.0843
mesenteric fat (kg)	0.7 ^a	1.0 ^b	0.6 ^a	0.07	0.006
Pelvic-renal fat (kg)	0.50	0.49	0.42	0.045	0.3453
L_{RAM}	50.9	55.2	50.6	1.51	0.079
a_{RAM}	42.5	46.1	38.7	3.66	0.377
b_{RAM}	30.8	28.9	25.1	2.33	0.217
L_{SCF}	71.4	70.2	70.6	1.83	0.901
a_{SCF}	17.8	17.1	16.2	1.17	0.643
b_{SCF}	28.5	26.4	27.3	1.30	0.545

T_0 : Control diet; T_1 : Diet containing 10% carob pulp; T_2 : Diet containing 20% carob pulp, ^{a,b} means followed by the same letter are not significantly different at $P=0.05$, SEM: Standard error of the mean, RAM: Rectus abdominis muscle. SCF: subcutaneous fat. L: lightness, a: redness, b: yellowness.

Table 5. Parameters of meat quality (pH, color and water holding capacity)

Parameters	Diet			SEM	P
	T_0 (0%CP)	T_1 (10%CP)	T_2 (20%CP)		
pH ₀	6.2	6.3	6.3	0.06	0.602
pH ₂₄ (Ultimate pH)	5.72	5.72	5.74	0.078	0.9693
L	19.9	22.8	21.1	1.07	0.191
a	46	45.6	45.6	0.81	0.911
b	21	21.2	21.2	0.85	0.963
Water holding capacity (%)	22.4	20.1	21.9	1.7	0.610

T_0 : Control diet, T_1 : Diet containing 10% carob pulp, T_2 : Diet containing 20% carob pulp, ^{a,b} Means with the same letter are not significantly different at $P=0.05$, SEM: Standard error of mean, pH₀: pH just after slaughtering. pH₂₄: pH after 24 hours of slaughtering, L: lightness, a: redness, b: yellowness.

al. (2000) reported that ultimate pH was higher in lambs fed diets containing tannins compared to diets free of tannins.

The meat color results are presented in Table 5. There is no significant difference between lamb's meat fed diets containing carob pulp (10 and 20%) and those fed diets without CP. Nevertheless, lambs meat fed with 10% CP and 20% CP diets tended to be lighter and less red compared to the control diet. Consistent with our results, Lanza *et al.* (2001) reported that incorporating 10% CP to the diet for fattening Barbaresca lambs leads to a lighter meat. This change in color was explained by a decrease in the concentration of metmyoglobin (MMb) and oxymyoglobin (MbO₂) at the *Longissimus dorsi* following the addition of quebracho (tannin-rich source) in the fattening concentrate of male lambs of a Lobón *et al.* (2017). In contrast, Obeidat *et al.* (2011) reported that inclusion of CP at levels 125 and 250g/kg to the diet for fattening Awassi lambs did not affect the meat color.

Water holding capacity (WHC) was similar for all treatment diets (Table 5). Results showed that incorporating CP at levels 10% and 20% did not affect the meat water holding capacity. However, the meat of lambs fed T₁ (10%) diet tends to lose less water compared with that of lambs fed T₂ (20%) compared to the control diets. The same results were obtained by Obeidat *et al.* (2011) using CP at the levels 125 and 250g/kg in Awassi lamb and Priolo *et al.* (1998) using CP at the level 20% in Comisana lambs. On the other hand, Priolo *et al.* (2000) found that inclusion of carob pulp at the level 56% with and without polyethylene glycol in Comisana lambs fed diets had no effect on water holding capacity.

CONCLUSION

Carob pulp could present a potential alternative option in small ruminant feeding during shortage forage periods of the year. The incorporation of 10% of carob pulp in the lambs' diets improves their fattening performance and reduces feeding cost of about 20% compared to the control diet. However, further studies are needed to evaluate the use of this alternative feedstuff in animals of different ages and physiological stages

in order to adopt the most appropriate feeding strategies in Moroccan arid and semi-arid areas.

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Conflict of Interest

The authors declare no conflict of interest.

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