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NUTRITIVE VALUE OF SUN-DRIED SULLA HAY (*HEDYSARUM FLEXUOSUM*) AND ITS EFFECT ON PERFORMANCE AND CARCASS CHARACTERISTICS OF GROWING RABBITS

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Abstract: The nutritive value and potential use of sundried sulla hay [(*Hedysarum flexuosum)*, g/kg as feed: 885 dry matter, 438 neutral detergent fibre (NDF), 337 acid detergent fibre, 80 acid detergent lignin and 147 crude protein (CP)] for growing rabbits was studied by comparing 3 diets containing an increasing inclusion rate of sulla hay (S): 0% (control, S0), 15% (S15) and 30% (S30) in substitution for control diet (294 g NDF and 179 g CP/ kg). Three groups of 30 rabbits (individually caged) were fed *ad libitum* the 3 diets from weaning (35 d, mean weight: 572±93 g) to 84 d of age. Faecal digestibility of the diets was measured between 42 and 46 d of age on 10 rabbits per group. The digestible energy (DE) concentration of sulla hay estimated by regression was 8.96±0.57 MJ/kg DM, thus 7% higher than standard alfalfa meal, which would account for its high NDF digestibility (54.9%). Digestibility of crude sulla protein was estimated at 42.8%, corresponding to a digestible crude protein concentration of 71.1±8.9 g/kg DM. Even at a high incorporation rate in the feed (30%), sulla hay did not cause adverse effects on the animal growth (mean 36.0 g/d), feed intake (mean 119 g/d) or health. Feed conversion was better for a moderate rate of sulla inclusion in the diet (about 15%) than for a higher inclusion rate (3.14 *vs*. 3.36, $P<0.001$). Health status and slaughter traits were not affected by the sulla incorporation rate. Sun-dried sulla hay (*Hedysarum flexuosum*) could thus be considered as a good fibre source for the rabbit as a substitute for alfalfa meal.

Key Words: rabbit, sulla hay, *Hedysarum flexuosum*, growth performance, nutritive value.

INTRODUCTION

In Algeria, one of the main limiting factors to the development of rabbit production remains the absence of balanced pellet feeds available at an acceptable price, as the supply of fibrous raw material remains difficult. Although expensive, imported dehydrated alfalfa (*Medicago sativa*) is the fibre source most utilised in diet formulation for the growing rabbit. Therefore, alternatives are required to produce balanced pelleted feeds using local raw materials, available at a lower price.

Hedysarum flexuosum is part of the genus *Hedysarum L*. often called "sulla" and also known as Italian or Spanish sainfoin, French honeysuckle or sweet vetch. It is a short-lived perennial

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leguminous plant (family *Fabaceae*) originating from the western Mediterranean region and North Africa (Ben Fadhel *et al*., 2006). Both *H. flexuosum* and *H. coronarium* are used in forage production (De Koning *et al*., 2003) and are the two most available in Algeria (Abdelguerfi-Berrekia *et al*., 1991), where they are extensively grown as a 2 yr forage crop for grazing or hay production (Issolah and Khalfallah, 2010). In recent literature, the plant has also been referred to as *Sulla flexuosa* (Choi and Ohashi, 2003). There is a great similarity between *H. coronarium*, the only cultivated sulla species, and *H. flexuosum* (Chennaoui-Kourda *et al*., 2007). The latter is characterised by its small, purplish crimson flowers (intense red in *H. coronarium*) and flexuous pods, while its size and height facilitate mowing (Abdelguerfi-Berrekia *et al*., 1991; Ben Fadhel *et al*., 2006).

In Algeria, *H. flexuosum* produces 50 t green matter/ha (approximately 20% dry matter, DM) with 2 cuts (Chouaki *et al*., 2006), similar to in Australian conditions (9.5 t DM/ha; De Koning *et al*., 2003). Sulla is highly palatable and used in feeding sheep (Molle *et al*., 2003), goats (Bonanno *et al*., 2007) or cows (Ramirez-Restrepo and Barry, 2005). In rabbit nutrition, Cucchiara (1989) included dehydrated *H. coronarium* up to 35% in total replacement of dehydrated alfalfa in fattening rabbit diet, obtaining better performances.

The aim was thus to determine the nutritive value of *Sulla flexuosa* (*Hedysarum flexuosum*) sun dried hay for the growing rabbit and the effect of its dietary inclusion on performance and carcass characteristics.

MATERIALS AND METHODS

Experimental design and feeds

A total of 90 rabbits of Algerian white local population (Zerrouki *et al.*, 2008) were used to assess the nutritive value of sulla and its effect on growth in a private rabbit breeding unit (farm temperature ranging from 15 to 23°C and under a 7:00 a.m. to 7:00 p.m. lighting schedule) located in Tizi-Ouzou area, Algeria. Chemical analyses were conducted at INRA laboratories in Toulouse (UMR 1289 Tandem), France.

Mature sulla plants were collected manually during spring period, at the beginning of the flowering stage, beside M. Mammeri University in Tizi-Ouzou area, and sun dried. Sulla samples were collected in the feed mill factory after grinding (3 mm diameter sieves) to determine the chemical composition. Three pelleted diets were formulated with an increasing sulla hay inclusion level (0, 15, 30%). Dietary ingredients and chemical composition are shown in Table 1. A basal mixture which contained dehydrated alfalfa, corn grain and soya bean meal as main ingredients was formulated to fit the nutritional requirement of the growing rabbit (De Blas and Mateos, 2010). Three experimental diets containing an increasing incorporation rate of sulla hay were prepared by substituting the basal diet, without minerals and premix, with 0, 15 or 30% of sulla hay (S0, S15, S30, Table 1). Mineral and premix were added to all diets at a fixed amount of 2%. The mixture was then pelleted (4 mm diameter, 9 mm length).

Animals and measurements

Rabbits were weaned at 35 d of age (mean weight: 572±93 g), allotted into 3 groups (30 per diet) according to weaning weight and litter origin. They were placed in individual wire mesh cages (56×38×28 cm) in flat deck disposition till 84 d old.

Table 1. Ingredient and chemical composition of experimental diets.

	S0	S15	S30
Ingredient, % as fed			
Sulla hay sun-dried	—	15.00	30.00
Dehydrated alfalfa	30.00	25.41	20.81
Wheat bran	17.00	14.40	11.80
Soybean meal	20.00	16.94	13.88
Corn grain	25.00	21.17	17.35
Crude olive cake	6.00	5.08	4.16
Sodium chloride	1.00	1.00	1.00
Vitamin/mineral premix[1]	1.00	1.00	1.00
Chemical composition, g/kg as fed			
Dry matter	882	896	892
Crude ash	65	71	81
Crude protein (N×6.25)	179	164	161
Neutral detergent fibre	294	374	473
Acid detergent fibre	154	198	274
Acid detergent lignin	48	62	69
Gross energy, MJ/kg	16.36	16.41	16.51

[1]Provided by Bouhzila S. A (Sétif, Algeria). Mineral and vitamin composition (g/kg premix): Se: 0.025, Mg: 5, Mn: 7.5, Zn: 7.5, I: 0.12, Fe: 3.6, Cu: 2.25, Co: 0.04, thiamin: 0.1, riboflavin: 0.45, calcium d-pantothenate: 0.6, pyridoxine: 0.15, biotin: 0.0015, nicotinic acid: 2, choline chloride: 35, folic acid: 0.4, vitamin K_3: 0.2, dl-α-tocopheryl acetate: 1.35, biotin: 0.0015, folic acid: 0.04, cyanocobalamin: 0.0006, vitamin A**:** 850000 IU, vitamin D_3: 170000 IU.

During the 7 wk of the experiment, rabbits were fed one of the 3 diets *ad libitum*, with a weekly control of body weight and feed consumption and daily control of mortality, following the EGRAN recommendations for applied nutrition experiments in rabbits (Fernández-Carmona *et al.,* 2005). Fresh water was always available.

After a 7 d adaptation period (42 d old), 10 rabbits per group were selected for the digestibility trial, following the European reference method described by Perez *et al*. (1995). Their cages were equipped with a wire net under the floor to collect the hard faeces individually and totally over a 4 d period. Faeces were stored daily in polyethylene bags at –20ºC until chemical analysis.

At the end of the experiment, 10 rabbits per group were slaughtered (without fasting) at 10 a.m. in controlled conditions, according to Blasco and Ouhayoun (1996), and the weight of full digestive tract, cold carcass, liver and perirenal fat recorded.

Chemical analyses

The chemical analyses were performed at INRA (UMR 1289 TANDEM) on diets, faeces (10 per group) and on the sulla hay, according to ISO methods and considering the recommendations proposed by the EGRAN group (EGRAN, 2001): DM (ISO 6496:1999), crude ash (ISO

5984:2002), CP (N×6.25, Dumas method, ISO 16634-2:2009), gross energy (ISO 9831:1998) and neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL)) using the Van Soest sequential method, ashless, without sodium sulphite, and using crucibles (Tecator apparatus) (AFNOR 1997, ISO 16472:2006 and ISO 13906:2008).

Statistical analyses

Data were analysed as a completely randomised design with type of diet as the main source of variation by using the GLM procedure from SAS software (OnlineDoc®, SAS Inst., Cary, NC). Mean comparisons were done using the Scheffe test. The linear effect of sulla hay inclusion was analysed with the REG procedure from SAS. The nutritive value of sulla hay was calculated with the regression and substitution methods described by Villamide *et al*. (2001).

RESULTS AND DISCUSSION

Sulla hay composition and experimental feeds

As for all forages, the composition of the sulla plant depends on the vegetative stage at cut. At the onset of the flowering stage, the sulla hay had a high fibre content (33.7% ADF, Table 2), with other fibre fractions comparable to alfalfa meal (Maertens *et al.*, 2002). Sulla also contained an appreciable amount of CP (14.7%), also similar to that found classically in alfalfa. The chemical composition of *H. flexuosum* hay used here was similar to that reported by Cucchiara (1989) for *H. coronarium*. However, the sulla hay presented a relatively high level of ash (12.5%, Table 2) as reported by Arab *et al.* (2009) for *H. coronarium* under similar climatic conditions.

Thus, sulla hay can be classified as a balanced fibre source for rabbit, also rich in protein that is close to the composition of alfalfa meal. As expected, the dietary incorporation of sulla sharply increased the fibre content of the diets (S15, S30) while the CP level decreased (Table 1).

Health status, feed intake and growth of animals

Throughout the experiment, the health status of rabbits was good, since only 1 rabbit died in groups S0 and S30, and only 2 in the S15 group (no antibiotic treatment was used during the trial).

Table 2. Chemical composition of the sun-dried sulla hay[1].

Raw basis (g/kg)	Sun-dried sulla hay
Dry matter	885
Crude ash	125
Crude protein (N×6.25)	147
Neutral detergent fibre	438
Acid detergent fibre	337
Acid detergent lignin	80
Gross energy, MJ/kg	15.07

[1] Analytical value of a sample from the material included in the pelleted feeds (S0, S15, S30).

Table 3. Effect of sulla hay dietary inclusion level on feed intake and growth of rabbits.

	Experimental diets				
	S0	S15	S30	SEM	*P*-value
No.[1]	29	28	29		
Period 35-56 d					
Body weight at 35 d, g (weaning)	561	563	565	28	0.7
Body weight at 56 d, g	1431	1405	1385	40	0.7
Daily weight gain, g/d	40.1	39.2	39.4	0.9	0.77
Daily feed intake, g/d	101[ab]	95.3[a]	106[b]	3	0.04
Feed conversion rate, g/g	2.62[b]	2.42[a]	2.77[b]	0.05	<0.001
Period 56-84 d					
Body weight at 84 d, g	2423	2419	2342	55	0.5
Daily weight gain, g/d	35.9	36.0	33.9	0.8	0.14
Daily feed intake, g/d	142	136	133	3	0.13
Feed conversion rate, g/g	3.96[b]	3.72[a]	3.89[ab]	0.06	0.03
Period 35-84 d					
Daily weight gain, g/d	37.6	38.0	35.9	0.8	0.17
Daily feed intake, g/d	125	122	119	3	0.33
Feed conversion rate, g/g	3.34[b]	3.14[a]	3.36[b]	0.04	<0.001

[1] No.: number of rabbits at the end of experimental period. SEM: standard error of the mean.
[a,b] Mean values in the same row with a different superscript differ, $P<0.05$.

Although an unbalanced feed formulation was chosen to assess the nutritive contribution of sulla hay, growth and intake over the whole fattening period did not differ among the 3 groups (Table 3), reaching high figures (37.2 g/d and 122 g/d, respectively, for the 35-84 d period). However, feed conversion rate was better ($P<0.001$) for a 15% sulla inclusion compared to the 2 other groups (3.14 *vs.* 3.35). During the post-weaning period (35-56 d) the intake of S15 group was lower than the other 2 groups (–5%) while the growth was similar among the 3 groups.

These performances reached a relatively high level, taking into account the genetic potential of our rabbit line. They were about 25% higher than those generally obtained with rabbits of the coloured local population (28 g/d) (Berchiche and Kadi, 2002; Lakabi *et al.*, 2008; Guemour *et al*., 2010).

Slaughter performances

Since average daily weight gain is high (37 g/d), the average slaughter body weight (Table 4) obtained at 84 d (2407 g) was about 20% higher than that generally obtained with rabbits of the local coloured population at the same age (Berchiche *et al.*, 2000; Lakabi *et al.*, 2008; Guemour *et al*., 2010). The incorporation of sulla hay did not impair the slaughter traits. The dressing out percentage (59%) was lower than that reported by Lakabi *et al*. (2008) but higher than that obtained by Gemour *et al*. (2010). Compared with that usually obtained with selected lines and in intensive conditions, this dress out percentage was similar to the values observed by Dalle Zotte *et al*. (2009) and Lazzaroni *et al.* (2009). Moreover, our average carcass weight reached 1460 g, and fits with the market weight as reported by Kadi *et al*. (2008).

Table 4. Effect of sulla hay dietary inclusion level on slaughter traits of rabbits[1].

	Experimental diets				
	S0	S15	S30	SEM[2]	*P*-value
Body weight (BW), g	2507	2434	2281	89	0.20
Full digestive tract, % BW	17.0	17.0	17.4	0.4	0.75
Cold carcass weight, g	1509	1391	1474	51	0.20
Liver weight, g	113	86	95	9	0.14
Perirenal fat, % BW	1.77[a]	1.24[b]	1.16[b]	0.11	0.001
Dressing out percentage, %	59.2	59.3	58.9	0.5	0.83

[1] Slaughter at 12 wk of age. [2] n=10 per treatment. SEM: standard error of the mean.
Mean values in the same row with a different superscript differ, $P<0.05$.

Perirenal fat, expressed as a percentage of body weight, was lower ($P=0.001$) when rabbits received diets with sulla hay but without effect of the inclusion rate (Table 4). The percentage of perirenal fat obtained here is better than that reported by Lazzaroni *et al.*(2009) (1.9%) and similar to that obtained by Dalle Zotte *et al.*(2009) (1.24%). These results might suggest a positive effect of sulla on the adiposity of the carcass as reported for lambs by Priolo *et al*. (2005). Further research with balanced diets is needed to determine the effect of this raw material on rabbit carcass.

Nutritive value of sulla hay

As usual, a close relationship was observed between the digestibility of the DM and that of energy (Table 5). For the majority of the diets, the digestibility of energy is 1 to 2 points less than that of the DM (Maertens and Van Herck, 2001).

The digestibility coefficient of gross energy and CP was not affected by sulla incorporation level (Table 5), suggesting that nutritive value of sulla hay might be close to basal diet (S0). In turn, the fibre digestion was linearly improved ($P<0.05$) with sulla hay dietary inclusion, suggesting

Table 5. Effect of sulla hay dietary inclusion level on faecal digestibility coefficients (%) and nutritive value of experimental diets in growing rabbits between 42 and 46 d of age.

	Experimental diets				
	S0	S15	S30	SEM[1]	*P*-value
Digestibility coefficients (%)					
Dry matter	63.5	62.6	61.1	0.8	0.27
Organic matter	63.6	62.5	61.3	0.8	0.16
Gross energy	60.7	60.5	58.4	0.9	0.28
Crude protein	68.1	66.5	63.6	1.3	0.17
Neutral detergent fibre[2]	22.0[a]	37.1[b]	46.7[c]	1.2	<0.001
Acid detergent fibre[2]	21.9[a]	32.6[b]	43.6[c]	1.6	<0.001
Dietary nutritive value					
Digestible crude protein (DP) (g/kg raw basis)	117[c]	111[b]	100[a]	2	<0.01
Digestible energy (DE) (MJ/kg raw basis)	9.51	9.54	9.01	0.14	0.064
Ratio DP/DE (g/MJ, raw basis)[2]	12.31[b]	11.63[ab]	11.14[a]	0.69	<0.01

[1] n=10 per treatment. SEM: standard error of the mean. [2]Significant linear effect ($P<0.05$).
[a,b] Mean values in the same row with a different superscript differ, $P<0.05$.

that sulla should contain fibre fractions that are highly digestible for the rabbit, such as pectins (Gidenne *et al.*, 2010). Thus, the sulla contains cell wall polysaccharides that could be more valuable for the rabbit than those contained in alfalfa meal and wheat bran (main fibre source in S0). In fact, sulla NDF digestibility calculated by regression was 54.9%.

Using the digestibility coefficient for gross energy and CP obtained on the 3 feeds, the regression method was used to obtain the equation to predict the digestible energy (DE (MJ/kg)=9.619–0.0169 S (%); R^2=0.20; with S: sulla inclusion level) and protein (DP (g/kg)=118.2–0.55 S (%); R^2=0.55; *P*=0.001) of sun-dried sulla hay. Accordingly, and using the calculation procedure proposed by Villamide *et al.* (2001), the DE of the sun-dried sulla hay reached a value of 7.93±0.57 MJ/kg raw basis. The energy value of our sulla hay was thus 7% higher than the mean value proposed for "alfalfa meal 15" in the EGRAN table (Maertens *et al*., 2002). Moreover, the standard error for the predicted value of digestible energy was low (7.2 %), and within the standards reported in the bibliography (Villamide, 1996). For a moderate inclusion rate (lower than 15%), we can estimate that the DE content of the sulla would be even higher: 9.67±0.10 MJ DE/kg when calculated by difference between S0 and S15 diets and 7.88 between S0 and S30. This high energy value of the sulla, compared to alfalfa, may be originated by the high digestibility of its fibre fraction as reported by Cucchiara (1989) for *H. coronarium*.

In return, the digestible protein (DP) of the sun-dried sulla hay reached a moderate value of 62.9±8.9 g DP/kg raw basis, which corresponded to a CP digestibility of 42.8%. In comparison, CP digestibility reported for alfalfa meal is 15 units higher (58%, Maertens *et al.*, 2002). Moreover, the standard error for the predicted value of DP was relatively high (14.1%). This moderate DP value should to be related to the potentially high tannin concentration in *H. flexuosum,* as found for *H. Coronarium* (Stienezen *et al.*,1996; Amato *et al.*, 2005). However, for moderate inclusion rate (lower than 15%), the DCP content of the sulla would be higher: 78.6±1.61 g DCP/kg (raw basis) when calculated by difference between S0 and S15 diets and 63.1 between S0 and S30.

CONCLUSION

The nutritive value obtained for sundried sulla hay (*Hedysarum flexuosum*) was 8.96±0.57 MJ DE/kg DM and 71.1±8.9 g DP/kg DM. Sun-dried sulla hay could thus be considered as a good and balanced fibre source for the growing rabbit to replace alfalfa meal. However, further experiments are necessary to confirm the present results and determine the maximum inclusion rates for this raw material in balanced feeds without impairment of performance.

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