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NUTRITIVE VALUE OF ASH LEAVES (*Fraxinus angustifolia*) FOR GROWING RABBITS

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ABSTRACT: The digestibility and nutritive value of ash (*Fraxinus angustifolia*) leaves, harvested in autumn was determined (direct method), using ten rabbits (individually caged) weaned at 35d old (mean body weight: 911g) fed ad libitum only fresh ash leaves during 16 days. Ash leaves composition was: organic matter (OM) 89.3%, crude protein (CP) 14.6%, neutral detergent fibre (NDF) 39.4, acid detergent fibre (ADF) 28.3, acid detergent lignin (ADL) 16.1% on dry matter (DM) basis. The faecal digestibility of the ash leaves was measured between 48 and 52 day sold. The digestibility of OM, CP, NDF and ADF were 74, 67, 59 and 59%, respectively. The concentration in digestible energy and digestible protein of the ash leaves was estimated to 13.6±0.90 MJ/kg DM and 98±10.43 g/kg DM, respectively. In general, ash leaves harvested in autumn could be considered as a good source of fibre and energy for the growing rabbit. Therefore, Incorporating ash leaves moderately in a pelleted and balanced diet with a sufficient level of ingestion should be considered in ration formulation of growing rabbits.

Keywords: Ash leaves, *Fraxinus angustifolia*, nutritive value, autumn, digestibility, Growing Rabbits

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INTRODUCTION

In Algeria, the quality of the dominant forage is often too poor to satisfy the nutritional requirement of the growing rabbit. Furthermore, this situation generates a supplementation with imported concentrates thus increasing the costs. Moreover, the fibres levels are generally too low to meet the fibre requirement of the growing rabbit (Gidenne et al., 2015). New low-cost alternatives fibre sources are thus needed, such local high-fibre materials and non-conventional forage. Indeed, tree leaves has been shown to be one possible alternative.

Fodder trees are exploited in animal feeding especially for ruminants. Leaves and twigs can be grazed directly or cut and distributed to the animals (El Shaer, 2000). Ash (*Fraxinus sp.*) is one of those fodder trees exploited in the whole Mediterranean area. *Fraxinus angustifolia* Vahl, synonym of *Fraxinus oxycarpa* Willd and *Fraxinus rotundifolia* Mill. subsp. *rotundifolia*, is a medium-sized tree also known as ash, narrow leaf ash, narrow-leafed ash or desert ash. It's native to North Africa and south-western Europe and covers central-southern Europe and northwest Africa, up to the Caucasus (Caudullo and Houston Durrant, 2016). In Kabylia (Algeria), *F. angustifolia* is the most available species of ash, and very common in garden, where it is planted in borders of plots, and street ornamental tree (Kadi and Zirmi-Zembri 2016). Several researchers reported its nutritional and medicinal benefits in many articles (Belkadi et al., 2015; Moulaoui et al., 2015; Ayouni et al., 2016).

Ash leaves has been reported to be a valuable component in ruminants feed due to its adequate content in energy and protein (Bourbouze, 1980). It's used in feeding of goats (Masson et Decaen, 1980; Bourbouze, 2005); sheep (Pereira et al., 2008) and cattle (Vergara et al., 2007).

Herbivore, rabbit is known to valorise roughage and fibrous resources. Several studies (Raharjo et al., 1986, Deshmukh et al., 1993a) have reported the possibility of incorporating tree leaves in rabbit diets. As everywhere in

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the world, tree leaves are used as fodder source for rabbits in traditional farms in Algeria (Saidj et al., 2013). However, the traditional knowledge about use of plants was not well explored (Lukefahr and Cheek, 1990).

Several studies (Raharjo et al., 1986; Deshmukh et al. 1993a; Kadi, 2012) have reported the possibility of incorporating tree leaves in rabbit diets. Nevertheless, their nutritive value is not available in feed tables; which is the case of most natural herbaceous fodders, where even the data about their chemical composition is scarce (Kadi and Zirmi-Zembri, 2016).

With 16.4 % of crude protein (Villar et al., 2006) and 12 to 15% of ADL (Petisco et al., 2005), ash leaves would fit the minimal nutrient requirement of growing rabbits reported by Gidenne et al. (2015). Accordingly, we aimed to determine, via the direct method (Villamide et al., 2010), the nutritive value for growing rabbits of the fresh ash (*Fraxinus angustifolia*) leaves harvested in autumn.

MATERIALS AND METHODS

Animals and diets

Ten local white rabbits, weaned at 35 d of age (mean weight: 911 ± 128 g) and placed in wire mesh individual cages (56 × 38 × 28 cm) in flat deck disposition, were used to assess the nutritive value of ash leaves. The study complied with the University of Tizi-Ouzou guidelines on ethical standards.The green leaves of ash tree (*Fraxinus angustifolia)* were harvested manually, daily in the morning and distributed *ad libitum* as sole feed for the rabbits (Figure 1). Permanent access to clean fresh water is available using an automatic watering. Samples of ash leaves were collected throughout the digestibility trial period, mixed and stored in polyethylene bag at –20 °C until the chemical analysis.

(A) (B)

Figure 1 - Preparation of leaves tufts after weighing (A) and suspension in the cage (B)

Digestibility trial

After a 12 days adaptation period (52 d old), rabbits were used for the digestibility trial, following the European reference method described by Perez et al. (1995). The cages were equipped with a wire net under the floor to collect individually and totally the hard faeces during a 4-day period. Faeces were stored daily in polyethylene bags at –20 °C until chemical analysis. Two samples of ash leaves were collected every day during the 4 days. The first sample is collected at the moment of the distribution for rabbits. The second concern the daily ash leaves refused in order to determine their dry matter.

Analytical methods

The chemical analyses were performed at INRA of Toulouse (UMR 1388 GenPhySe, France). Dry matter, crude ash, crude protein (N x 6.25), energy (adiabatic calorimeter Parr), Van Soest fibre (NDF, ADF and ADL) were measured on ash leaves and faeces according to EGRAN harmonised procedures (EGRAN, 2001).

Statistical analysis

The results obtained were treated using Excel 2013 Microsoft® software. Because only one diet was used, the results are presented with only mean and standard error and without any statistical test. Apparent digestibility coefficients for dry matter, organic matter, crude protein, gross energy, neutral detergent fibre and acids detergent fibre of ash leaves were determined for each animal as:

Apparent digestibility = (NI – NFE/NI) * 100

With:

NI = Nutrient intake, NFE = Nutrient fecal excretion

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RESULTS AND DISCUSSION

Chemical composition

According to their chemical composition (Table 1), ash tree leaves seem to be relatively balanced feedstuff for rabbits. Indeed, their crude protein content was interesting (147 g/kg DM) for fresh tree leaves and close to that of some raw material reported in EGRAN tables by Maertens et al. (2002) and usually incorporated in rabbit diets. It is the case of some cereal by-product as wheat bran, wheat feed and rice bran but especially for that considered as fibrous feedstuffs. However, the value of CP content in ash leaves was higher than those obtained by Ibrahim et al. (2011) who reported that CP content of lemon pulp, orange pulp and yellow corn was 70.4, 64 and 77 g/kg DM, respectively. However, it is extensively lower to the four other legumes: *Leucaena leucocephala*, *Moringa oleifera*, *Gliricidia sepium* and *Enterolobium cyclocarpum*: 298, 245, 269 and 287*vs* 147 g/kg DM, respectively (Abu and Turner 2016). They contain more protein (131 g/Kg if reconsidered for 90% DM as in EGRAN tables of Maertens et al., 2002) that Alfalfa meal 12 (126 g/Kg), Beet pulp (90 g/kg), Citrus pulp (59 g/Kg), Olive leaves (90 g/Kg) or carob meal (47 g/Kg). Villar et al. (2006) reported a level of 16.3 % of crude protein for *F. angustifolia* leaves harvested in Cordoba (Spain). While, surprisingly, Mebirouk-Boudechiche et al. (2015) pointed out a rate of 22.6g/kg DM for *F. angustifolia* leaves in eastern Algeria, probably because the samples were collected in spring.

For instance, ash leaves can be considered as fibre source (NDF: 394 g/kg DM, ADF: 283 g/kg DM, ADL: 161 g/kg DM). Petisco et al. (2005) reported a rate of 14.3 % of lignin for those ash leaves. According to Gomez and Fillat (1984), the chemical composition of ash leaves depends on the period in which they are harvested and their digestibility decreases if they are cut in September and October compared with month of August.

Table 1 - Composition of fresh ash leaves (*Fraxinus angustifolia*) given as a sole ration for growing rabbits in this study compared to Sulla hay (*Hedysarum flexuosum*) and Lucene hay (*Medicago sativa*)

Items	Ash leaves composition[1]		Sulla hay (*Hedysarum flexuosum*)[2]	Lucerne 15 hay (*Medicago sativa*)[3]
	g/kg raw basis	g/kg DM	g/kg DM	g/kg DM
Dry Matter (DM)	410	–	–	–
Organic matter (OM)	366	893	859	890
Crude ash	44	107	141	110
Crude protein (CP)	60	146.7	166	170
Neutral detergent fibre (NDF)	162	394	495	464
Acid detergent fibre (ADF)	108	283	381	362
Acid detergent lignin (ADL)	62	161	90	81
Energy (MJ/kg)	7.95	19.39	17.03	-

[1]Sample of ash offered during the digestibility period; [2] Kadi et al. (2011); [3] Maertens et al. (2002).

Moreover, it is known that the fibrous feedstuffs that contain amounts of protein are scarce. According to Carabano and Fraga (1992), fibrous raw materials containing a significant amount of protein are very suitable for rabbit feeding. It's precisely the case of fresh ash leaves which contain appreciable amounts of protein (146.7 g/kg DM), fibre (ADL: 161 g/kg DM) but also energy (19.4 MJ/kg DM). Indeed, protein content of the fresh ash leaves studied here are higher than that obtained by Deshmukh et al. (1993b) for coastal Bermuda grass (116 g/kg DM) and El Shaer (2000) for *Acacia saligna* (125 g/ kg DM). This amount of protein is close of those of reference legume such as Lucerne and Sulla hay (Table 1). Therefore, those amounts of proteins and fibre justified the use of direct method for estimating the nutritive value of those leaves for the growing rabbits.

Consumption and digestibility

Ash leaves were appreciated by rabbits and were much consumed (Figure 2). The amount of intake of ash leaves recorded here (97 g DM/day, Table 1) is higher than the one (78.5 g DM/day) reported for herbage intake by Martin et al. (2016). The fresh intake thus reached 236 g as fed/day indicating a high intake capacity of the rabbit for fresh forages. According to Lebas (2013), the maximum intake capacity of rabbit per day is about 5 to 9% of its live weight expressed as dry mater. But, with fresh products such as green forage, the maximum intake capacity is about 20-25% of live weight, calculated on as feed basis (Lebas, 2013). Effectively, the daily intake (236 g as fed/day) recorded in this study was about 25% of the live weight (911 g).

Contrary to ruminants, in the rabbit an increase of diet's fiber content increases the speed of transit, allowing the animal to increase also its feed intake (Lebas, 2013). Effectively, ash leaves are high fibrous source which could increase their consumption by the rabbits. Moreover, Fraga et al. (1991) reported that fresh forages stimulate stomach growth, which accounted for subsequent higher feed intake capacity compared to rabbits fed only pellets.

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According to De Blas et al. (1985), the requirements in terms of Digestible Crude Protein/Digestible Energy (DCP/DE) ratio for maintenance are close to 6.8 g MJ/d. The daily average intake of DCP and DE were 9.52 g and 1.32MJ, respectively, which implies that ash leaves assure the maintenance requirements for rabbit (average daily gain of 2 g during 13 days).

(A) (B)

Figure 2 - Ash leaves at moment of distribution (Photo A) and one day after (Photo B)

The apparent digestibility coefficient of energy (Table 2) of ash leaves was 70%. It was slightly higher to the norms generally recorded with forages, which vary from 45 to 65 % (Villamide et al., 2010). The faecal digestibility of ash leaves energy was high (70%) and higher to those obtained by Raharjo et al. (1986) for all the species they studied. The energy of those leaves was much better digested than that (51.6%) of a fresh legume as Sulla felexuosa (*Hedysarum flesuousm*, Kadi et al., 2012). This digestibility coefficient of energy is also higher than that reported by Perez (1994) who obtained a coefficient ranged from 42.5 to 58.9% for twelve batches of luceme differing by their protein (16 to 26% DM) and crude fibre content.

The faecal digestibility of ash leaves protein was 67%, a classical normal value for forages. It's similar to the values obtained with direct method and reported in the bibliography for ryegrass (67 %) (Fernandez-Carmona et al., 2001); but slightly higher than that of Lucerne (64%) (Fernandez-Carmona et al., 1998) or Sulla flexuosa (64%) (Kadi et al., 2012) and slightly lower than that of *Leucaena leucocephala* leaves (75.9%) (Raharjo et al., 1986). NDF and ADF digestibility were high (59%) probably due to a high level of digestible fibres such as pectins (Gidenne et al., 2010).

A slight live weight loss during the digestibility trial is recorded (Table 2) as often observed in the first weeks of several studies (Raharjo et al., 1986; Deshmukh et al., 1990; Deshmukh et al., 1993b) when forage was fed as sole diet for rabbits. Accordingly, as reported by Deshmukh et al. (1990), a minimum adaptation period of at least three weeks is necessary to rabbits when they are fed solely by forage to see a trend of increase in body weight.

Table 2 - Body weights, feed intake and digestibility coefficients of the fresh ash leaves (*Fraxinus angustifolia*) given as a sole ration for growing rabbits.

Items	Weight and feed intake		Digestibility (%)	
	Mean	SE	Mean (%)	SE
Initial body weight (g)	911	52		
Final body weight (g)	903	77		
Ash leaves intake (g DM/day)	97	04		
Ash leaves intake (g as fed/day)	236	10		
Dry Matter (DM)			75	1.6
Organic matter (OM)			74	1.6
Crude protein (CP)			67	2.9
Neutral detergent fibre (NDF)			59	2.4
Acid detergent fibre (ADF)			59	2.4
Energy			70	2.0

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Nutritive value

The digestible energy (DE) was 13.6 MJ/kg DM. The standard error calculated by the equation proposed by Villamide (1996) was 0.36 (Table 3). While comparing this value to those returned in the EGRAN tables (Maertens et al., 2002), it appears that this value is higher to the value of oat seed, cereals by-products (gluten feed and wheat shorts) and oils meals (palm cake). Also, it is located at the neighborhood of the beet molasses and lupin.

The digestible proteins (DP) was 98.0g DP/kg DM (Table 3) with a standard error of 10.43 according to the equation of Villamide (1996). The ash leaves have more digestible proteins than the sundried maize whole plant silage (44 *vs.* 98) and less that the brewer's grain (157 *vs.* 98) used like raw materials at the formulation of two complete diets by Guermah and Maertens (2016).

In most publications on the rabbit nutrition, the formulation of balanced diets take into account the ratio is expressed by the report digestible proteins on the energy digestible (Gidenne et al., 2015). The ratio DP/DE calculated in this study was lower to the optimum recommended by Maertens (1996) and that is of 45-46 g digestible protein/1000 kcal of DE. This slightly low report (45 *vs.* 30) is assigned to digestible energy excess in relation to the quantity of digestible proteins of ash leaves.

Table 3 - Nutritive value of fresh Ash leaves (*Fraxinus angustifolia*)

Items	Dietary nutritive value	
	Mean	SE
Digestible Energy or DE (MJ/Kg DM)	13.59	0.36
Digestible Protein or DP (g/Kg DM)	98.08	4.26

CONCLUSION

The nutritive value of fresh ash (*Fraxinus angustifolia*) leaves harvested at autumn season and estimated by direct method was 13.6±0.90 MJ DE/kg DM and 98.1±10.43 g DP/kg DM. The ash leaves can be considered as fibrous source for growing rabbits. They are capable of supplying the maintenance requirements and perhaps also for production after an adaptation period. Their moderate incorporation in a pelleted and balanced diet (about 20%) with a sufficient level of ingestion, those ash leaves can become a good source of fibers and energy.

Besides, those results seem interesting and must be confirmed especially by the regression method proposed by Villamide et al. (2001). Moreover, the optimal incorporation level in a diet should be studied using balanced diets and measuring growth performances and health of the growing rabbits.

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Author's contribution

All authors contributed equally to this work.

Competing interests

The authors declare that they have no competing interests.

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