UDC: 633.31
review paper

Acta Agriculturae Serbica, Vol. XIII, 26 (2008) 85-95

Acta Agriculturae Serbica FACULTY OF AGRONOMY • ČAČAK •

Yield, Nutritional and Medicinal Properties of Alfalfa

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Abstract: The present study examines plant height, green forage (GF) and dry matter (DM) yields of 24 local alfalfa cultivars released over 1964 – 2007. The long-term research results suggest that alfalfa cultivars grown under different agroenvironmental conditions gave on average 65.6 t ha^{-1} GF i.e. 15.3 t ha^{-1} DM. The content of crude proteins was 162.2-223.8 g kg^{-1} DM (199.6 g kg^{-1} DM on average), that of crude fibres - 213-326 g kg^{-1} DM (261.8 g kg^{-1} DM on average), and NFE content - 315.3-427.5 g kg^{-1} DM (392.0 g kg^{-1} DM on average). Additionally, the study gives an overview of the chemical composition, nutritional value and amino acid composition of dry matter (4,136 samples) at different crude protein contents, vitamin content and quality of processed alfalfa products. It also outlines medicinal and prophylactic properties of alfalfa.

Key words: alfalfa, yield, quality, nutritional value, medicinal properties.

Introduction

Alfalfa is one of the most important perennial forage crops in Serbia and worldwide. The total cultivated area of alfalfa in Serbia is 192,800 ha on an annual basis, producing yields of about 5.0 t ha^{-1} dry matter (Statistical Yearbook

of Serbia 2007). The alfalfa stand can last five to seven years under average agroenvironmental conditions and with an adequate exploitation system employed or even more under favourable conditions.

Alfalfa is used as a superb quality feedstuff for all kinds and categories of livestock. Processed alfalfa products are used as components of monogastric livestock concentrate feeds (Djukic 2002, Djukic *et al*. 2004, 2006).

Significant variations are observed in the dry matter quality of alfalfa among different growth and development stages and among alfalfa cuts. Namely, the crop aging induces a reduction in the crude protein content, on the one hand, and an increase in crude fibre percentage in all alfalfa cuts, on the other, the NFE content slightly ranging, mostly in the fourth cut and at the full blooming stage (Ocokoljic *et al*. 1977, Negovanovic *et al*. 1992, Djukic *et al*. 2005, Stanacevic *et al*. 2007). As regards the dry matter quality, and particularly the content of essential amino acids, the lysine content increases, but the methionine content decreases from the initial to full-bloom stages (Balde *et al*. 1993).

Given the high economic and agronomic significance of alfalfa, the objective of the present study was to underline major quantitative traits of the crop related to the yield and quality of dry matter, the nutritional properties of alfalfa as a livestock feed, as well as its medicinal traits.

Dry matter yield – The results of a number of studies (Ivanov 1980, Djukic *et al*. 1995, 1998, 2001, 2004, 2007, Stevovic *et al*. 2005a, 2005b, 2006) suggest a high dry matter yield potential of local alfalfa cultivars, which can produce over 15 t ha^{-1} of dry matter per three to four annual cuts under diverse agroenvironmental conditions and without irrigation (Tab. 1).

Djukic *et al*. (2007) reported that the 24 alfalfa cultivars developed at the research centres in Novi Sad (13 cultivars), Krusevac (6 cultivars), Zajecar (4 cultivars) and Aleksinac (1 cultivar) under different agroenvironmental conditions in Serbia exhibited a high yield and quality potential of biomass. As the stalk height is an important yield-affecting quantitative trait, the average stalk length in local cultivars was 69.8 cm. Stalk height was 60-70 cm in 12 alfalfa cultivars and 70.1-78.0 cm in 11 cultivars, the differences obtained being very significant (CV=6.9%), (Tab. 1).

The average biomass yield of local alfalfa cultivars was 65.6 t ha^{-1} of green forage; nine cultivars produced 50-60 t ha^{-1}, seven cultivars – 60.1-70.0 t ha^{-1} and seven cultivars – 70.1-88.9 t ha^{-1}, the differences obtained being very significant (CV=16.6%).

Being dependent on the dry forage yield and dry matter content at the time of cutting, the dry matter yield ranged from 11-18.9 t ha^{-1} giving the average of 15.3 t ha^{-1}. In terms of the above trait, cultivars were classified into three groups: four cultivars produced an average yield of 11-14 t ha^{-1} DM, 10 cultivars gave an average yield of 14-16 t ha^{-1} DM and 10 cultivars - 16-18.9 t ha^{-1} DM, the differences obtained being very significant (CV=12,1%) (Tab. 1).

Tab. 1. Plant height (cm), green forage (GF) and dry matter (DM) yields and quality of local alfalfa cultivars (Djukic *et al*. 2007)

Cultivar origin and year of cultivar release			Height (cm)	Yield (t ha^{-1})		In g kg^{-1} DM		
				GF	DM	CP	CF	NFE
NS	1	NS-Bačka ZMS I (1964)	75.0	64.1	15.4	197.0	213.0	391.0
	2	NS-Banat ZMS II (1964)	75.0	66.4	16.1	198.0	222.0	399.0
	3	NS-Vršac ZMS IV (1973)	70.0	55.9	14.1	202.0	225.0	407.0
	4	NS-Mediana ZMS V^{x} (1980)	73.7	53.3	13.5	189.9	219.7	400.7
	5	Novosađanka H-11^{x} (1988)	72.0	68.9	15.5	189.0	253.0	408.9
	6	NS-Slavija* (1990)	66.7	69.1	16.5	205.0	220.0	416.0
	7	Rasinka* (1996)	68.7	54.6	13.5	195.7	217.9	395.6
	8	Tisa* (1997)	70.9	58.2	14.8	174.7	282.6	389.3
	9	Begej* (1997)	70.3	57.4	14.2	182.2	269.6	394.4
	10	Danka^{x} (2005)	65.2	55.5	14.5	188.5	307.0	383.9
	11	Banat VS* (2005)	67.2	88.4	18.7	201.0	323.0	363.2
	12	NS Alfa* (2005)	65.6	88.8	18.9	211.0	313.0	361.7
	13	Nijagara $^{(x)}$ (2007)	65.0	82.5	15.7	222.0	277.0	376.0
KŠ	14	K-1 (1965)	60.0	57.8	13.6	223.5	230.0	427.5
	15	M-2 (1974)	63.3	59.3	14.1	228.7	239,1	403,0
	16	K-22 (^{x}) (1982)	69.0	76.7	17.6	163.1	326,0	415,0
	17	K-23 * (1983)	78.0	64.3	14.9	162.2	279,9	399,2
	18	K-28* (1989)	74.6	71.2	16.5	201.1	264,3	398,2
	19	K-42* (2006)	68.6	50.6	11.5	223.8	262,2	389,4
ZA	20	Zaječarska 83* (1984)	72.0	3.8	17.0	209.7	249,6	413,8
	21	Krajina* (1986)	75.0	61.5	15.6	206.0	241,0	401,8
	22	Zaječarska 05* (2005)	65.4	73.2	16.8	194.4	300,3	382,6
	23	Iva * (2006)	68.9	69.9	16.3	221.0	275,5	376,4
AL	24	Morava-1 (2000)	75.1	53.9	12.1	200.5	273,2	315,3
		Average	69,8	65,6	15.3	199.6	261.8	392.0
		CV$_{(\%)}$	6,5	16,6	12.1	8.9	13.4	5.9

^{x} hybrid cultivar; *synthetic cultivar; (^{x}) cultivar developed through inbreeding

Dry matter quality – In terms of the dry matter quality of local alfalfa cultivars, the average content of crude proteins was 199.6 g kg^{-1} DM and that of crude fibre and NFE – 261.8 g kg^{-1} DM and 392.0 g kg^{-1} DM, respectively (Tab. 1). Significant differences were observed in dry matter quality among the alfalfa cultivars studied, three of them exhibiting the lowest CP content (162.2-180.0 g kg^{-1} DM), nine cultivars having a medium content (181.0-200.0 g kg^{-1}) and 12 cultivars – a high one (> 200.0 g kg^{-1} DM).

Given the negative correlation between the crude protein and crude fibre contents, alfalfa cultivars produced an average CF content of 261.8 g kg^{-1} DM, with

10 cultivars having the lowest proportion of CF (217-250 g kg^{-1} DM) and 14 cultivars – 250.0 g kg^{-1} DM and more than 300.0 g kg^{-1} DM, resulting in highly significant differences (CV=13.4%).

As opposed to the crude protein and crude fibre contents, the lowest variations in dry matter quality were recorded with the content of nitrogen-free extracts – NFE (CV=5.9%), ranging from 361.0-427.5 g kg^{-1} DM and giving an average of 392.0 g kg^{-1} DM (Table 1).

Guy *et al.* (1991) and Emil *et al.* (1997) gave the priority in alfalfa cultivation to cultivars that have a higher potential for dry matter yield per cuts, increased leaf percentage, higher organic matter digestibility and increased energy value of dry matter (Tab. 2).

Tab. 2. Dry matter yield (t ha-1) and organic matter digestibility in alfalfa (Guy *et. al.* 1991., Emil *et al.* 1997)

Property	Europe		63-28 P	
	1st cut	2nd cut	1st cut	2nd cut
Dry matter yield per cut	5.70	4.05	4,30	3,90
Total (1st + 2nd cuts)	9.75 t ha^{-1}		8.20 t ha^{-1}	
Leaf percentage (%)	45.0	58.6	52,6	62,4
In vitro organic matter digestibility (%)	62.8		67.7	
In vivo organic matter digestibility (%)	66.9		68.8	
Net energy for lactation (MJ)	5.61		5.89	

Furthermore, several researchers reported the effect of the growth stage of alfalfa on dry matter quality. According to Balde *et al.* (1993), the highest crude protein content in alfalfa was produced prior to bud formation (25.2% CP), decreasing thereafter until the onset of flowering and, eventually, reaching its minimum at the full-bloom stage (18.3% CP). Concurrently, changes occurred in the content of amino acids, including lysine and methionine + cysteine (Tab. 3).

Tab. 3. Crude protein (%) and amino acid (lysine, methionine + cysteine) contents at different growth stages of alfalfa (Balde *et al.* 1993)

Dry matter quality	Growth stage			
	Prior to bud formation	Onset of flowering	Mid-flowering	Full bloom
CP content (% of DM)	25.2	23.2	18.7	18.3
Amino acids (% of CP)				
Lysine	4.00	3.81	4.56	4.27
Methionine + Cysteine	1.85	2.33	1.96	1.87

Kirilov *et al.* (1994) reported that the digestibility of organic matter in alfalfa was dependent on the lignin content, the digestibility ranging in young alfalfa from 77-73%, at the stage of bud development – from 75-68% and at the onset of flowering – from 60-58%, further decreasing with plant aging.

Sauvant *et al.* (2002) reported the chemical composition, nutritional value and the content of amino acids in the dry matter of alfalfa at different crude protein contents (Tabs. 4, 5). The CP content in the total of 4,136 alfalfa samples, as registered by the above authors, was found to be lower than 16% in 955 samples, 17-18% in 1,005 samples, 18-19% in 1,703 samples and 22-25% in 473 samples. The CP content in alfalfa feed ranged from 13.8 (91.4% DM) to 20.9% (89.8% DM). Conversely, the crude fibre content was the highest (29.2%) at the lowest CP content, and the lowest (18.9%) at the highest CP content. As opposed to the CP and CF contents, relatively stable values were determined for the forage contents of crude fats (2.2-3.1%) and ash (9.9-11.6%) (Tab. 4).

Although there were variations in forage quality, the total energy was quite uniform (3840-3930 kcal kg^{-1}), as opposed to metabolic energy required for ruminant nutrition (1760-2010 kcal kg^{-1}). Slight deviations were observed in the concentration of other elements, the contents of phosphorus, sodium, molybdenum and other elements being highly uniform (Tab. 4).

Tab. 4. Quality of alfalfa at different crude protein contents in DM (Sauvant *et al*. 2002)

Content	CP content in 100% DM and number of samples (n)			
	<16% n=955	17-18% n=1005	18-19% n=1703	22-25% n=473
Dry matter (%)	**91.4**	**90.6**	**90.6**	**89.8**
Crude proteins (%)	13.8	15.8	16.7	20.9
Crude fibres (%)	29.2	26.7	25.7	18.9
Crude fats (%)	2.2	2.5	2.6	3.1
Crude ash (%)	9.9	10.4	10.6	11.6
Total sugars	3.2	3.8	4.2	6.0
Net energy (kcal kg^{-1})	3930	3900	3900	3840
Met. energy for ruminant nutrition (kcal kg^{-1})	1760	1810	1850	2010
Concentration of minerals				
Calcium(g kg^{-1})	18.6	19.7	20.2	22.6
Phosphorus (g kg^{-1})	2.4	2.4	2.4	2.4
Magnesium (g kg^{-1})	1.5	1.5	1.6	1.7
Potassium (g kg^{-1})	21.3	22.8	23.5	26.6
Sodium (g kg^{-1})	0.2	0.2	0.2	0.2
Chlorine (g kg^{-1})	5.8	6.0	6.1	6.5
Sulphur (g kg^{-1})	2.4	2.5	2.6	2.7
Manganese (mg kg^{-1})	40	49	56	37
Zinc (mg kg^{-1})	21	19	19	26
Copper (mg kg^{-1})	9	5	5	7
Iron (mg kg^{-1})	315	312	312	309
Selenium (mg kg^{-1})	0.25	0.25	0.25	0.24
Cobalt (mg kg^{-1})	0.86	0.85	0.85	0.84
Molybdenum (mg kg^{-1})	1.4	1.4	1.4	1.4

Mauriès (1994) reported the average concentrations of potassium (1.2-2.3%), sodium (0.06-0.23%), magnesium (0.12-0.22%), calcium (1.1-1.9%) and phosphorus (0.20-0.35%) in the dry matter of alfalfa, as well as a highly variable concentration of oligoelements (copper 5.8-10.5 mg kg^{-1} DM, zinc 28-46.0 mg kg^{-1} DM, manganese 48-150 mg kg^{-1} DM, molybdenum 0.04-2.04 mg kg^{-1}DM).

Alfalfa is characterized by a good-quality amino acid composition of dry matter and particulary by the essential amino acid content, excepting the somewhat lower methionine content. Furthermore, it has a significant content of other non-essential amino acids (Tab. 5).

Tab. 5. Amino acid composition (g kg^{-1} DM) and amino acid percentage (% of CP) of alfalfa at different crude protein contents (Sauvant *et al*. 2002)

Content	Crude protein content (%) and number of samples (n)							
	<16% n=955		17-18% n=1005		18-19% N=1703		22-25% n=473	
Dry matter (%)	91,4		90,6		90,6		89,8	
Amino acids:	g kg^{-1}	% of CP	g kg^{-1}	% of CP	g kg^{-1}	% of CP	g kg^{-1}	% of CP
LYS	5.8	4.2	7.2	4.5	7.7	4.6	10.5	5.0
THR	5.5	4.0	6.4	4.0	6.8	4.1	8.7	4.2
MET	1.8	1.3	2.2	1.4	2.5	1.5	3.4	1.6
CYS	2.0	1.5	2.2	1.4	2.3	1.4	2.6	1.3
MET + CYS	3.8	2.8	4.5	2.8	4.7	2.8	6.1	2.9
TRP	1.9	1.4	2.2	1.4	2.4	1.4	3.0	1.4
ILE	4.9	3.5	6.0	3.8	6.5	3.9	8.8	4.2
VAL	7.5	5.4	8.7	5.5	9.2	5.5	11.7	5.6
LEU	8.8	6.4	10.8	6.8	11.6	7.0	15.7	7.5
PHE	5.6	4.1	7.0	4.4	7.5	4.5	10.2	4.9
TYR	3.8	2.8	4.8	3.0	5.2	3.1	7.1	3.4
PHE + TYR	9.4	6.8	11.7	7.4	12.7	7.6	17.3	8.3
HIS	2.8	2.0	3.4	2.1	3.6	2.2	4.8	2.3
ARG	5.6	4.1	6.9	4.3	7.4	4.4	9.9	4.7
ALA	7.2	5.2	8.5	5.4	9.0	5.4	11.6	5.5
ASP	17.1	12.4	18.7	11.8	19.4	11.6	22.7	10.9
GLU	12.8	9.3	14.9	9.4	15.8	9.5	20.1	9.6
GLY	5.9	4.3	7.0	4.4	7.5	4.5	9.8	4.7
SER	6.1	4.4	6.8	4.3	7.1	4.2	8.6	4.1
PRO	7.1	5.2	7.8	5.0	8.2	4.9	9.7	4.6

Depending on the forage quality, the lysine content ranged from 5.8 g kg^{-1} DM or 4.2% of CP to 10.5 g kg^{-1}DM or 5.0% of CP, that of methionine + cysteine being rather uniform.

The abundance of vitamins is a specific quality of alfalfa (Tab. 6).

Tab. 6. Vitamin content of alfalfa (mg/kg DM) (Piccioni, 1989)

Plant growth stage	Carotene	Vitamin				
		E	D	B_1	B_2	B_6
Onset of flowering	270	200		6.7	17.4	6.5
High-quality hay	40		570	3.3	14.5	
Low-quality hay	30		300	2.6	13.2	
Alfalfa meal	160	125		3.4	15.7	

The content of group B vitamins (B1, B2, B6) was highest at the onset of flowering, the vitamin C content (about 0.5%) being highest in green fodder. The vitamin D content, depending on the alfalfa hay quality, was highest in high-quality alfalfa (570 mg kg-1 DM), as opposed to 300 mg kg^{-1} DM in the low-quality hay (Tab. 6).

The carotene or provitamin A content was positively correlated with the nitrogen content in alfalfa. During the growth and development of alfalfa, it decreased from the vegetative stage (400 mg kg^{-1} DM) to the onset of flowering – about 270 mg kg^{-1} DM (Piccioni 1989, Mauriès 1994).

As regards further alfalfa processing, the production of concentrates by fresh forage pressing gains increasing importance. In some world countries, such as France, over 12,000 t of alfalfa proteine concentrate are being produced annually. As a high-quality industrial product, the proteine concentrate is used as a feed supplement in the diet of different kinds and categories of livestock, in the final beef cattle fattening for increased meat quality, increased cow and sheep fertility, in the diet of young cattle, poultry, rabbits etc. (Tab. 7).

Alfalfa concentrate is of superb quality, being reflected primarily through the high content of crude proteins (50.0%), low conent of crude fibre (3.3%), increased percentage of fats (9.8%) and energy value of the feed (16.8 MJ/kg DM). Additionally, calcium and phosphorus concentrations substantially increased, as did the content of amino acids (lysine, methionine + cysteine) (Tab. 7).

Table 7. Dry matter quality of industrial alfalfa concentrate (Tartari *et al*. 1992, Antongiovanni and Bruni 1994)

Property	% of DM
Dry matter (DM) content	92.0
• Crude protein (CP) content	50.0
• Crude Fibre (CF) content	3.3
• Fats (F) content	9.8
• Ash (A) content	15.2
• Calcium	4.3
• Phosphorus	0.9
Amino acids (% of CP)	
• Lysine	3.4
• Methionine + cysteine	1.6
Digestible energy (MJ/kg DM)	16.8

Medicinal properties – Different studies on the dry matter yield and quality of alfalfa have stressed the high nutritional, energy and biological values of the crop which has been also praised for its remarkable nutritional, prophylactic and medicinal properties (Tucakov 1971). Therefore, alfalfa is used not only as a livestock feed, but also as a human dietary supplement. As a medicinal plant, it has been renowned in folk medicine for its wealth of ß carotene, vitamins B, C, E and K, potassium, calcium, phosphorus and iron.

Owing to its important medicinal or healing properties, alfalfa leaf has been used worldwide in the production of a number of products such as Green Care and others. The so-called green product is used as a prophylactic, in treating acute and chronic intestinal disturbances, abdominal swelling, gastritis, gastric and duodenal ulcers as well as in preventing excessive bacteria/fungi growth in the intestines. At the same time, it is a laxative and a diuretic, it enhances nutrient resorption and the immune system, improves physical energy levels, increases vigour and vitality, reduces the pain of rheumatoid arthritis etc. (Catalogue of Products – Calivita International 2007).

According to Zeno (2007), "Liquid Chlorophyll" is produced by the extraction of liquid chlorophyll from alfalfa. It is highly important for internal detoxication of human organism. In a human organism, it forms solid molecular compounds with potential carcinogenic substances, leading to their reduced resorption from the digestive tract. It also affects the liver cytochrome P-450 enzyme which prevents the malignant transformation of DNA in the cells induced by carcinogenic substances. Furthermore, owing to its highly alkaline effect on the digestive tract, the above product induces improvements in the treatment of digestive problems, gastric ulcer, inflammation-induced changes in the intestines, bad breath, disturbances of the intestinal flora, rheumatoid artritis etc. The liquid chlorophyll is also used to help enhance the immune system and circulation. It is also a powerful antioxidant.

Conclusion

The long-term research results on the properties of local alfalfa cultivars under different agroenvironmental conditions suggest the following:

Local alfalfa cultivars were characterized by a high biomass yield potential – 65.6 t ha^{-1} green forage or 15.3 t ha^{-1} dry matter on average.

The cultivars exhibited a very good quality of dry matter, the crude protein content ranging from 162.2-223.8 g kg^{-1} DM (199.6 g kg^{-1} DM on average) and the crude fibre and ash contents from 213-326 g kg^{-1} DM (261.8 g kg^{-1} DM on average) and 315.3-427.5 g kg^{-1} DM (392.0 g kg^{-1} DM on average), respectively.

The chemical composition, nutritional value and amino acid composition of a total of 4,136 samples of foreign alfalfa cultivars at different crude protein levels were found to be highly favourable. Additionally, an abundance of vitamins is a specific value of alfalfa.

The alfalfa products are of superb quality, being reflected through the high content of crude proteins (50.0%), the low content of crude fibre (3.3%), increased content of fats (9.8%) as well as through the increased energy value of the feed (16.8 MJ/kg DM).

Being not just a livestock feed, alfalfa is also used as a human dietary supplement. In folk medicine, it has been long used as a medicinal plant, being renowned for its abundance of ß carotene, vitamins B, C, E and K, potassium, calcium, phosphorus and iron.

The application of different methods of alfalfa cultivation and exploitation should be based on modernization of production, preparation and processing of alfalfa, specific focus being given to its agrobiological properties and its contribution to environmental protection and preservation.

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PRINOS, HRANLJIVA I LEKOVITA SVOJSTVA LUCERKE

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Rezime

U radu se prikazane neke kvalitativne i kvantitativne osobine 24 domaće sorte lucerke priznatih u periodu 1964. do 2007. godine. Na osnovu višegodišnjih rezultata istraživanja, u različitim agroekološkim uslovima sorte lucerke su dale prosečno 65,6 t ha^{-1} ZK, odnosno 15,3 t ha^{-1} SM. Sadržaj sirovih proteina je bio 162,2-223,8 g kg^{-1} SM (prosečno 199,6 g kg^{-1} SM), sirove celuloze 213-326 g kg^{-1} SM (prosečno 261,8 g kg^{-1} SM), a udeo BEM-a 315,3-427,5 g kg^{-1} SM (prosečno 392,0 g kg^{-1} SM). Takođe, dat je prikaz hemijskog sastava, hranljive vrednosti i aminokiselinski sastav suve materije (4.136 uzoraka) pri različitom sadržaju sirovih proteina, sadržaj vitamina i kvalitet proizvoda industrijske prerade lucerke. Istovremeno, dat je prikaz lekovitih i profilaktičkih svojstava lucerke.