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NUTRITIVE VALUE OF SUN-DRIED COMMON REED (*PHRAGMITES AUSTRALIS*) LEAVES AND ITS EFFECT ON PERFORMANCE AND CARCASS CHARACTERISTICS OF THE GROWING RABBIT[1]

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Abstract: The nutritive value and potential use of sun-dried common reed (*Phragmites australis*) leaves (CRL), for growing rabbits was studied by comparing 3 diets (regression method) containing an increasing incorporation rate of CRL: 0% (control, CRL0), 15% (CRL15) and 30% (CRL30) in substitution for the control diet (356 g neutral detergent fibre (NDF) and 197 g crude protein (CP)/kg). Three groups of 37 rabbits (individually caged) were fed the 3 diets *ad libitum* from weaning (35 d, mean weight: 722±142 g) to 77 d of age. The faecal digestibility of the diets was measured between 42 and 46 d of age in 10 rabbits per group. CRL can be considered high-fibre roughage, as it contained 64% of NDF (38% of ADF and 10% ADL) and 10.2% of CP. The digestible energy (DE) content of CRL calculated by regression was null (–1.8±0.29 MJ/kg as fed). CP digestibility reached 29%, corresponding to a digestible crude protein concentration of 29.0±5.6 g/kg as fed basis. The fibre digestibility was reduced with CRL incorporation. Dietary incorporation of CRL impaired the rabbit growth (34.2 *vs*. 31.5 g/d during the period 35-77 d without CRL or with CRL (CRL15 and CRL30), respectively; P=0.002). Consequently, feed conversion was impaired with the high incorporation rate in feed (30%). Health status or main slaughter traits were not affected by CRL incorporation rate. Thus, the sun-dried common reed leaves had a poor nutritive value for growing rabbits and it can be considered a high-fibre feedstuff, interesting to supply low digested fibres (cellulose) and lignin.

Key Words: growing rabbit, digestion, common reed leaves, growth performance, nutritive value.

INTRODUCTION

In Algeria and other Maghreb countries (Morocco, Tunisia), dehydrated alfalfa (*Medicago sativa*) and wheat by-products are the main fibre sources for rabbit feed formulations. Alfalfa is imported and becomes very expensive. Therefore, alternatives are required to produce balanced pelleted feeds using local raw materials, available at a lower price. For instance, recent studies reported the interest in using sulla (*Hedysarum flexuosum*) as a fibre and protein source when incorporated in a complete pelleted feed for the growing rabbit (Kadi *et al.,* 2011).

Phragmites australis (Cav.) Trin. exSteud. (Poaceae) (previously *P. communis* or *P. Phragmites*) is a large perennial rhizomatous grass often called common reed and also known as giant reed, giant reed grass, Roseau, Roseau cane, yellow cane and cane (Uchytil, 1992). It is an invading plant with one of the largest geographical distribution of any flowering plant in the world and found on every continent except Antarctica (Brix, 1999). The plant is tall (2.0-4.0 m) and common in and near freshwater, brackish and alkaline wetlands in temperate zones world-wide (Marks *et al.,* 1994). According to the same authors, common reed is frequently regarded as an aggressive and unwanted invader because it is typically the dominant species in the areas that it occupies (Lavoie, 2008). Common reed has been used throughout history for the production of non-food commodities such as paper pulp, roofing and building materials or

[1] One part of these results was presented during the 10th World Rabbit Congress (Sharm El-Sheikh, Egypt, September 2012).

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litter material, as well as heating and as forage feed (Allirand and Gosse, 1995; Kiviat and Hamilton, 2001). Recently, Zhao *et al.* (2011) reported that common reed biomass has great potential for producing biofuel.

Early in the growing season, common reed is high-quality forage for cattle, horses (Majchrzak, 1992) and goats (Sun *et al.,* 2008), but also for ostrich (Cilliers and Angel, 1999). In fact, Baran *et al.* (2002) concluded that this feedstuff could possibly be used as a partial replacement of roughage for ruminants. Reed leaves are already used as forage in some traditional rabbitries in Algeria (Kadi *et al.,* unpublished data), and could be a potential source of fibre and protein as the crude protein (CP) content reached 12.7% (De La Cruz, 1983). To our knowledge, there are no reports in the literature on the effect of sun-dried common reed (*Phragmites australis*) leaves (CRL) incorporation in pelleted complete feed for growing rabbits. So, we aimed to determine the nutritive value of CRL for the growing rabbit.

MATERIALS AND METHODS

Experimental design and feeds

A total of 111 rabbits of Algerian white local population (Zerrouki *et al.,* 2008) were used to assess the nutritive value of CRL and its effect on growth at the rabbitry of the Mechtras vocational training centre, located near Tizi-Ouzou in Algeria (15 to 23°C, 7:00-19:00 lighting schedule). Chemical analyses were conducted at INRA of Toulouse (INRA Toulouse, UMR 1388 GenPhySE, France).

CRL were harvested after flowering stage at the end of autumn, when their colour begins to change from initially fully green to bright yellow, at the Mechtras vocational training centre in the Tizi-Ouzou area. Then, the leaves were manually separated from stems and sun-dried. Samples of CRL were collected in the feed mill factory, and after grinding (3 mm diameter sieves) their chemical composition was determined (Table 1). Three pelleted diets were formulated with an increasing CRL inclusion level (0, 15, and 30%, Table 2). A basal mixture was formulated to fit with nutritional requirement of the growing rabbit (De Blas and Mateos, 2010) and contained dehydrated alfalfa, maize and soya bean meal as main ingredients. Three experimental diets containing an increasing incorporation rate of CRL were prepared by substituting the basal diet, without minerals and premix, with 0, 15 or 30% of dried common reed leaves (CRL0, CRL15, CRL30, Table 2). 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 old (mean weight: 722±142 g) and allotted to 3 groups (37 per diet), according to weaning weight and litter origin. They were placed in wire mesh individual cages (56×38×28 cm) in flat deck layout till 77 d old.

During the 6 wk of the experiment, rabbits were fed *ad libitum* one of the 3 diets, with a weekly control of live weight and feed consumption and a daily control of mortality, following the recommendations for applied nutrition experiments in rabbits of the EGRAN (Fernández-Carmona *et al.,* 2005). Fresh water was always available.

Table 1: Chemical composition of sun-dried common reed leaves (g/kg raw basis)[1].

Dry matter	932
Crude ash	121
Crude protein (N×6.25)	102
Neutral detergent fibre	642
Acid detergent fibre	380
Acid detergent lignin	107
Gross energy (MJ/kg)	17.3

[1]Analytical value of a sample from the material incorporated in the experimental diets.

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 –20°C until chemical analysis.

Diets and faeces were analysed following the EGRAN recommendations (EGRAN, 2001).

At the end of the experiment, 18 rabbits per group were slaughtered (without fasting) at 10 a.m. in controlled

Table 2: Ingredient and chemical composition of experimental diets including 0, 15 and 30% of common reed leaves (CRL0, CRL15 and CRL30, respectively).

Ingredient (% as fed)	CRL0	CRL15	CRL30
Sun-dried common reed leaves	-	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	890	899	894
Crude ash	94	102	106
Crude protein (N×6.25)	197	181	164
Neutral detergent fibre	356	388	431
Acid detergent fibre	170	199	228
Acid detergent lignin	53	64	71
Gross energy (MJ/kg)	16.95	17.01	16.68

[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; cyanocobalamin, 0.0006; vitamin A, 850000 IU; vitamin D3, 170000 IU.

conditions, according to Blasco and Ouhayoun (1996), to record the weight of skin, full digestive tract, hot carcass and liver.

Chemical analyses

The chemical analyses were performed at INRA (UMR 1289 TANDEM) on diets, faeces (10 per group) and the common reed leaves, according to ISO methods and considering the recommendations proposed by the EGRAN group (EGRAN, 2001): dry matter (ISO 6496:1999), crude ash (ISO 5984:2002), crude protein (N×6.25, Dumas method, ISO 16634-2:2009), energy (ISO 9831:1998) and neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) according to sequential method of Van Soest, ashless, without sodium sulphite, and using crucibles (Tecator apparatus) (AFNOR 1997, ISO 16472:2006 and ISO 13906:2008).

The nutritive value of CRL was determined according to the regression and substitution methods described by Villamide *et al.* (2001).

Statistical analyses

Data were analysed as a completely randomised design with type of diet as the main source of variation, using the GLM procedure from SAS software (OnlineDoc®, SAS Inst., Cary, NC). Means comparison were performed using the Scheffe test. The linear effect of CRL incorporation was analysed with the REG procedure of SAS.

RESULTS AND DISCUSSION

Sun-dried common reed leaves composition and experimental feeds

According to their chemical composition (Table 1), CRL can be classified as a very fibrous feedstuff, with values close to those found by Sun *et al.* (2008) but for the whole plant. This may be due to the earlier stage of growth of plants used by those authors and to the latest stage of maturity of leaves used in our trial. At maturity stage, NDF concentration reached 64.2%, with other fibre fractions comparable to the most fibrous feedstuffs such as wheat straw or grape pomace (Maertens *et al.,* 2002). CRL contained a moderate amount of CP, close to that reported by De la Cruz (1983) (12.7%), but higher than that reported for some fibrous feedstuffs usually used in rabbit feed formulation, such as beet pulp, grape seed meal or wheat straw. In addition, CRL presented a relatively high level of ash (12.1%), higher than that reported for the same raw material by Ho (1981; 9.1%) and De la Cruz (1983; 8.6%), mostly owing to their silica content (Schaller *et al.,* 2011), and can also be attributed to soil contamination. However, this ash content is within the range reported by Nikolaje*vs.*kij (1971; between 10 and 18%).

Accordingly, the crude ash level of the diets increased from 9.4 in CRL0 to 10.6% in CRL30.

As expected, the dietary incorporation of CRL increased the NDF level from 35 (CRL0) to 43% (CRL30), while the CP level decreased by 3 units (Table 2).

Nutritive value of common reed leaves

As expected, the dry matter digestibility decreased linearly from CRL0 to CRL30, according to the CRL dietary incorporation (Table 3). Classically, when the dietary fibre level increases the diet digestion is reduced, because of the lower digestion of fibrous components (Gidenne *et al.* 2010a). As usual, a close relationship was observed between the digestibility of organic matter and that of energy. For the majority of the diets, the digestibility of gross energy is 1 to 2 points less than that of organic matter (Maertens and Van Herck, 2001).

Gross energy digestibility was very negatively influenced by CRL level, as it decreased by 20 percentage points from CRL0 to CRL30 (P<0.001). This result agrees with the literature (De Blas *et al.,* 1984, 1989; Gidenne *et al.,* 2010a), which established that the fibre content is the main factor affecting energy digestibility. According to García *et al.* (2002) and Nicodemus *et al.* (2002), dietary inclusion of fibrous feedstuffs at levels of 100-150 g/kg has little effect on rabbit performance. However, an excessive substitution of lucerne hay with highly lignified sources of fibre, which was the case in this assay, depresses energy digestibility (García *et al.,* 1999).

CP digestibility was negatively influenced by CRL incorporation (P=0.001) and it could be explained by the fact that proteins could be associated with cell walls, as usually found in roughages, and their availability being limited.

The fibre fractions digestibility was linearly impaired with CRL dietary inclusion. Indeed, the NDF and ADF digestibility was reduced by 3 and 2 times from CRL0 to CRL30, respectively, probably due to harvesting at the latest stage of maturity of CRL, which increased the content in cellulose, perhaps with high crystallinity for the cellulose molecule due to their silica content, as reported by Schaller *et al.* (2011). Indeed, dry fodders such as cereal straws are generally high in silica and may reach 9% (Gowda *et al.,* 2004).

Table 3: Effect of common reed leaves dietary incorporation level [0, 15 and 30% of common reed leaves (CRL0, CRL15 and CRL30, respectively)] on faecal digestibility coefficients (%) and nutritive value of experimental diets in growing rabbits between 42 and 46 d of age.

	Experimental diets				
	CRL0	CRL15	CRL30	*SEM*	*P*-value
Digestibility coefficients (%)					
Dry matter	57.1^c	44.8^b	38.3^a	0.25	<0.001
Organic matter	57.2^c	44.5^b	38.2^a	0.26	<0.001
Gross energy	56.8^c	44.1^b	36.8^a	0.26	<0.001
Crude protein	63^b	58.6^a	58.5^a	0.74	0.001
Neutral detergent fibre	33.9^c	25.1^b	11.1^a	1.51	<0.001
Acid detergent fibre	22.6^b	17.7^{ab}	11.4^a	1.58	0.002
Dietary nutritive value					
DP (g/kg)	119^c	102^b	92^a	1.28	<0.001
DE (MJ/kg)	9.20^c	7.18^b	5.88^a	0.04	<0.001
Ratio DP/DE (g/MJ)	12.9^c	14.2^b	15.6^a	0.20	<0.001

SEM: Standard error of the mean (n=10 per treatment). DP: digestible crude protein. DE: digestible energy.
[a,b,c]Mean values in the same row with a different superscript differ at P<0.05.

Using the digestibility coefficient for energy and protein obtained on the 3 feeds, we devised equations to predict the digestible energy [DE (MJ/kg)=9.081–0.1088 CRL (%)] and digestible protein [DP (g/kg)=117.91–0.89 CRL] of CRL by the regression method. Accordingly, and using the calculation procedure proposed by Villamide *et al.* (2001), the DE obtained for sun-dried CRL was not different from zero (–1.8±0.29 MJ/kg) and showed a relatively high standard error (16%). In rabbit nutrition there were few studies that dealt with highly fibrous raw material, such forages or by-products. For instance, García *et al.* (1996) reported a negative value (–4.6 MJ/kg DM), for DE for sunflower hulls, and even at a low substitution level (6%). Moreover, the DE value of CRL was similar to that of the wheat straw estimated by Lebas and Djago (2001), which was also not different from zero. For other species, the metabolisable energy of common reed whole plant is estimated to be 2.8 MJ/kg for fowl and 8.7 MJ/kg for ostriches (Cilliers and Angel, 1999).

DP content of the CRL was also relatively low (29.0±5.6 g DP/kg), which corresponded to a CP digestibility coefficient of 28.5%. This value is close to that of cacao hulls (25%), but much higher than that of sunflower hulls (15%) and carob meal (20%), whose fibre content is lower (Maertens *et al.,* 2002). The DP of CRL was more than twice as high in pre-flowering green oat forage (12.4 g/kg) found by Deshmukh *at al.* (1990). The standard error for the predicted value of DP content was also relatively high (19%). Although the CP digestibility variation is only slightly explained by the chemical composition (16% according to Villamide *et al.,* 2010), this DP content should to be related to the fibre concentration in CRL as for the majority of fibrous feedstuffs in EGRAN tables reported by Maertens *et al.* (2002).

Moreover, a high level of substitution of the basal diet with a high fibrous but low fermentable raw material could impair the digestibility of the basal diet and accordingly underestimate its nutritive value, as observed for wheat straw (De Blas *et al.,* 1989).

Health status, feed intake and growth of animals

Throughout the experiment, the health status of rabbits was good, as only 2 rabbits died in the CRL0 groups and 4 in CRL15, but none in the CRL30 group (no antibiotic treatment was used during the trial).

As we choose an unbalanced feed formulation to assess the nutritive contribution of the CRL, growth and intake over the whole fattening period was better in the control group (Table 4). According to Motta-Ferreira *et al.* (1996), an excessive substitution of lucerne hay with highly lignified sources of fibre impairs average daily gain and feed efficiency. However, global growth rate exceeded 30 g/d, while feed intake varied from 114 g/d in the CRL15 group to 129 g/d in the CRL30 group (P<0.05). Consequently, the global feed conversion ratio was better (P<0.001) for the control group and CRL15 compared to CRL30 (3.6 *vs.* 4.16). These results are in agreement with the literature.

The performances deteriorated during the second period 56-77 d of fattening with the decrease in growth rate and increase in feed intake, especially in the CRL30 group. Consequently, the feed conversion ratio is the worst but similar in the 3 groups.

Accordingly, for the whole fattening period (35-77 d), feed intake was 13% higher in CRL30 than in CRL15. This was the consequence of the capacity of the rabbits to control their feed intake according to the dietary DE content, although when the DE content is lower than 9 MJ/kg a reduction of DE intake is usually observed (Lebas, 1975). Here, diets CRL15 and CRL30 are under this threshold, with a DE content of 7.1 and 5.8 MJ/kg respectively. Accordingly, rabbits attempt to increase their feed intake to satisfy energetic needs, but it is not enough because of the high fibre level (Gidenne and Lebas, 2002). For instance, DE intake (35-77 d) decreased with CRL incorporation: 1.1, 0.82 and 0.76 MJ/d ingested respectively in CRL0, CRL15 and CRL30. However, as the reduction of DP is less abrupt, the DP to DE ratio increases from 12.9 in CRL0 to 15.65 g/MJ in CRL30. Thus, the growth rate was not modified, but presented a sensible increase of feed conversion ratio, as reported by several authors (Maertens, 1992; Lebas and Djago, 2001; Xiccato and Trocino, 2010).

Overall, rabbits used here reached a relatively high growth performance compared to those generally obtained with “Kabyle” rabbits of the local population. For instance, they were about 11% higher than those reported by Lakabi-Ioualitene *et al.* (2008) and Guemour *et al.* (2010) but 32% higher than those reported by Lounaouci-Ouyed *et al.* (2009).

Table 4: Effect of common reed leaves dietary incorporation [0, 15 and 30% of common reed leaves (CRL0, CRL15 and CRL30, respectively)] on feed intake and growth of rabbits.

	Experimental diets				
	CRL0	CRL15	CRL30	SEM	*P*-value
n	35	33	37		
Period 35-56 d					
Live weight at 35 d (g)	720	729	716	45.4	0.98
Live weight at 56 d (g)	1512	1508	1419	56.7	0.42
Weight gain (g/d)	38.9^{b}	38.4^{b}	33.9^{a}	0.82	<0.001
Daily intake (g/d)	106.0^{a}	118.8^{b}	107.0^{a}	4.0	0.048
Feed conversion (g/d)	2.89	3.18	3.15	0.11	0.129
Period 56-77 d					
Live weight at 77 d (g)	2130	2050	2020	55.7	0.35
Weight gain (g/d)	29.5^{b}	26.5^{a}	28.6^{ab}	0.80	0.04
Daily intake (g/d)	127.3^{b}	115.8^{a}	137.8^{c}	3.02	<0.001
Feed conversion (g/d)	4.38^{a}	4.40^{a}	4.81^{b}	0.12	0.035
Period 35-77 d					
Weight gain (g/d)	34.2^{b}	31.8^{a}	31.1^{a}	0.62	0.002
Daily intake (g/d)	119.9^{ab}	114.4^{a}	129.5^{b}	2.85	0.001
Feed conversion (g/d)	3.59^{a}	3.64^{a}	4.16^{b}	0.09	<0.001

n: number of rabbits at the end of experimental period. SEM: Standard error of the mean.
^{a,b}Mean values in the same raw with a different superscript differ, *P*<0.05.

Slaughter performances

The average slaughter live weight (Table 5) obtained at 77 d (2309 g) was usual in our breeding conditions with white population rabbits. For instance, it was similar to that reported by Kadi *et al.* (2011) for this line in the same breeding conditions. However, compared to live weight at slaughter usually reached by rabbits of local population "Kabyle", it is 60% higher than that found by Guemour *et al.* (2010) and 26% than that reported by Lakabi-Ioualitene *et al.* (2008).

As a consequence of the very low NDF digestibility of CRL, and of the increased fibre level of feeds with CRL incorporation, the weight of the full digestive tract increased linearly. This may be explained, as already underlined by Gidenne *et al.* (1991) and Gidenne (1992), by the physical adaptation of the rabbits' digestive tract to the increase in diet intake, a consequence of high cell wall levels (43% NDF in CRL30). Hence, the full digestive tract weight linearly impairs dressing out percentage. As pointed out by Hernández and Dalle Zotte (2010), when a high dietary fibre level decreases the growth rate, slaughter yield falls due to increased digestive tract proportions. Indeed, Tao and Li

Table 5: Effect of dietary level of inclusion of common reed leaves [0, 15 and 30% of common reed leaves (CRL0, CRL15 and CRL30, respectively)] on slaughter traits of rabbits[1].

	Experimental diets				
	CRL0	CRL15	CRL30	SEM	*P*-value
Slaughter weight (SLW), g	2310	2277	2341	50.4	0.73
Skin weight, g	248	237	240	8.0	0.39
Full digestive tract, g	340^{a}	363^{a}	409^{b}	10.2	<0.001
Hot carcass weight (HC), g	1619	1571	1569	38.2	0.33
Liver weight, g	81^{ab}	78^{a}	90^{b}	2.81	0.047
Dressing out percentage HC/SLW, %	70.1^{b}	69.3^{b}	67^{a}	9.9	<0.001

[1] Slaughter at 11 wk of age. [2] Standard error of the mean (n=18 per treatment).
^{a,b}Mean values in the same raw with a different superscript differ, *P*<0.05.

(2006) reported that caecum weight and proportion of caecum weight to body weight increases when the dietary NDF concentration increased.

Hot carcass weight was not significantly affected by CRL inclusion rate, and reached an average weight of 1586 g, which is slightly higher than the local market weight (Kadi *et al.,* 2008).

Liver weight was influenced either by CRL incorporation but also by the rate of incorporation with, on av., values close to those reported in the literature (Eiben *et al.,* 2010). The fibre digestion was so low and linearly impaired with CRL dietary incorporation that it can be suspected to increase liver weight. Recently, Papadomichelakis *et al.* (2012) reported that liver weight of rabbits decreased with increasing degradable fibre in the diet.

CONCLUSION

The nutritive value for the growing rabbit appears poor, either in terms of its DE (around zero) and its DP levels (29 g DP/kg as fed basis). CRL can therefore be considered as a high fibre feedstuff, interesting to cover the fibre requirements of the growing rabbit in cellulose and lignin. In perspective, we should consider an earlier harvest of the CRL, before the maturity stage, and expect a lower mineral content and a higher protein concentration. Moreover, further research with balanced diets is necessary to determine the effect of reed leaves on rabbit performance and health.

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