

MODERN TECHNIQUES FOR LEGUMES ENSILAGING

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The quality and nutrient value of biomass of plants of family *Papilionaceae* primarily depends on the phase of development and the ways of conservation. Of the perennial legumes the most important species for production of bulk feed are alfalfa and red clover, and of annual legumes are vetch and forage pea. Any applied way of conserving leads to a smaller or larger loss of nutritional substances. The end result of this contributes to a lesser or greater reduction of the production of milk or meat. Modern trends in legumes ensilaging technology are based on the knowledge of biomass from the aspect of suitability for ensilaging, wilting, addition of carbohydrate feed, use of biological additives, etc. Today, the experiments are conducted, worldwide, with inoculates, which, in addition to homofermentative, also contain heterofermentative lactic acid bacteria. Products of such inoculants contribute to the increase of aerobic stability of silages so their implementation is good for all types of silage. In addition to the usage of those additions, modern technology of silage is based on the maximum mechanization of the ensilaging process, as well as preparing the silage in the form of roto-bales and silo tubes (most inexpensive way of conservation) as well as permanent facilities.

Key words: legumes; silage; carbohydrates; buffer capacity; wilting; carbohydrate feed; inoculants

МОДЕРНИ ТЕХНИКИ ЗА СИЛАЖИРАЊЕ НА ЛЕГУМИНОЗИ

Квалитетот и хранливоста на биомасата на растенијата од фамилијата *Papilionaceae* главно зависат од фазата на развојот и начинот на конзервација. Од двогодишните легуминози најважните специеси за производство на суровина за добиточна храна е луцерката и црвената детелина, а од едногодишните граорцијата и сточниот грашок. Секој применет начин на конзервирање води кон помали или поголеми загуби на хранливите состојки. Крајниот резултат на ова придонесува за помало или поголемо намалување на производството на млеко или месо. Модерните трендови во технологијата на силажирање на легуминози се базираат на познавањето на биомасата од аспект на погодноста за силажирање, овенатоста, додавање на јаглехидратни крми, користење на биолошки додатоци и др. Во сегашно време низ светот експериментите се поставуваат со инокуланти кои со додавање на хомоферментативна исто така содржат и хетероферментативни млечнокиселински бактерии. Производите од овие инокуланти придонесуваат за зголемување на аеробната стабилност на силажата, така што нивната примена е добра за сите типови силажа. Употребувајќи ги овие додатоци, модерната технологија на силажирање се базира на максимална употреба на механизација во процесот на силажирање, како и на подготовката на силажа во форма на рото-бали и сило-трапови (најпознат најекономичен начин за конзервација), како и на постојани подобрувања.

Клучни зборови: легуминози, силажа, јаглени хидрати, пуферен капацитет, овенување, јагленохидратни крми, инокуланти

INTRODUCTION

The general characteristic of livestock nutrition in the lowland and mountain area of Serbia is unfavorable ratio of nutritive substances, or the lack of protein feed. Excess energy in the feed is

the result of the presence of maize grain, silage and the corn plant parts. Solution to this problem is to increase the proportion of protein feed in meals. The concentrated protein feed (pellets, oil-seed cakes, etc.) are mainly imported and their price is high. A solution to the above problem is to

increase proportion of the quality of the bulk food made of the legumes.

Of perennial legumes used for the production of the bulk feed in Serbia, the most important are alfalfa, red and white clover, bird's-foot trefoil and lupine. Of annual legumes the most important are vetch and forage pea, and less significant are soy, lupine, forage fava beans, etc. The importance of legumes for the forage feed production.

High nutritious value of the voluminous mass of legumes is underused. The lesser part of the total amount of legumes is used as the green mass, while the most part is conserved using different techniques. Conserving the legumes, as well as other feed, is the inevitable need, primarily because of providing food during the annual period of vegetation hibernation (Djordjević and Dinić, 2003). Livestock feed with legumes, in relation to grass feed, provides better utilization of production potential of livestock. Factors that contribute to the superiority of legumes in relation to the grass are: the animals consume larger quantities, decomposition of consumed food and the exploitation of the nutritional substances are more efficient and it contains more specific biological elements (Marten, 1984). One of the most important characteristics of legumes is the ability to use nitrogen from the atmosphere and the preservation of ecosystems. Alfalfa is the most important forage plant in Serbia. It is bred in the area of 189,000 ha (Statistic yearbook, 2008). It provides high and stable yield, in the experimental conditions, of 15–20 t of

dry matter and about 3.000 kg of crude protein after the first year (Mejakić et al., 1997). In addition to a high ratio, alfalfa protein contains a large amount of carotene, xanthophyll and calcium and is the first class of forage feed for all livestock. In favor of this are the studies conducted by Sredojević et al. (1991), in which carotenoide-protein concentrates are produced from alfalfa, which in the dry matter contains 57% of crude protein, crude cellulose 2.10%, 10.57% of crude fat, 35.35% of essential amino acids, 1052 mgkg⁻¹ of xanthophyll and 547 mgkg⁻¹ of β -carotene.

Red clover is the second important forage culture of the group of perennial legumes. Behind it is white clover, bird's foot trefoil, lupine and others. Quality, as well as in alfalfa, depends on the phase of plant development. The content of crude protein in the dry matter of red clover is 180–200 gkg⁻¹ DM (dry matter), crude cellulose from 210–257 gkg⁻¹ to DM, BEM 430–440 gkg⁻¹ to DM, Ca 13–15 gkg⁻¹ to DM and P 3.3 gkg⁻¹ to DM (Dinić et al., 1994; Djukić et al., 2008).

In terms of the content of nutrient substances for livestock feed, the biomass of white clover is one of the highest forage quality. It has the high content of protein and minerals and low content of crude cellulose (Dinić et al., 1994). It is the one of the forage plants with the most uniform nutritional substances content during the vegetation period, meaning there is the least quality oscillations. The chemical composition of red and white clover and the silage suitability are presented in Table 1.

Table 1

Chemical composition and buffer capacity of red clover, white clover and maize meal, gkg⁻¹ SM (Dinić et al., 1994a)

Parameters	Red clover (a1)		White clover (a2)		Maize meal
	Non wilted	Wilted	Non wilted	Wilted	
Dry matter	204.0	320.0	161.3	281.3	870.0
Organic matter	897.4	899.1	880.3	894.0	890.4
Ash	102.6	100.9	119.7	106.0	19.6
Crude proteins	180.4	192.5	257.3	240.8	101.7
Crude fiber	257.1	247.3	232.4	212.1	26.4
Lipids	21.6	28.7	31.1	26.3	48.3
NFE	438.3	430.6	359.5	411.4	804.0
Ca	14.3	12.9	13.0	12.6	0.2
P	3.2	3.3	4.2	3.9	3.4
Sugar (S)	106	124	87	95	44
Buffer capacity (BC)	60	58	72	50	16
S/BC	1.77	2.14	1.21	1.90	2.75

Bird's foot trefoil is forage culture, which is characterized by a solid yield of DM (9.42–13.62 tha^{-1}), and an excellent quality, which is documented in the study by Radović et al. (2003). Content of crude protein is 218–234 gkg^{-1} DM, 283–326 gkg^{-1} DM of crude cellulose, crude fat 28–53 gkg^{-1} SM, BEM 325–370 gkg^{-1} DM and mineral substances 99–112 gkg^{-1} DM. The quality of other perennial legumes that are cultivated in this area is not much behind the above mentioned.

Of perennial legumes in Serbia, mostly forage pea and vetch are used for the production of the bulk animal feed, and rarely or very rarely soy, fava bean and lupine. Forage pea in Serbia in 2005 was cultivated on the area of 4655 ha, and vetch on the area of 7697 ha, which together is 12,352 ha (Eric et al., 2007). Annual legumes are a very important group of forage crops, because they provide high yield of green mass (30–50 tha green mass $^{-1}$) of excellent quality. In the pure crop, protein content was 18–22%, 22–26% of cellulose and 33–40% BEM in the dry matter (Mišković, 1986). They can be cultivated in winter, spring or summer sowing, both as a single crop or combined with grain cultures. They, also, fixate nitrogen as the other legumes.

Annual legumes, due to the tendency to lie down, are cultivated in combination with grain crops (oats, rye, wheat, etc.). The quality of biomass, in this case, depends on the proportion of legumes and grain crops. However, in some studies, annual legumes are cultivated in combination with grasses and perennial legumes. In the studies of Latre et al. (2008) there were the following combinations of barley + pea, pea + perennial ryegrass + white clover, forage fava beans + spring wheat and pea + alfalfa. When there are favorable conditions or where irrigation is possible, there is a possibility of cultivating annual legumes and grain crops in summer sowing. Dinić et al. (1999) ensilaged crops of summer sowing such as maize + soybean, maize + forage fava beans, sorghum + soybean and sorghum + forage fava beans in different weight ratio, in percents of 100:0, 75:25, 50:50, 25:75 and 0:100, where the initial material was of the quality presented in Table 2.

Table 2

Chemical composition of green mass, gkg^{-1} DM (Dinić et al, 1999)

Sample	CP	CF	Ash	Ca	P
Zea mays	88.7	252.1	65.0	2.8	3.3
Sorghum	84.4	294.6	92.9	3.6	3.4
Soybean	207.2	261.0	89.1	8.6	4.0
Vicia faba	165.9	366.5	82.9	3.8	4.9
LSD 0,05	10.23	25.66	4.69	1.00	0.71
LSD 0,01	15.50	38.88	7.10	1.56	1.07

SUITABILITY OF LEGUMES FOR ENSILAGING

Biomass conservation, especially the biomass of perennial legumes, is followed by certain losses in dry matter. Due to that, the best way is to use the green biomass (pasture). But there is no vegetation in the course of the year, and some legumes have anti-nutritive properties, and can cause certain problems in animal nutrition (bloating, etc.). So, it is necessary to conserve biomass. Hay and silage are the main forms of conserved bulk feed. The hay quality is influenced by weather conditions, so hay is less prepared and used. Its place is taken by silage. Hay is, above all, expensive feed, but minimum amounts are necessary for normal functioning of the complex digestive system of ruminants. In many countries there is a trend to prepare and use large amounts of silage compared to hay (Wilkinson and Toivonen, 2003).

Ensilaging is the process of conservation of plant biomass and plant by-products by lactic acid. Lactic acid is the product of the natural microflora or added (inoculated) selected lactic acid bacteria strains. Suitability of plants for ensilaging can be precisely determined based on the sugar (s) content and on the buffer capacity (BC) (Dinić et al., 1998). If the present sugar to be used for the synthesis of lactic acid is with 100% efficiency, the ratio of sugar and buffer capacity (S/BK) could be 1.00. However, in practice only 50% is used for the synthesis of lactic acid, which means that the ratio of S/BK must be significantly greater than 2.00, although Weissbach (1967) considered being 3.0.

High buffer capacity of legumes (a consequence of the high percentage of protein and minerals – calcium) and small amounts of fermentable

carbohydrates are the main limiting factors for the application of silage technology for legumes on the large scale (Dinić et al., 1998). Therefore, since the thirties of the twentieth century, many experiments were performed around the world. The task is to find ways for the successful alfalfa red clover, pea, vetch, soybean, and etc. conservation by ensilaging (Djordjević and Dinić, 2003). During the development of technology of silage the results of numerous experiments have been successfully used in practice (chemical preservatives based on organic acids, carbohydrate additives, wilting and biological products). Today, in Europe and worldwide, biological products and organic acids are mostly used. The main goal of the modern technologies is making silage with higher quality, with smaller losses of dry matter, the maximum aerobic stability and nutritive value.

THE WILTING

The amount of dry matter in silo mass is one of the most important factors for the level of losses of dry matter and directing the fermentation process in silo mass, especially when it comes to silo mass that is rich in protein and minerals (Dinić, 1990; Dinić et al., 1997). Wilting, or short-term drying, is certainly the least expensive solution for successful ensilaging of legumes and mixtures of legumes and grain crops. The effective conservation of wilted crops is explained by ability of lactic acid bacteria to be active in the area with increased osmotic pressure, while most other anaerobic microorganisms can not compete with them. Positive experiences in using this technology are demonstrated experimentally and in local research (Dinić, 1990; Đorđević, 1995) and are largely applied in practice on our farms (Djordjević and Dinić, 2003).

There were a lot of studies on the subject of silo mass wilting, but the most complete researches were done under the direction of Zimmer and Wilkins (1984). The general conclusions of their researches were that there were smaller losses of dry matter in the field in non wilted silo mass (2.5:8.6 %), significantly higher in the silo in the silage of non wilted silo mass with a preserving agent in relation to the wilted silo mass without a preserving agent (16.1:8.5%). Silages were generally well kept in the two treatments. The preserving agents in silage from non wilted silo mass were based on formic acid, and the wilted silo mass had

a 30–40% of dry matter. However, Verbič (1995) points out that the size of the field loss and quality of silage does not only depend on the amount of dry matter in the silo mass, but, also, on the speed of wilting. Wilting is important due to restraining impact on the level of proteolysis in the legume silages (Djordjevic et al., 2004). However, the possibility of wilting depends on weather conditions, and can not be always done. Also, wilting requires further engagement of mechanization and manpower for the collection of the forage mass from the ground, which can easily lead to the contamination with dirt, sand and other substances. Only the biomasses of annual legumes + grain crops in the phase of the beginning of pod formation, with dry matter content about 300 gkg⁻¹ can be successfully ensilaged without wilting, or with direct ensilaging (Dinić et al., 2008).

MIXING WITH THE EASILY ENSILAGED CROPS AND THE ADDITION OF CARBOHYDRATE FEED

The mixing with the crops that are easy for ensilaging is usually done in the early fall, at the time of the last alfalfa cut, as well as silage maize or sorghum from the main or additional sowing (Dinić et al., 1988, 1995). In addition, it is possible to combine alfalfa with grain crops, but in this case the second alfalfa cut is mainly used (Djordjević and Dinić, 2003). In such combinations, the grain crops provide the required amount of carbohydrates, and legumes enrich the ensilaged mass with protein. In the studies by our authors, it is found that the maximum share of alfalfa in the combined silages with maize is 50: 50% (Dinić et al., 1988). On the practical side, the ratio of maize and alfalfa in the mixture for ensilaging depends first of the available amount of alfalfa.

In order to provide the necessary amount of carbohydrates for lactic fermentation it is practiced to add carbohydrate feed such as ground maize (5–10%), molasses (1%), dry chopped beet (5–10%) and others (Koljajić et al., 1997).

THE USE OF CHEMICAL PRESERVING AGENTS

The chemical conservation of crops is based on the inhibition of the plant enzymes by reducing the pH values below 4.5. Today, a small number of

chemical preserving agents, mostly organic acids (formic and propionic) and their salts, are being used worldwide. One of the main reasons for this is the aspiration to produce food, both for human and livestock nutrition, as natural as possible, and to obtain healthier products. In the last decades, in our country, numerous experiments with the use of formic acid were conducted. The effects of formic acid were compared with chemical preservative agents of mineral acids and their salts, carbohydrate additives or bacterial inoculates (Dinić et al., 1994-B, 1996, 1997; Đorđević et al., 2003). Despite very good results, these kinds of additives are not used in our country because of high prices.

Today in Europe there are various commercial preparations in the form of a mixture of two organic acids, acids and salts or several salts (Lattemae et al., 2003). In these mixtures it may come to mutual completing of the effects of individual ingredients, because neither one of them has universal effect. Thus, for example, formic acid has bactericidal, and propionic acid has fungicidal property, so by mixing them in a correct ratio more efficient conserving is achieved. The composition of these types of mixtures is usually unknown, and it is the manufacturer's secret.

THE USE OF BIOLOGICAL ADDITIVES

The advantage of biological additives in relation to the chemical preserving agents is primarily in that they do not leave residue and do not negatively affect the health of livestock and the quality of their products. Due to this, they increasingly push out the chemical preserving agents, regardless of their lower efficiency. The experiments conducted in our country confirmed the positive influence of the biological preparations (Djordjevic, 1995, Djordjevic et al., 2000), which are now applied in practice in our large farms (Djordjević and Dinić, 2003). The greatest effects of bacterial inoculation are expressed in the feeds which are difficult to ensilage, especially legumes. By using the homofermentative bacteria cultures the present soluble carbohydrates, which are at the border sugar minimum, are being exploited.

The original products based on lactic acid bacteria contained the homofermentative microorganisms in monoculture or in the combination of several species. The majority of the experiments proved that the combination of different bacteria is

more flexible in regard to the choice of the nutritional substances, temperature intervals and other conditions, meaning they complete various aspects of their activities, in relation to the monoculture. Modern biological preparations contain *Lactobacillus plantarum* and other *Lactobacillus* species, in combination with *Enterococcus*, *Lactococcus* and *Pediococcus* species. In the next phase of development of this technology there is a trend of combining the lactic fermentation bacteria with cellulolytic enzymes. By using these products, the intensification of lactic acid fermentation of homofermentative type is achieved. Also, the decomposition of different fractions of fibers, and at the same time increasing the content of fermentable carbohydrates, is achieved. Recently, a great attention is paid to the increase of the aerobic stability of silages, especially of maize silages, but, also, of other forage species, due to lactic acid being the main product of fermentation of sugar in the ensilaged mass. The lactic acid has very strong bactericide but weak fungicide properties. In contrast, acetic, butyric and propionic acid have expressed fungicide effects, so the lesser amount of these acids is even desirable in maize silages, as in the other forage species silages (Table 3).

Table 3

Biochemical changes in alfalfa silages *Avasi et al. 1999)*

Parameters	Control	Sil-All	Feed Tech
PH	5,12	4,75**	4,82**
Acids, %			
Lactic	1,86	2,76**	2,21**
Acetic	0,74	0,98*	0,81**
i-butyric	0,015	0,015	0,0120
n-butyric	0,035**	0,00	0,00
Propionic	0,065**	0,015	0,015
NH ₃ -N, mg%	157,0*	150,2	130,7

Sil-All = *Streptococcus faecium*, *Pediococcus acidilactici*, *Lactobacillus plantarum* + enzymes cellulase;
Feedtech = *Pediococcus acidilactici*+*Lactobacillus plantarum*,
2,5×10⁸ cell/g. *p<0,05; **p<0,01

The prospect of further increase of the effects of inoculants is the selection and genetic manipulation with lactic acid bacteria. The future aim of selection is to create the most effective strains of bacteria in accordance with the type and chemical

composition of the forage material, as well as climatic conditions (Merry et al., 1997).

THE SIGNIFICANCE OF MODERN MECHANIZATION FOR THE LEGUMES ENSILAGING

One of the modern methods in the technology of feed ensilaging is preparing haylage in bales, wrapped in foils. Currently in the United States, the most economic way of ensilaging is in the form of silo tubes. This does not require the existence of the specialized silo buildings. The prepared bales and silo tubes can be stored under the eaves, or on the field, to the moment of use. Dried plant material that is baled should contain as little moisture as possible, because it is compacted using the press, and it can be further treated with chemicals or inoculates in order to get better quality. The great advantage of haylage prepared in bales is that it is easy to handle. Due to this, feed that is ensilaged in this way is suitable for market (Dinić and Djordjević, 2005).

Results of the research conducted so far indicate that equal quality of alfalfa silages is achieved by ensilaging in bales and by ensilaging in the classic silo buildings (Jatkauskas and Vrotniakiene, 2003) (Table 4).

Table 4

Chemical composition of silages ensiled by different methods, feed intake and animal performance in the experimental period (Jatkauskas and Vrotniakiene, 2003)

Parameters	Silage made in trenches	Silage made in big bales	SEM	P
pH	4.52	4.65	0.1	NS
Lactic acid	22.1	21.7	0.9	NS
Acetic acid	17.6	14.5	1.2	NS
Butyric acid	0.01	0.00	0.0	NS
NH ₃ -N, g/kg N	50.8	45.6	2.4	NS
ME, MJ/kg DM	8.89	8.94	0.9	NS
NE intake, MJ/day	88.91	98.82	–	–
Silage intake, kg DM	7.19	7.26	–	–
Initial live weight, kg	356.33±18.64	354.60±19.17	–	–
Total live weight, kg	159.44±14.13	163.50±4.35	–	–
Average live weight gain, kg/day	1.115±0.09	1.143±0.03	–	–

CONCLUSION

Modern trends in technology of legumes ensilaging are based on the latest scientific and technical achievements. Different procedures are first tested in the experiments, and then introduced into practice. Numerous researches were conducted in our country in accordance with specific conditions, and the acquired knowledge is translated into concrete recommendations, which are largely applied in our practice. Biomasses of both perennial and annual legumes were studied from the aspect of suitability for ensilaging and of the content of water-soluble carbohydrates and buffer capacity. The effect of increasing the content of dry matter (by wilting) on the quality of fermentation and preservation of nutritional substances was, also, studied. The influence of the share of biomass of legumes that are easy to ensile, the impact of share of annual legumes and grain crops on the fermentation quality and nutritive value of silage was studied. The aim of using modern methods of ensilaging is to get the silage of the highest quality from different raw materials, with the optimal satisfaction of a number of nutrient requests, and to produce the maximum healthy products of animal origin for the human use.

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