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Nutritional value of introduced bamboo used in feeding beef cows raised in the Central Balkan Mountains

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Abstract

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The experiment was conducted from 2017 to 2019 at the Research Institute of Mountain Stockbreeding and Agriculture, Troyan. The aim was to determine the quality and nutritional value of foliar fodder from introduced bamboo used in raising hornless Hereford beef cattle breed, and its impact on the appetite of ruminants fed with the dry fodder mass. A chemical analysis included characteristics, such as moisture, crude protein, crude fat, carbohydrates and crude ash. Chemical analysis data were used to calculate the energy value of the introduced bamboo. Its impact on consumption and appetite was monitored.

The results obtained indicate high digestibility (77.38–83.39%), which correlates positively with crude protein content (r = 0.867), mineral substances (r = 0.722) and minerals, such as N, P and Ca (r = 0.848 – 0.901) in dry matter.

The energy value of fodder is highly regression dependent on the crude fat content at a coefficient of determination of R^2 = 0.9942 (for GE) and R^2 = 0.9999 (for EE).

The energy value expressed in feed unit for milk performed the highest regression dependence with the concentration of ADF (R^2 = 0.9996), NFE (R^2 = 0.9995) and EE (R^2 = 0.9994).

The content of the basic nutrients is in the following ranges: crude protein 11.39 to 18.60, NFE from 27.8 to 38.32, minerals from 9.36 to 11.79% and crude fat from 1.33 to 3.45%.

Bamboo foliar fodder is highly palatable (44.2%). In the dry matter content, the amount of crude protein ranged from 11.39 to 18.60%, nitrogen-free extractable substances from 27.28 to 38.32%, minerals from 9.36 to 11.79% and crude fat from 1.33 to 3.45%.

Keywords: Bambusease; nutritional value; palatability

Introduction

A number of authors (Scurlock et al., 2000; Bystriakova et al., 2003) have identified bamboo as a tree species belonging to *Poaceae* family, subfamily *Bambusoideae*, genus *Bambusease*, with a wide areal of distribution (from the tropics and subtropics in Asia, Africa and America up to 4 500 m above sea level in the Himalayas. In northern Japan, *Sasa senanensis* is the dominant and widespread (low-growing) species used in the creation of new bamboo populations (Miyazaki et al., 2009), and in the western parts of the country, the leaves of the shoots of young *Sasa nipponica* plants are the main fodder of many herds of spotted deers (*Cervus nippon*) (Itô & Hino, 2004). Bamboo (*Fargesia* species) is a major source of food for pandas in China. In some tropical areas, reed and bamboo fodder are combined, in the similar way as straw and cornstalks are used in Bulgaria (Kimambo & Muya, 1991). Bamboo forests are a powerful tool in combating global warming, protecting the environment and limiting soil erosion (Abe et al., 2001; Benzhi et al., 2005).

Bamboo is a monocarp, a winter resistant plant whose root system allows for rapid recovery after cutting down the aboveground mass. The multifunctional application of biological material (Xuhe, 2003), the amount of bioagents, phytosterols (Kritchevsky & Chen, 2005; Phillips et al., 2005; Ostlund, 2007) and amino acids (Shi & Yang, 1992; Nongdam & Tikendra, 2014), make bamboo in an alternative crop worldwide. Bamboo foliar fodder is rich in carbohydrates and vitamins in groups A, B and E (Xia, 1989; Nongdam & Tikendra, 2014). Fresh biomass contains protein (2.60 g/100 g – 3.69 g/100 g) and minerals (Bhargava et al., 1996; Nongdam & Tikendra, 2014), which are actively involved in the metabolic processes in the animal body. The leaf mass is characterized by a high content of saponins, coumarin and cyanogenic glycosides (Coffie et al., 2014).

In Bulgaria, bamboo is an introduced species. Habitat areas (along the Veleka, the Maritza and the Danube rivers, etc.) are predominantly marsh and riverside forests (Ivanov et al., 2007). The texture of the bamboo particles allows to use its biomass for the production of carbon adsorbents (Savova et al., 2001) with high adsorption capacity (Budinova et al., 2008). Studies on bamboo as an alternative fodder crop are still limited in Bulgaria. There is also a lack of comprehensive worldwide research on its impact on the consumption and health status of productive animals.

The present study aims, by determining the composition and nutritional value of introduced bamboo, to observe its influence on palatability and consumption in ruminants and to determine the nutritive value of foliar fodder from introduced bamboo and its effect on ruminant palatability.

Material and Methods

The experiment was conducted at the Research Institute of Mountain Stockbreeding and Agriculture in Troyan. For three years at the experimental farm with beef cows (hornless Hereford breed), during the autumn-winter (December-January) period, the animals were fed by introduced bamboo foliar fodder, which was a part of the main ration with 2.5 kg. Fodder's palatability was monitored and determined using the so called "nursery cafeteria", a method by Gillet et al. (1983). The bamboo fodder palatability examined was compared (for the purpose of a clearer definition of the indicator) with beech, linden and willow foliar fodder. Palatability was determined by the amount of fodder consumed (taken for 100% of the animal's feed over the first 10–15 min). The most palatable fodder was the one with the highest consumption (Todorov et al., 2007).

The chemical composition of dried and ground fodder biomass of introduced bamboo (five samples n = 5) included analysis of: crude fiber (CF, %) by *Weende* analysis; crude protein (CP, %) by Kjeldahl method (according to BDS/ISO-5983); crude fat (Cft, %) by extraction in a Soxhlet type extractor; Ash (minerals, %) – gradual burning of the sample in a muffle furnace at 550°C; dry matter (DM, %); calcium (Ca, %) – Stotz – complexometric; phosphorus (P, %) – according to Gericke & Kurmis and Nitrogen-free extractable substances (NFE, %) = 100 – (CP, % + DM, % + Cft, % + Ash, % + Moisture, %).

The fiber composition of the cell walls was determined by the method of Van Soest et al. (1991) and included: Neutral Detergent Fibers (NDF, %), Acid detergent fibers (ADF, %) and Acid detergent lignin (ADL, %). The following are empirically calculated: Hemicellulose (%) and Cellulose (%). The degree of lignification is expressed as a coefficient on the percentage of ADL/NDF (Akin & Chesson, 1990). The fodder nutritional value was evaluated by the Bulgarian system as Feed units for growth (FUG). It was calculated on the basis of equations according to the experimental values of CP, CFr, Cft and NFE, recalculated by the coefficients for digestibility by Todorov (2010):

In vitro dry matter digestibility (IVDMD, %) was determined according to the method of Aufrere (1982).

Statistical processing was performed by *Analysis Toolpak for Microsoft Excel 2010* и *STATSOFT Satistics for Windows 10*.

Results and Discussion

Chemical composition of foliar fodder from introduced bamboo

The composition and nutritional value of fodder largely determines the productivity of the animals. According to Bhardwaj et al. (2019), the carbohydrate content of leaf mass in some types of bamboo could reach values from 57.0 to 69.0%, and of crude fat and crude ash, respectively: from 4.7 to 7.6% and from 11.8 to 21.5%.

The concentration of crude protein varied from 11.39% to 18.60% in the composition of the dry matter. The percentage of nitrogen-free extractable substances was 27.28–38.32%. The amount of minerals in dry fodder mass was 9.36–11.79%, and crude fats from 1.33% to 3.45% (Table 1).

According to Mulholland et al. (1996) and Sahoo et al. (2010), the amount of essential macronutrients in the dry fodder mass is important for the normal course of life, especially for young adolescent animals, since the foliage is highly digestible and high in nitrogen. The nitrogen amount (2.31%) was predominant in dry matter composition compared to calcium and phosphorus by 47.6% and 93.5% respectively. The calcium percentage varied from 0.52% to 2.09%.

Table 1. Basic chemical composition of dry matter of bamboo foliar fodder, %

Indicators / Year	DM	CP	Cft	CF	Ash	NFE	Ca	P	N
2017	95.31	11.39	3.45	32.79	9.36	38.32	0.52	0.08	1.73
2018	91.24	18.60	1.33	31.99	11.79	27.28	1.01	0.19	2.75
2019	91.79	16.78	1.84	32.91	10.65	29.61	2.09	0.17	2.46
Mean±SD	92.78±2.21	15.59±3.75	2.21±1.11	32.56±0.50	10.60±1.22	31.74±5.82	1.21±0.80	0.15±0.06	2.31±0.53

Table 2. Main structural fiber components of cell walls in introduced bamboo, %

Indicators Year	NDF	ADF	Hemicellulose	Cellulose
2017	77.60	38.78	38.83	23.99
2018	58.25	32.59	25.66	23.46
2019	66.37	34.01	32.36	26.94
Mean±SD	67.41±9.72	35.13±3.24	32.28±6.59	24.80±1.88

The crude fiber content was 32.56%, which was a significant factor in assessing the quality and digestibility of fodder.

***In vitro* digestibility and potential energy nutritional value of dry matter of foliar fodder of introduced bamboo**

The fiber composition of the plant cell walls determines the energy nutritional value and digestibility of fodder (Naydenova et al., 2015; Bozhanska, 2019).

Neutral-detergent fibers are predominant component in the cell walls of foliar fodder (Table 2).

The values are high (58.25–77.60%) and have an impact on free uptake of fodder by ruminants. The average content of lignocellulosic complex (ADF – 35.13%) is by 32.28% lower than that NDF.

Hemicellulose and cellulose are the main sources of energy in ruminants. The concentration of hemicellulose (32.28%), a completely digestible polyoside by ruminants, was higher than the partially digested cellulose component (24.80%).

The amount of acid-detergent lignin as an integral part of the cell wall is an essential prerequisite for fodder digestibility.

The significance of lignin fraction is a decrease in the percentage of the trait and an increase in the values of *in vitro* fodder digestibility (Naydenova et al., 2015).

The data analysis indicates a high digestibility (77.38–83.39%) of fodder mass with a relatively low content of acid-detergent lignin (7.07-14.79%) in the dry matter composition (Figure 1).

The lignification degree (Figure 2), as an evaluation of a biological process, gives a clear idea of the percentage of neutral and acid-detergent fibers in the composition of plant cell. The coefficient values varied from 10.66 to 19.05.

The lower lignification degree is a result of a lower concentration of NDF in the cell walls followed by higher fodder digestibility and assimilability by ruminants.

High correlation dependences (Table 3) of digestibility was found with the amount of mineral substances (r =

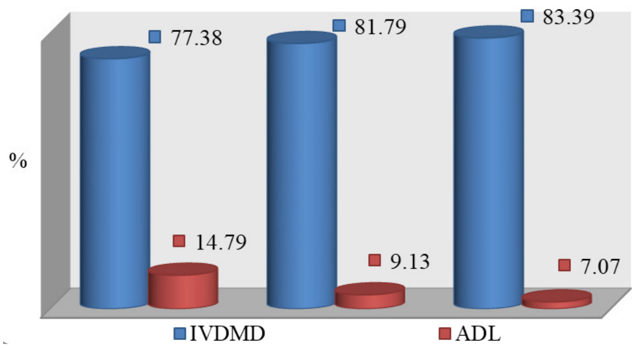

Fig. 1. Content of the amount of acid-detergent lignin and enzyme digestibility of bamboo dry matter

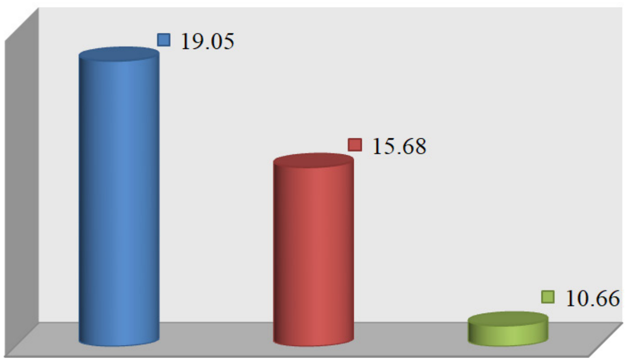

Fig. 2. Lignification degree of foliar fodder of introduced bamboo (coefficient)

Table 3. Correlation dependencies of key indicators affecting the nutritional value of foliar fodder of introduced bamboo

	IVDMD	Ca	P	N	CP	Ash
IVDMD	1					
Ca	0.896	1				
P	0.901	0.615	1			
N	0.848	0.525	0.994	1		
CP	0.867	0.555	0.997	0.999	1	
Ash	0.722	0.339	0.950	0.979	0.971	1

Significant at a probability level of $P < 0.05$

0.722), some basic macronutrients (r = 0.848 – 0.901) and crude protein content (r = 0.867) in the fodder at high significance level ($P < 0.05$).

Phosphorus content performs good correlation dependence with crude protein concentration (r = 0.997), nitrogen (r = 0.994) and ash (r = 0.950). The protein amount is a function of the nitrogen percentage in the dry matter of leaves, which is also confirmed by the obtained maximum values (r = 0.999) of a positive correlation between both indicators.

The fodder energy value is determined to the highest extent by fiber content indicators (NDF, ADF, ADL and hemicellulose), nitrogen-free extractable substances, crude protein, crude fat and dry matter (Tables 4 and 5). The concentration of fiber components also has a significant impact on the forage value of the forage mass (Bozhanska & Churkova, 2020).

Table 4. Gross and exchangeable energy regression dependencies with some indicators of chemical composition and structural fiber components in introduced bamboo leaf fodder

№	Y	X	Equation	R^2
1	GE	DM	y = 0.2449x – 5.9436	0.9665
2	GE	Cft	y = 0.4957x + 15.687	0.9942
3	GE	NFE	y = 0.094x + 13.798	0.9885
4	GE	NDF	y = 0.0562x + 12.993	0.9852
5	GE	ADF	y = 0.169x + 10.845	0.9922
6	GE	ADL	y = 0.1159x + 15.584	0.7092
7	GE	Hemicellulose	y = 0.0814x + 14.152	0.9504
8	EE	DM	y = 0.1637x – 7.9728	0.9901
9	EE	CP	y = -0.0969x + 8.7287	0.9996
10	EE	Cft	y = 0.3284x + 6.4936	0.9999
11	EE	NFE	y = 0.0624x + 5.237	0.9995
12	EE	NDF	y = 0.0366x + 4.7511	0.9579
13	EE	ADF	y = 0.1121x + 3.282	0.9995
14	EE	ADL	y = 0.0804x + 6.3875	0.7826
15	EE	Hemicellulose	y = 0.0526x + 5.5214	0.9074
16	EE	GE	y = 0.6581x – 3.8253	0.9929

Significant at a probability level of $P < 0.05$; R^2 – multiple correlation of determination; Y – dependent indicator; X – independent indicator

The highest regression dependence was found between the amount of gross and exchangeable energy and the crude fat content. The regression equations show the highest coefficient of determination over those of the other indicators, respectively, $R^2 = 0.9942$ (GE) and $R^2 = 0.9999$ (EE).

Table 5. Regression dependencies of fodder units for milk and growth with some indices of chemical composition and structural fiber components in introduced bamboo leaf fodder

№	Y	X	Equation	R^2
1	FUG	DM	y = 0.0161x – 0.897	0.9944
2	FUG	Cft	y = 0.0323x + 0.5281	0.9989
3	FUG	NFE	y = 0.0061x + 0.4045	0.9995
4	FUG	NDF	y = 0.0036x + 0.3581	0.9474
5	FUG	ADF	y = 0.011x + 0.2125	0.9996
6	FUG	ADL	y = 0.008x + 0.5166	0.8026
7	FUG	Hemicellulose	y = 0.0051x + 0.4339	0.8926
8	FUG	GE	y = 0.0645x – 0.4835	0.9881
9	FUG	EE	y = 0.0983x – 0.1099	0.9994

Significant at a probability level of $P < 0.05$; R^2 – multiple correlation of determination; Y – dependent indicator; X – independent indicator.

Structural fiber components are a major source of energy for ruminants. By means of the regression equations of NDF, ADF, ADL and hemicellulose, at high coefficient of determination $R^2 = 0.7092 – 0.9922$ (for GE) and $R^2 = 0.7826 – 0.9995$ (for EE) the energy nutritional value of the foliar fodder could be predicted.

The equation that allows to predict the exchanged energy amount by the crude protein is at a high significance level ($P < 0.05$) at a coefficient of determination – $R^2 = 0.9996$.

The fodder units for growth show the maximum dependence with the concentration of acid-detergent fibers ($R^2 = 0.9996$), the carbohydrate content ($R^2 = 0.9995$) in the fodder mass and the amount of exchangeable energy ($R^2 = 0.9994$).

The established regression dependences, expressed theoretically by regression equations, allow them to be used to tentatively predict the fodder value of dry foliar fodder from introduced bamboo.

Palatability is a relative parameter including all the nutritional qualities of fodders and a determinant of fodder quality (Emile et al., 1997). Relative palatability values make it possible to compare groups of fodders and to present their overall nutritional qualities (Kirilov, 2010; Kirilov et al., 2016).

The palatability results of the compared fodders are presented in Figure 3.

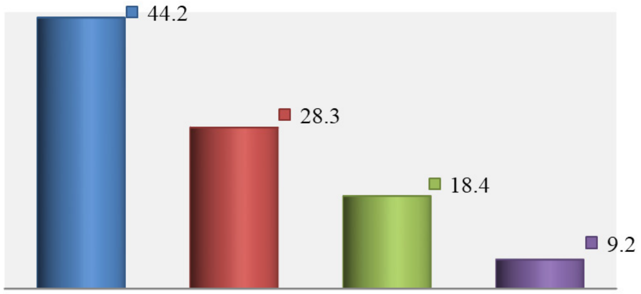

Fig. 3. Palatability of foliar fodder of bamboo, beech, linden and willow (% of total consumption)

Bamboo leaf fodder recorded the highest palatability (44.2%) compared to other roughages. In second place is beech (28.3%) followed by linden foliar fodder (18.2%). The animals demonstrated the lowest palatability when fed with willow foliar fodder (9.2%). The reasons for the differences in the values characterizing the palatability of the fodder are the structure of the fodder mass and the taste qualities of the types of foliar fodder.

Conclusions

Nutritional value and palatability of bamboo dry fodder are influenced by crude protein content (11.39–18.60%), nitrogen-free extractable substances (27.28–38.32%), minerals (9.36–11.79%) and crude fat (1.33–3.45 %) in the dry matter.

A positive correlation of dry matter *in vitro* digestibility (77.38–83.39%) with the crude protein content (r = 0.867), minerals (r = 0.722) and the concentration of N, P and Ca macronutrients was found (r = 0.848–0.901).

The fodder energy value was in a high regression dependence on the content of the structural fiber components, nitrogen-free extractable substances and the exchangeable energy.

Bamboo dry matter was relishly received by ruminants, which showed relatively high appetite (44.2%).

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