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Original article

Effect of partially or totally replacing soybean meal and maize by chickpeas (*Cicer arietinum* L.) in lamb diets: growth performances, carcass and meat quality

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Abstract — Twenty-seven weaned Barbaresca lambs, divided on the basis of live weight into three groups of nine animals, were offered access to one of three different diets addressing the partial or total replacement of soybean meal and maize by chickpeas (*Cicer arietinum* L.). Soybean meal, maize and chickpeas were present in the diets in the following proportions (% on an as-fed basis): 13-30-0 (SBM); 7-18-20 (C20) and 0-0-42 (C42). The diets had similar crude protein (162.6, 163.9 and 166.4 g·kg^{-1} DM for SBM, C20 and C42 diets, respectively) and neutral-detergent fibre (NDF: 265.8, 250.0 and 253.1 g·kg^{-1} DM, respectively). Lambs from the SBM and C20 groups tended ($P < 0.10$) to grow faster compared to lambs from the C42 group (276 and 285 vs. 225 g·d^{-1}, respectively). Accordingly, final weight and empty body weight were higher ($P < 0.10$) in the SBM and C20 groups than in the C42 group. Carcass fat score, caudal fat colour and firmness were not different across treatments. On hind leg dissection, a higher ($P < 0.10$) lean/bone ratio was observed in C20 and C42 groups than SBM. Meat ultimate pH, colour coordinates, drip and cooking losses and shear force were not affected by diet as well as the chemical composition of the meat. In conclusion, partially replacing soybean meal and maize by 20% chickpeas did not negatively affect growth performance compared to totally replacing (42% chickpeas). Furthermore, the lean/bone ratio was more favourable in lambs fed diets with soybean meal and maize partially or totally replaced by chickpeas. Meat quality was not affected by the diet treatments.

chickpea / lamb / Barbaresca / meat quality

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Résumé — Remplacement total ou partiel du tourteau de soja et du maïs par du pois chiche (*Cicer arietinum* L.) dans des régimes pour agneaux : croissance et qualité de la carcasse et de la viande. Vingt-sept agneaux de race Barbaresca, ont été répartis en 3 lots de 9 animaux sur la base de leurs poids vifs. Chaque lot a reçu un régime différent avec une proportion de tourteau de soja, de maïs et de pois chiche (*Cicer arietinum* L.) variable. Ces 3 aliments représentaient respectivement 13-30-0 % ; 7-18-20 % et 0-0-42 % pour les rations SBM, C20 et C42. Les teneurs en MAT (respectivement 162,6, 163,9 et 166,4 $g \cdot kg^{-1}$ MS pour les régimes SBM, C20 et C42) et en NDF (respectivement 265,8, 250 et 253,1 $g \cdot kg^{-1}$ MS) étaient équivalentes dans les 3 régimes. Comparativement aux agneaux du groupe C42, la croissance des agneaux des groupes SBM et C20 a eu tendance ($P < 0,10$) à être plus rapide (225 vs. 276 et 285 $g \cdot d^{-1}$ respectivement) et leurs poids vifs vides finaux ont été supérieurs ($P < 0,10$). La quantité de gras, la couleur et la fermeté du gras caudal ont été identiques dans les 3 groupes. Le rapport muscle/os du membre postérieur a été plus élevé ($P < 0,10$) pour les agneaux des groupes C20 et C42 que pour les agneaux du groupe SBM. Le pH ultime de la viande, ses paramètres de couleur, les pertes d'eau lors du ressuyage ou de la cuisson ainsi que la force de cisaillement de Warner Bratzler n'ont pas été affectés par le traitement. De plus, l'analyse chimique de la viande n'a révélé aucune différence entre les trois lots d'animaux. Dans cet essai, le remplacement partiel du tourteau de soja et du maïs par du pois chiche n'a pas affecté les performances de croissance des agneaux. Le remplacement total ou partiel du tourteau de soja et du maïs par du pois chiche a augmenté le rapport muscle/os. La qualité de la viande n'a pas été modifiée par les traitements.

pois chiche / agneaux / Barbaresca / qualité de la viande

1. INTRODUCTION

In the Mediterranean area, the protein and energy requirements of fast-growing, intensively fattened lambs are usually satisfied by soybean and maize, the major ingredients in concentrates, largely imported at high costs. Furthermore, these feedstuffs are often derived from genetically modified varieties which is of concern to consumers. In addition, the dramatic restriction in the use of animal protein (related to the incidence of BSE) produced a gap in protein supply for ruminants [23], and therefore the use of legume grains, in animal nutrition, is expected to increase further in the near future [11]. In many Mediterranean countries, legume crops could be introduced into rotation systems with cereals, largely practiced as continuous crop production [10]. In previous trials the use of legume seeds such as the faba bean (*Vicia faba* var. *minor*) and peas (*Pisum sativum* L.) in lamb diets did not negatively affect growth and carcass characteristics but the effects on meat quality were contradictory [14, 15].

Chickpea (*Cicer arietinum*) is a legume crop well-adapted to semi-arid conditions. It has a high protein content (19–28% of dry matter) as well as starch content [10, 12, 18]. The different protein degradability of feeds included in the diets can affect rumen efficiency with a dramatic effect on amino acid absorption in the small intestine and consequently on growth performance. Chickpea protein is described as being more degradable in the rumen than that of soybean meal [10].

In lamb feeding, the replacement of soybean meal and barley grain by chickpeas does not affect the growth performance but improves the digestion coefficients of dry matter, organic matter and crude protein [10].

The objective of this study was to evaluate the effects of partial or total replacement of soybean meal and maize by chickpeas on

lamb growth, the carcass and quality of the resultant meat.

2. MATERIALS AND METHODS

2.1. Measurements in vivo and at slaughter

The trial involved twenty-seven male Barbaresca lambs, born within a 5-day period and reared on their's mother milk until weaning at 60 days of age. From the second week of age, the animals were allowed access to a starter commercial concentrate (21% CP) and vetch-oat hay. After weaning, the lambs were randomly assigned to three groups of nine animals, homogeneous for live weight, and stalled into three collective boxes on straw litter.

From day 60 to 67 of age, the lambs were gradually adapted to the experimental diets. Soybean meal, maize and chickpeas (the "Volcano" variety) were included in the diets in the following proportions (% on an as-fed basis), respectively: 13-30-0 (SBM); 7-18-20 (C20) and 0-0-42 (C42). The diets were ground and pelletted and supplied ad libitum. Fresh feed was offered once daily at the same time (9.00 h) and feed refusals were recorded in order to evaluate the voluntary feed intake. One lamb from the C42 group was removed from the experiment because of a health problem. The lambs were individually weighed once weekly before feed supply. The composition of the diets and their chemical analyses are shown in Table I.

Table I. Composition of diets and chemical analyses (g·kg^{-1} DM unless otherwise stated).

	Treatment		
Ingredients (%, on as-fed basis)	SBM	C20	C42
Lucerne dehydrated	20	20	20
Maize	30	18	–
Barley	25	23	27
Soybean meal	13	7	–
Carob pulp	7	7	6
Brewer's yeast	2.5	2.5	2.5
Chickpeas	–	20	42
Limestone	1	1	1
Ca monophosphate	0.5	0.5	0.5
Salt	0.5	0.5	0.5
Vitamin-mineral premix	0.5	0.5	0.5
Chemical composition			
Dry matter (g·kg^{-1} fresh)	880	885	888
Crude protein	163	164	166
Soluble protein (g·kg^{-1} CP)	22	52	79
NDIN (g·kg^{-1} CP)	22	18	19
A–protein fraction (g·kg^{-1} CP)	18	33	45
B_1–protein fraction (g·kg^{-1} CP)	4	19	34
B_2–protein fraction (g·kg^{-1} CP)	119	94	69
B_3–protein fraction (g·kg^{-1} CP)	12	4	10
C–protein fraction (g·kg^{-1} CP)	10	14	9
NDF	266	250	253
ADF	134	133	138
ADL	35	35	34
Crude lipids	26	31	35
Ash	71	76	72

Proportion of soybean meal, maize and chickpeas in SBM (13-30-0), C20 (7-18-20) and C42 (0-0-42), respectively; CP: crude protein; NDIN: neutral detergent insoluble nitrogen; A = Kjeldahl nitrogen – true protein nitrogen precipitated with tungstic acid; B_1 = true protein – buffer insoluble nitrogen; B_2 = buffer insoluble nitrogen – NDIN; B_3 = NDIN – ADIN (acid detergent insoluble nitrogen); C = ADIN.

Neutral-detergent fibre (NDF), acid-detergent fibre (ADF) and acid-detergent lignin (ADL) were measured according to a procedure of Goering and Van Soest [7]. Crude protein, ash and ether extract were analysed according to AOAC procedures [1]. Protein fractions were determined according to procedures described by Licitra et al. [17]. Soluble protein ($A + B_1$) was measured by an extraction with a borate-phosphate buffer at rumen pH and was calculated by subtracting the buffer-insoluble nitrogen ($B_2 + B_3 + C$ fractions) from the Kjeldahl nitrogen. Non-protein nitrogen (NPN, A fraction) was calculated from the difference between Kjeldahl nitrogen and true protein nitrogen precipitated with tungstic acid. The B_1 fraction was determined by the difference between true protein and buffer-insoluble nitrogen. NDIN ($B_3 + C$ fractions) and ADIN (C protein

fraction) are the neutral detergent-insoluble nitrogen and the acid detergent-insoluble nitrogen, respectively, and were determined according to an alternate procedure using a Fibertec apparatus described by Licitra et al. [17]. The B_2 fraction was calculated by the difference between buffer-insoluble nitrogen and NDIN. The B_3 fraction was calculated from the difference between NDIN and ADIN.

The lambs were slaughtered by throat cutting, after captive bolt stunning, at 132 days of age, after a 12 h-fasting period (water was allowed). The parameters measured at the abattoir were the slaughter weight, the empty body weight, the hot carcass weight and the net dressing percentage.

The hot carcasses were assessed for fatness according to Dransfield et al. [6] (1–15 point-scale) and then, after 6 h at room temperature (around 13 °C), stored in a refrigerated room set to 4 °C.

At 24 h post mortem in the caudal region, carcass subcutaneous fat colour was measured according to the CIE (L*a*b*) system [4] and fat subjective firmness was estimated using a 9-point scale (1 being the most firm, …, 9 being the most oily).

2.2. Meat instrumental analyses

At 24 h post mortem, carcasses were halved into two sides and the hind leg was separated from the right side to evaluate lean, fat and bone percentage.

Meat ultimate pH was measured on the *longissimus dorsi* (between the 3rd and 5th lumbar vertebrae) muscle using an Orion 210A pH meter equipped with an Orion 9106 penetrating glass electrode. Colour was measured on the same muscle according to the CIE (L*a*b*) system on 3-cm thick muscle slices allowed to bloom for 2 hours at 4 °C. For these measurements a MINOLTA CM 2002 colour meter (light source: D_{65}; visual angle: 10°) was used perpendicularly to the cut surface of the muscle. Chroma (C*) and hue angle (H*) were also calculated according to the following formulae: $C^* = (a^{*2} + b^{*2})^{1/2}$; $H^* = \tan^{-1}(b^*/a^*)(180/\pi)$.

At 96 h post mortem, *longissimus dorsi* (between the 6th and 13th thoracic vertebrae) samples were weighed (about 100 g) and put on a plastic hurdle. Then both items (meat samples on the plastic hurdle) were put into sealed polyethylene bags hermetically closed to prevent surface evaporative loss. After a 24 h storage period at 4 °C, the meat samples were removed from the bag and reweighed. The difference in the weight of the samples, before and after storage, divided by the sample weight before storage × 100 accounted for the % drip loss [2].

The measurement of cooking losses was conducted on the *longissimus dorsi* (between the 6th and 13th thoracic vertebrae) samples weighed and held in plastic bags and immersed in a 75 °C water-bath until the internal temperature reached 75 °C as monitored with a thermocouple. Then, the bags were cooled under running tap water for 30 min and blotted dry with paper towels and reweighed. Cooking losses, as percentages, were then calculated from the difference between the weights.

Warner-Bratzler shear force was measured on *longissimus dorsi* (between the 6th and 13th thoracic vertebrae) samples cooked as above. One portion of muscle was divided into 10 × 10 mm blocks with the longitudinal axis parallel to the fibres and sheared perpendicularly to the fibre direction with a Warner-Bratzler shear device mounted on an INSTRON 4411 universal testing machine (cross-head speed 100 mm·min^{-1}).

For chemical analyses, meat samples (*longissimus dorsi* between the 6th and 13th thoracic vertebra) were vacuum-packed and stored at –24 °C until analysis. Then after 24 h thawing at 4 °C, moisture, fat, and ash were evaluated according to

AOAC [1] while protein was calculated from the difference.

2.3. Statistical analysis

All data were subjected to analysis of covariance for initial weight and processed by ANOVA, testing the diet effect. When covariance was not significant ($P > 0.05$) it was removed from the model. The Student-Newman-Keuls test was used to discriminate means when a significant treatment ($P < 0.10$) effect was observed.

3. RESULTS AND DISCUSSION

The chemical composition of experimental diets is reported in Table I. The diets had comparable crude protein content and NDF. The protein level (around 16% DM) was comparable to that suggested by Hadjipanayiotou [8] for Chios lambs weighing 28–41 kg. The C42 and C20 diets had a higher soluble protein content than the SBM diet. Chickpeas and several other legume seeds are richer in soluble and rapidly degradable protein as compared to soybean meal and this accounted for this difference [10]. The true soluble protein/non-protein nitrogen ratio (B_1 fraction/A fraction) was higher in the C42 diet as compared to the C20 and SBM diets (0.75 vs. 0.57 and 0.22, respectively), with the B_1 protein fraction rising as chickpeas increased in the diets. The diet with the higher soybean meal content (SBM) showed the higher B_2-protein fraction percentage as compared to C42 and C20 according to previous results [13, 15, 16]. The SBM diet revealed a 16–22% more NDIN than the C20 and C42 diets and the higher B_3/C fraction ratio compared with the other two diets (1.20 vs. 0.28 and 1.11 for SBM, C20 and C42, respectively).

The C42 and C20 diets had higher crude lipids content (+34.6% and +19.2%, respectively) than SBM. The higher fat content in chickpeas compared to soybean meal is in accordance to that reported by Hadjipanayiotou et al. [9].

Growth rates and carcass results are presented in Table II. The lambs from the SBM and C20 groups tended ($P < 0.10$) to grow faster compared to those from the C42 group. Consequently, there was a significant ($P < 0.10$) difference in final weights with the lambs in group SBM and C20 being 10.7% and 12.3% higher compared to lambs from C42. Probably the association of soybean meal and chickpeas was more efficient in satisfying the amino acid requirements of lambs, thus enhancing growth performances. Furthermore, the much higher soluble protein content of the C42 diet (more than threefold as compared to the SBM diet and +52% as compared to C20 diet, respectively) may have reduced the efficiency of protein utilization with lower amino acid absorption according to previous results [13]. Hadjipanayiotou [10] reported that Chios lambs fed diets with 13.6% and 32.9% chickpeas did not have a significant difference in final weight and daily gain as compared to the soybean group.

The daily DM intake tended to decrease as chickpeas increased in the diets according to the results of Illg et al. [12] in growing heifers but in contrast to the results of Hadjipanayiotou [10] in lambs and kids. Lambs fed SBM and C20 diets consumed 27 and 19% more feed, respectively, than lambs fed C42. Feed conversion ratio was more favourable from lambs fed the C20 diet compared to lambs fed the SBM and C42 diets. In line with final weight and daily gain, the lambs from the SBM and C20 groups had a higher ($P < 0.10$) empty body weight than the lambs from C42.

Hot carcass weight and net dressing percentage were comparable among the treatments. Carcass fatness score was also comparable among the groups and was assessed as "ideal" and "abundant" according to the SEUROP grid, but still acceptable for the local market [15]. Carcass fatness was

Table II. Lamb performances in vivo and at slaughter.

	Diet treatment			SEM[a]	*P*-value
	SBM	C20	C42		
Initial weight (kg)	17.0	16.1	16.1	0.470	NS
Final weight[1] (kg)	34.1^{x}	34.6^{x}	30.8^{y}	1.210	0.077
Average daily gain[1] 67–131 d (g·d^{-1})	276^{x}	285^{x}	225^{y}	13.700	0.077
Voluntary feed intake (g DM·d^{-1})	1112	1046	877	NA	NA
Feed conversion ratio (g DM·g^{-1} gain)	4.03	3.67	3.90	NA	NA
Empty body weight[1] (kg)	31.0^{x}	31.4^{x}	28.1^{y}	1.060	0.084
Hot carcass weight[1] (kg)	16.3	16.5	14.9	0.578	NS
Net dressing (%)	52.77	52.55	52.94	0.490	NS
Carcass fatness[1] (score)	9.91	9.67	9.35	0.368	NS
Subcutaneous fat lightness (L*)	64.90	66.86	64.78	0.992	NS
Subcutaneous fat redness (a*)	7.71	7.23	7.53	0.215	NS
Subcutaneous fat yellowness (b*)	9.23	8.56	8.54	0.224	NS
Subcutaneous fat firmness (score)	4.22	3.89	4.50	0.299	NS

[1] In this and subsequent tables, for these parameters, analysis of covariance for initial weight was significant ($P < 0.05$) and was included in the model.
[a] In this and subsequent tables, SEM: standard error of the mean; NA: not applicable; NS: not significant; $^{x, y}$ $P < 0.10$.

positively correlated (r = 0.52; $P < 0.001$) to carcass weight according to the literature [3]. Carcass fat colour was not affected by the treatments as shown by comparable lightness (L*), redness (a*) and yellowness (b*) values. The lower reflectivity (L*) associated to higher redness (a*) in comparison to that reported for white fat carcasses accounted for carcasses with brown-red subcutaneous fat. Brown-red adipose tissue often comes from animals fed on concentrates and is thought to be related to a softness effect on light reflectivity or as an excess in heme pigment concentration or, more, as an effect of peroxidation of unsaturated fatty acids [19]. Fat firmness was similar among groups and identified a subcutaneous fat intermediate between soft and firm.

The hind leg dissection did not reveal significant differences among the treatments with regards to lean, fat and bone percentages. Nevertheless, the lean/bone ratio was higher ($P < 0.10$) in the C20 and C42 groups than in SBM (Tab. III). This trend accounted for a favourable use of chickpea diets, which allowed the repartition of nutrients towards more lean than bone deposition.

The results of the meat instrumental and chemical analyses are reported in Table IV. Ultimate pH were comparable among groups and within a range of normal values with no evidence of stress problems [5]. Lightness (L*), redness (a*) and yellowness (b*) values of *longissimus dorsi* muscle were comparable between treatments as well as hue and chroma values. Lightness was inversely correlated ($P < 0.05$; r = –0.15) to ultimate pH as expected. Meat colour differences can occur with regards to a direct effect of diet on myoglobin [21]. Other factors such as ultimate pH, carcass fatness, age, carcass weight and intramuscular fat

Table III. Hind leg dissection.

	Diet			SEM[a]	*P*-value
	SBM	C20	C42		
Leg weight[1] (kg)	2.4	2.4	2.1	0.092	NS
Lean[1](% leg weight)	59.66	62.19	63.09	0.785	NS
Fat (% leg weight)	16.70	15.80	15.30	0.747	NS
Bone (% leg weight)	23.24	22.24	21.82	0.477	NS
Lean/fat	3.60	3.92	4.11	0.252	NS
Lean/bone[1]	2.56[y]	2.82[x]	2.98[x]	0.080	0.076

[1, a]: see Table II.

Table IV. Physical and chemical characteristics of *longissimus dorsi* muscle.

	Diet			SEM[a]	*P*-value
	SBM	C20	C42		
pH[1]	5.56	5.55	5.57	0.011	NS
Lightness (L*)	50.41	49.37	45.98	0.942	NS
Redness[1] (a*)	16.82	16.40	16.52	0.465	NS
Yellowness (b*)	7.53	8.11	7.96	0.319	NS
Chroma[1]	18.42	18.37	18.37	0.531	NS
Hue angle	23.58	26.32	25.64	0.603	NS
Drip losses (%)	1.88	2.03	3.01	0.240	NS
Cooking losses (%)	22.46	24.19	23.54	0.850	NS
Shear force (kg F·cm^{-2})	6.30	5.82	4.92	0.392	NS
Moisture[1] (%)	74.23	74.54	75.10	0.210	NS
Protein[1] (%)	22.11	21.57	21.62	0.196	NS
Crude fat (%)	2.15	2.46	1.67	0.199	NS
Ash[1] (%)	1.48	1.45	1.63	0.052	NS

[1, a]: see Table II.

content seem to play a major role [20]. All these parameters were similar among treatments and collectively contributed towards differences in meat colour.

Water holding capacity measured as drip and cooking losses were comparable among the treatments. The drip losses were weakly correlated ($P < 0.10$; r = –0.33) to slaughter weight in accordance with the findings of Solomon et al. [22]. Tenderness, measured as the Warner-Bratzler shear force at 96 h post mortem, was similar among treatments and below 8 kg F·cm^{-2} which accounted for acceptable tender samples [5]. Chemical analyses of *longissimus dorsi* muscle did not reveal significant differences among the three groups with respect to the content of moisture, intramuscular fat, protein and ash.

4. CONCLUSIONS

The trial was designed to examine the use of chickpeas as an alternative protein and energy source in the diet of lambs. Partially replacing soybean meal and maize by 20% chickpeas did not affect lamb growth and meat quality. When the lambs were fed a diet containing 42% chickpeas as a total replacement of soybean meal and maize, growth rate was reduced. Dissection of the hind leg showed that the lean/bone ratio was more favourable in lambs receiving chickpeas compared to those given a diet with soybean meal and maize. In conclusion, the use of 20% chickpeas in the diet of growing lambs is feasible with little detrimental effect on growth, carcass and meat quality characteristics.

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