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Digestibility and energy content of Paulownia (*Paulownia elongata* S.Y.Hu) leaves

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Abstract. *The aim of the study was to determine the digestibility and energy content of Paulownia elongata S.Y.Hu leaves after leaf fall. Leaves together with petioles were dried at room temperature and milled with a roughage mill before feeding to animals. A classical digestion trial was performed, with three rams weighing 55.4kg on average, by determining the chemical composition of consumed feed, feed leftovers and excreted faeces. Digestibility was evaluated as difference in the amount of ingested nutrients and nutrients excreted with faeces and it was determined to be 50.72, 52.08, 31.63, 54.09, 55.15 and 56.06% for dry matter (DM), organic matter (OM), crude protein (CP), ether extract (EE), crude fibre (CF) and nitrogen-free extract (NFE). The energy value for ruminants calculated on the basis of chemical composition and established digestibility was 8.29 MJ digestible energy (DE)/kg DM, 6.55 MJ metabolizable energy (ME)/kg DM, 0.59 feed units for milk (FUM)/kg DM and 0.52 feed units for growth (FUG)/kg DM.*

Keywords: Paulownia (*Paulownia elongata* S.Y.HU) leaves, digestibility, energy content

Abbreviations: CP – crude protein, CF – crude fibre, DE – digestible energy, DEE – digestible ether extract, DF – digestible fibre, DNFE – digestible nitrogen free extract, DP – digestible protein, DM – dry mater, EE – ether extract, FUG – feed unit for gain, FUM – feed unit for milk, ME – metabolizable energy, NFE – nitrogen-free extract, OM – organic matter.

Introduction

The *Paulownia* tree (family Paulowniaceae) is a deciduous rapidly growing species with hard wood. It is encountered in the wild or cultured in different parts of the world – China, Japan, South-eastern Asia, Central and North America, Australia, Europe. It is easily accustomed to different climatic conditions, growing well also on depleted and eroded soils. It is characterised by high resistance to drought, pests and diseases. The tree is mostly grown because of the excellent quality and beautiful wood, used for making furniture, musical instruments, floorings, panellings, etc. The *Paulownia* leaves, reaching up to 80cm in diameter, are also interesting. Their high capacity for CO_2 fixation contributes to decontamination of air, and fallen leaves improve soil quality by increasing its organic matter content. *Paulownia* leaves are palatable and with good energy value, so they are appropriate as an animal feed ingredient (Zhaohua, 1987; Mueller et al., 2001; Barton et al., 2007; Koleva et al., 2011; Descals et al., 2013; Bodnár et al., 2014; Stewart et al., 2018). The crude protein content varies from 11.3 to 27.1% (Descals et al., 2013) and is characterised with high content of glutamic acid (16.04%) and aspartic acid (11.30%), contains also higher amounts of essential amino acids compared to other leafy feeds (Koleva et al., 2011a). Mineral content of leaves is 6-9% (Stewart et al., 2018), including 2.1% calcium, 0.6% phosphorus, 0.9% zinc and 0.6% iron (El-Showk and El-Showk, 2003). The Ca:P ratio varies from 2.29:1 to 6.7:1 (Mueller et al., 2001; Al-Sagheer et al., 2019). A tree aged 8-10 years could yield up to 100kg fresh leaves (Woods, 2008).

Paulownia leaves could be used for feeding animals both fresh and dried, as well as in the form of silage. Dried leaves are most commonly used as a component of compound feeds. Available research data showed increased egg production by 3.3% and egg weight by 1.7% after using more than 19% leaves collected after leaf fall in compound poultry feeds (Wang and Shogren, 1991) and increased weight gain of growing and finisher pigs (Boying, 1995). The utilisation of 15% *Paulownia* leaves in the rations of rabbits did not have any adverse effect on weight gain, blood biochemistry, ration digestibility and dietary energy content, whereas the inclusion of 30% leaves decreased the digestibility of nitrogen-free extract and dietary energy content. The nutritional value of leaves depends not only on nutrient content, but also on nutrient digestibility. According to Hongfu et al. (1995) the higher digestibility was the factor determining the higher nutritional value of *Paulownia* leaves compared to rice and wheat straw. The dry matter and organic matter digestibility of *Paulownia* leaves were evaluated in *in vitro* experiments (Mueller et al., 2001; Gutierrez et al., 2015). Our aim was to determine the digestibility and energy content of *P. elongata* leaves collected after leaf fall in *in vivo* trials with rams.

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Material and methods

The trials were conducted in the experimental base of the Faculty of Agriculture, Trakia University – Stara Zagora. Assayed *P. elongata* leaves were collected in November, after leaf fall. Leaves, along with petioles were dried at room temperature (20-25°C) and milled with a roughage mill before feeding to animals.

Digestibility was evaluated via the classical method with three rams with average live weight 55.4kg, placed in individual cages with appliances for collection of faeces and urine. The trial included a 7-day preparation period and a 5-day experimental period. The feed intake and leftovers, as well as the amount of excreted faeces were determined. Feed, weighed at the beginning of the trial, was offered twice: in the morning at 9.00AM and in the afternoon at 4.00PM. From faeces, collected in canvas bags, average daily samples representing 10% of the total amount collected for analysis after homogenization were obtained throughout the experiment. Samples were dried at 65°C until constant weight and then ground for analysis.

Chemical analysis – dry mater, crude protein, ether extract, crude fibre, ash of consumed feed, feed leftovers and excreted faeces was done according the methods described by AOAC International (2007). All samples were analysed in duplicate.

Digestibility was calculated as difference in consumed nutrients and nutrients excreted with faeces.

Energy content was calculated on the basis of chemical composition and digestibility of leaves obtained from the *in vivo* digestibility trial, using the equations (Todorov et al., 2007):

GE = 0.0242 CP + 0.0366 EE + 0.0209 CF + 0.017 NFE;

DE = 0.0242 DP + 0.0341 DEE + 0.0185 DCF + 0.017 DNFE;

ME = 0.0152 DP + 0.0342 DEE + 0.0128 DCF + 0.0159 DNFE;

FUM = ME (0.075 + 0.039q);

FUG = ME (0.04 + 0.1q);

q = ME/GE.

All data for feed and faeces content are presented on dry matter basis.

The analysis of data was done with Statistica software, Windows.

Results and discussion

Chemical analysis results are presented in Table 1. Crude protein content of leaves was 8.85%. Substantially higher CP values were reported by El-Showk and El-Showk (2003) – 22.6% and by Descals et al. (2013) – 27.1% for young leaves. Similar crude protein percentage was demonstrated by Mueller et al. (2001) in a comparison of various *Paulownia* genotypes – the CP in *P. elongata* leaves without petioles was found to be 25.1% in September 1997 and 21.4% in June 1998. Almost constant throughout the vegetation period, but lower CP values within 17.41–17.75% were reported by Bodnár et al. (2014), Stewart et al. (2018) and Al-Sagheer et al. (2019). Gutiérrez et al. (2015) observed that leaves collected between August and mid-October contained from 14.24 to 14.79% crude protein.

Table 1. Chemical composition and digestibility of Paulownia leaves

Parameters	DM	% on DM basis				
		OM	CP	EE	CF	NFE
Chemical composition	91.75	85.06	8.85	0.94	40.81	34.46
Digestibility coefficients	50.72±0.83*	52.08±0.76	31.63±1.17	54.09±1.89	55.15±1.40	56.06±0.94

*Standard error of the mean

Our data were the closest to the data of Descals et al. (2013), who found out 11.3% crude protein in leaves gathered in late autumn. Low CP content of leaves at that time could be attributed to the fact that nitrogen accumulation had a seasonal character and it decreased in autumn, whereas the accumulation in stems and roots of the plant increased in relation to forthcoming leaf fall (Gutiérrez et al., 2015). Lower CP values in our study were also probably due to the use of leaves with petioles, and protein content in the latter was significantly lower (Mueller et al., 2001; Koleva et al., 2011).

Crude protein in *P. elongata* leaves was lower compared to other leafy fodders such as acacia (13.8%), ash (14.1%), poplar (11.6%), birch (9.0%) and oak (13.5-15.0%), which, although at limited extent, are used in animal nutrition (Todorov et al., 2007).

Ether extract in *P. elongata* leaves was 0.94%, which was considerably lower than data reported in other research studies. According to Stewart et al. (2018), average EE in leaves was 2.83% with range from 1.9 to 3.8% from April to November. Comparable results were obtained by Bodnár et al. (2014) – 2.84%. Al-Sagheer et al. (2019) reported ether extract content of 3.84% in *P. tomentosa* (Thunb.) leaves gathered in October. Following out the changes in the chemical content of leaves, Descals et al. (2013) established a reduction of ether extract content from 4.1% in the spring to 2.2% after leaf fall. Considerably higher ether extract content of leaves was found out by Gutiérrez et al. (2015). During the vegetation, ether extract content increased from 4.44% in early August to 7.29% in 60% bloom in September and decreased to 5.54% in full bloom in October.

The results from the analyses showed crude fibre content of 40.81%. This value was significantly higher that that reported in other studies. According to Al-Sagheer et al. (2019) crude fibre content of leaves gathered in October was 23.87%. Descals et al. (2013) reported leaf crude fibre content of 15.7% after leaf fall. The lowest CF percentage was found out in spring – 12.9%, then it increased to 15.7% in summer and decreased to 14.1% in autumn before leaf fall. Even lower values of 12.43% CF were reported by Bodnár et al. (2014).

Ash content was 14.94% which was higher than that found by Bodnár et al. (2014) – 10.5% and reported in early August and mid-October by Gutiérrez et al. (2015): 7.62% and 10.76%, respectively. Values from 6% to 9% were reported by Stewart et al. (2018) between the vegetation period, whereas in leaves collected in October, crude ash content reported by Al-Sagheer et al. (2019) was 8.85%.

The results from the digestibility trial are also presented in Table 1. Digestibility of dry matter was 50.72% - lower than that reported in other studies. The closest value – 56.14% was obtained for *P. elongata* leaves gathered in October in *in vitro* experiments (Gutiérrez et al., 2015). The authors found out changes in digestibility during the vegetation, with the highest values for leaves gathered in the beginning of August (57.44%). Substantially higher DM digestibility was reported in leaves analysed by Mueller et al. (2001) – 77.0% in September 1997, 80.1% in June 1998 and 67.4% in August 1998. The researchers found out also high digestibility of DM of petioles – 71.5%.

Organic matter (OM) digestibility was 52.08%. Higher percentage was reported in *in vitro* experiments of Gutiérrez et al. (2015) – 58.95% for leaves gathered in October.

The digestibility of crude protein (CP), ether extract (EE), crude fibre (CF) and nitrogen-free extract (NFE) was 31.63, 54.09, 55.15 and 56.06%, respectively. In literature, there are no data concerning digestibility of different nutrients. Only a report by Al-Sagheer et al. (2019) in trials with rabbits reported lack of statistically significant differences ($p>0.05$) in the digestibility of DM, CP, EE and CF of rations in which alfalfa hay (30% of compound feed) was replaced by 15 and 30% *Paulownia* leaves. The only statistically significant difference was observed for NFE digestibility which decreased when a part or the entire amount of alfalfa hay in compound feed was replaced by *P. tomentosa* leaves.

The energy content of *P. elongata* leaves for ruminants, calculated on the basis of chemical composition and digestibility of leaves was 8.29 MJ DE/kg DM, 6.55 MJ ME/kg DM (1.57 Mcal DE/kg DM), 0.59 FUM/kg DM and 0.52 FUG/kg DM. Similar results for digestible energy were presented by Descals et al. (2013). The researchers obtained variable DE of leaves – 2.3 in summer, 1.9 in autumn and 1.7 Mcal/kg for leaves after leaf fall. Slightly higher values for DE for ruminants – 2.05 Mcal/kg for leaves gathered before leaf fall (October) were reported by Gutiérrez et al. (2015).

The lower CP and EE content, the higher CF and lower energy value of *P. elongata* leaves found in this study was probably due to the fact that petioles were not removed before milling of leaves and feeding them to animals. In most studies reporting higher CP, EE and lower CF values, regardless of the month of collection of leaves, not only the petioles but also the rough veins of leaves were removed. The higher CF content in our study was responsible for the lower dry matter and organic matter digestibility of leaves gathered after the leaf fall.

The comparison of *Paulownia* leaves gathered in different vegetation stages to other fodders with respect to their chemical composition and nutritional value demonstrated that they had higher protein content than some traditional for our country roughages (corn silage, straw) but lower than alfalfa hay. A similar relationship was observed also by Gutiérrez et al. (2015). According to Descals et al. (2013), however, CP content of *Paulownia* leaves was lower than that of alfalfa hay only after the leaf fall, whereas leaves gathered in the autumn had similar CP content and those gathered in the spring and summer – even higher as compared to alfalfa hay. The digestibility of DM and OM was higher that that of straw from cereals and almost similar to digestibility of other leafy fodders (Todorov et al., 2007; Gutiérrez et al., 2015). The metabolisable energy content of leaves gathered in the spring and summer was higher that that of alfalfa, whereas in older leaves gathered in the autumn, ME was lower compared to that of alfalfa hay yet higher than ME of wheat straw (Descals et al., 2013).

Most investigations reporting data from the chemical composition and nutritional value of *Paulownia* leaves have previously removed the petioles, which is labourious and practically hardly applicable. Therefore, additional studies are needed to establish the effect from gathering leaves in the period when their nutritional value is the highest, and whether removal of petioles before feeding the leaves to animals is economically justified.

Conclusion

The conducted trials demonstrated that *Paulownia* leaves could be successfully used in ruminant nutrition replacing a part of roughage in rations but when they were gathered in the appropriate vegetation stage. The present data showed the nutritional value of leaves without removing the petioles, could be directly used in formulation of diets for ruminants.

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