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Effect of the addition of *Nigella sativa* seeds to low or high concentrate diets on intake, digestion, blood metabolites, growth and carcass traits of Barbarine lamb

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ABSTRACT

This 82-day feeding experiment aimed to determine the response of sheep to high or low concentrate diets enriched or not with the seeds of *Nigella sativa*. Twenty eight Barbarine male lambs (Initial body weight 24.6 ± 1.87 kg) were randomly divided into four groups (n = 7). Each group was assigned to one of the following dietary treatments (as fed basis): low concentrate diet (LC) composed of 700 g/kg barley hay and 300 g/kg concentrate (Low concentrate, LC), high concentrate diet (HC) composed of 300 g/kg barley hay and 700 g/kg concentrate, LC enriched with 12 g/kg *Nigella sativa* seeds (LCN) and HC enriched with 12 g/kg *Nigella sativa* seeds (HCN). Sheep receiving HC-diets exhibited higher ($P < 0.05$) diet dry matter, organic matter and crude protein apparent digestibility, nitrogen retention, ruminal ammonia nitrogen (NH3-N) concentrations and average daily gain than LC-diets. Irrespective of the proportion of concentrate in the diet, the addition of *Nigella* seeds increased ($P < 0.003$) CP intake and ($P < 0.05$) the concentration of NH3-N (+10.7% for HC and 7.6% for LC), but it decreased ($P < 0.05$) protozoa population in the rumen mainly with LC diet ($P < 0.001$) and the concentration of plasma triglycerides. Sheep receiving *Nigella* seeds grew more ($P < 0.001$) than those fed on *Nigella*-free diets. The interaction between *Nigella* seed addition and forage to concentrate ratio decreased ($P = 0.03$) the feed conversion ratio (FCR) in LCN lambs. Carcass yield was not affected ($P > 0.05$) by forage to concentrate ratio and the addition of *Nigella* seeds to the diet. It is concluded that the addition of *Nigella sativa* seeds (12 g/day) to concentrate increased significantly the growth rate of Barbarine lamb receiving either low or high concentrate diets. Such positive impact was more important with HC than LC diet and is likely the result of the substantial increase of total dry matter intake.

1. Introduction

The seeds of many crops and natural plants are used since while as energy and or protein (rapeseed, linseed, vetch seeds, *etc.*) supplements to enhance livestock productivity. These seeds may also contain some specific phytochemicals (*e.g.* tannins, saponins, trypsin inhibitors, flavonoids, *etc.*) that could impact positively on digestion, hence further improve the production performance of animals (Makkar et al., 2007). Most importantly, the seeds of some specific plants have been used as alternative growth promoters to synthetic chemicals and their positive effects on digestive and metabolic utilization, and meat and milk production and quality (*e.g.* fatty acid profile and lipid oxidation) had been proven in numerous studies as reviewed by Valenzuela-Grijalva et al. (2017). Nowadays, the consumer is increasingly concerned about the safety of meat and milk and is often looking for products of animals not receiving chemical additives. Therefore, scientists are intensifying efforts to identify potential plants that have seeds endowed with the above mentioned characteristics and that could be advantageously used in livestock feeding. *Nigella sativa* is among the lesser known plants that hold promise as natural additive to improve production performance of animals. This plant species is cropped for seed production mainly in India, Iran and Pakistan. It can also grow in North Africa, Southern Europe, and Southwest Asia (Khare, 2004). Paarakh (2010) claimed that *Nigella sativa* seeds contain an array of secondary compounds (*e.g.* Nigellone, tannins, resin, saponins, flavonoids, and volatile oils) that could have positive impact on human and animal health. The seeds of this plant which are also high in oil (35–42%) have been successfully used in poultry feeding. Their administration in the diet had increased

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the growth performance of broilers (Guler et al., 2006; Ziad and Abu-Dieyeh, 2008; Islam et al., 2016). However, few studies investigated the potential use of *Nigella sativa* seeds in sheep (Zanouny et al., 2013) and goat (Habeeb and El-Tarabany, 2012) feeding. They came up with optimal levels of *Nigella* seeds comprised between 1 and 3% of diet which had positive effect on livestock performance. It is worth to note that diets used in these studies had different compositions. Therefore, the response of sheep to the addition of *Nigella* seeds to the diet may vary with its composition. To the best of our knowledge this aspect is not yet investigated. Feeding grass hays or cereal straws-based diets supplemented by some concentrate feeds, mainly barley grains, for sheep production is a common practice in the semiarid and arid areas of North Africa (Ben Salem and Smith, 2008). Intensive fattening through feeding concentrate-based diets is increasingly adopted by Tunisian smallholder farmers to produce heavy lambs for commercialization during the period of mouton sacrifice feast. The *pros* and *cons* of varying the forage to concentrate ratio on production performance of sheep raised under the dry conditions prevailing in North Africa are not well documented. Majdoub-Mathlouthi et al. (2013) showed that Barbarine breed lamb grew more when fed on high rather than low concentrate diet. A question arose as to whether the addition of small amounts of *Nigella sativa* seeds to forage or concentrate based diets would result in further improvement of the growth rate of sheep. Therefore, this study aimed to respond to this question through the determination of the effect of incorporation of *Nigella* seeds in concentrate on diet intake and digestion, blood metabolites, rumen fermentation parameters, average daily gain and carcass traits of Barbarine lamb fed on concentrate or hay-based diet.

2. Materials and methods

2.1. Animals and diets

This experiment was conducted in the experimental station of the National Institute of Agricultural Research of Tunisia (INRAT) at Bourbia from May to August 2015. It is part of the research program of the laboratory of animal and forage productions of INRAT which was approved by the national committee of evaluation of research activities of Tunisia. Twenty-eight Barbarine male lambs, born in late November 2014, were weaned at 120 days of age. From 4 to 6 months of age, the feeding management of these lambs comprised pasture grazing and barley hay distributed in the barn. At 180 days of age, the lambs were weighed (Initial body weight 24.6 ± 1.87 kg) and treated against parasites using Ivermectyl (1 ml/50 kg BW, 1 g Ivermectine/100 ml; Medvet Santé Animale, Soliman, Tunisia) and housed indoors in individual pens (1 m × 1 m). They were randomly allocated to four homogeneous groups (n = 7) and each group was randomly assigned to one of the four following dietary treatments (as fed basis): low concentrate diet (LC) composed of 700 g/kg barley hay and 300 g/kg concentrate (Low concentrate, LC), high concentrate diet (HC) composed of 300 g/kg barley hay and 700 g/kg concentrate, LC enriched with 12 g/kg *Nigella sativa* seeds (LCN) and HC enriched with 12 g/kg *Nigella sativa* seeds (HCN). This quantity of *Nigella* seeds has been fixed on the basis of the optimum levels (1–3% of diet) reported in previous studies (Aydin et al., 2008; Zanouny et al., 2013). The concentrate was composed of processed barley grains (700 g/kg), soybean meal (250 g/kg) and commercial mineral and vitamin supplement (MVS, 50 g/kg). The ingredients and composition of the experimental diets are shown in Tables 1 and 2, respectively. During a 2-week pre-experimental period, the voluntary hay intake was daily controlled. The amount of hay offered was adjusted based on the intake of the previous day to ensure a 10% refusal. The average intake of hay was then considered in the experimental period while fixing the forage to concentrate ratios. The *Nigella*-free diets (LC and HC diets) were formulated to meet energy (Metabolisable energy 8–10 MJ/day) and crude protein (70–125 g/day) requirements of growing lambs aged 4–8 months and growing at a growth rate of 100 g/day (NRC, 1985). Along the experimental period, the concentrate enriched or not with 12 g *Nigella* seeds had been distributed first to animals. After consumption of the whole amount of concentrate and *Nigella* seeds, hay was distributed to lambs taking into consideration the forage to concentrate ratios assigned to LC (30:70) and HC (70:30) diets. Feed refusals were weighed in the following day at 7:00 h to calculate the individual feed intake. Water was continuously available in each pen. In the last day of the growth trial and after weighing, lambs have been transferred to individual metabolic cages. They have been allowed to familiarize to the new housing conditions for 4 days before starting the 5-day total collection period (Day 74–Day 79). On day 82, lambs were weighed in the morning then slaughtered in the same day.

Table 1
Ingredient quantity of the experimental diets[a] (g/kg DM).

Feed ingredients	LC	LCN	HC	HCN
Concentrate[b]	303.2	299.5	703.1	694.7
Nigella sativa seeds	0.0	12.0	0.0	12.0
Barley hay	696.8	688.4	296.9	293.3

[a] LC: diet composed of 700 g hay/kg + 300 g concentrate/kg; LCN: LC + 12 g *Nigella sativa* seeds; HC: diet composed of 700 g concentrate + 300 g hay; HCN: HC + 12 g *Nigella sativa* seeds/kg.

[b] The concentrate is composed of barley grains (700 g/kg), soybean meal (250 g/kg) and a commercial mineral and vitamin supplement (MVS, 50 g/kg). The MVS is composed of macro-minerals (/kg): Ca (32), Mg (1.1), Na (5.5), trace elements (mg/kg): Zn (2685), Fe (985), Cu (7.4), Mn (1645), I (19), Se (3), Co (4.5), and vitamins (UI/kg): vitamin A (325000), Vitamin D3 (72000), Vitamin E (313).

Table 2
Chemical composition of diets (g/kg DM).

Diets[a]	DM	OM	CP	NDF	ADF	ADL	ME[b] (MJ/kg DM)
Feed ingredients							
Barley hay	907.2	934.3	96.1	679.5	381	107.2	7.2
Concentrate	921	944.5	180	451.2	109.1	15.9	12.1
Nigella seeds	921.6	968.6	231.4	551.3	293.6	75	8.5
Experimental diets							
LC	911.3	854.3	110.8	556.2	272.1	72.5	8.5
LCN	911.3	854.6	111.3	557.3	274.1	73.1	8.5
HC	916.9	863.2	142.2	475.8	174.0	39.4	10.6
HCN	916.9	863.5	142.8	476.9	176.1	40.1	10.6

[a] LC: diet composed of 700 g hay/kg + 300 g concentrate/kg; LCN: LC + 12 g *Nigella sativa* seeds; HC: diet composed of 700 g concentrate + 300 g hay; HCN: HC + 12 g *Nigella sativa* seeds/kg.

[b] Metabolisable energy.

2.2. Measurements and sampling

Along with the growth trial, feed intake was determined daily by weighing the amounts of feeds distributed and refusals in the plastic feeders. The amount of hay distributed represents 1.1 fold of the hay intake of the previous day. In any case, the two forage-to-concentrate ratios have been maintained constant along with the feeding and the *in vivo* digestibility trials. Lambs were weighed in morning before feed distribution at the start and the end of the growth trial and also at 17-day intervals.

In the digestibility trial, individual feces and urine were collected daily between 08:00 and 09:00. They were weighed and a 10% aliquot was taken from each sample and stored at 4 °C. Fecal and urine aliquots from each lamb were composited by the 5-day collection period, and subsamples of individual feces and urine were frozen (−20 °C) until analyzed. Amounts of feed offered and refused were weighed daily and subsamples of feeds and refusals were taken. At the end of the digestibility trial, refusal samples from each animal were composited by period and the corresponding subsamples were stored until analyzed.