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HARVESTING SILAGE FROM PERENNIAL LEGUMES AND CEREALS

Ovsiienko S.
Vinnytsia national agrarian university, associate professor
Ukraine

Abstract

Hay, haylage and silage form the basis of ruminants` winter rations, they largely determine the effectiveness of animal husbandry.

It is possible to increase significantly the silage of high-protein crops and reduce the loss of nutrients during storage by wrapping raw materials. However, this technology requires additional material, energy and time costs, which are often limited. The best way to solve this problem is to obtain good quality silage from highly nutritious low-silage green mass of perennial legumes, i.e. alfalfa and clover without their preliminary drying to moisture (70-60%) due to equivalent mixing with green mass of bluegrass and fairway crested grass with dry matter content (37.8% and 49.2%) before ensiling. It is established that the high content of dry matter in the green mass provides the conditions for obtaining good quality silage.

The application of microbial preparation of EM-A crops creates conditions for targeted lactic acid fermentation providing organoleptic and biochemical parameters of high-quality silage with a higher lactic acid content of 73.1%, which is 24.5% higher than the control one.

Experimental research on ruminants has shown that the consumption and digestibility of the main nutrients in the diet of bluegrass and fairway crested grass are high with a positive nitrogen balance in their body.

Keywords: alfalfa, meadow clover, bluegrass, fairway crested grass, silage, digestibility.

Statement of the problem. Today, the feed production main task is to procure a sufficient amount of feed, and to ensure high quality and maximum preservation of nutrients in them.

The ensiling of feed is an essential component of cattle feeding in recent years. The share of silage in the diets of cattle reaches 30-50% by dry matter and 43-45% by nutritional value of the total amount of bulky feed. High-quality silage increases the productivity of cows, the muscle mass of animals for fattening, and promotes better assimilation of roughage. Many countries have found high efficiency of its year-round application for ruminants.

It is known from the literature that there are no significant differences in the chemical composition of each type of forage crops. Biochemical, physiological and feeding studies on animals to determine the degree of digestibility of nutrients from feed of new varieties of fodder crops give an objective assessment of the fodder value and purposefulness of selection work to spread the most suitable varieties in fodder production or hybrid of fodder crops.

Analysis of recent studies and publications, which started solving the problem. Silage is an anaerobic process during which plant sugars are processed by the microflora into organic acids, mainly lactic and acetic, it leads to a decrease in pH to 4.2-4.0.

The feed does not spoil and can be stored for a long time in the absence of air access due to the presence of lactic acid of the appropriate concentration (2-3% by weight of the feed). This process is mainly due to lactic acid bacteria. Their number usually does not exceed 1% of the microflora contained in the vegetative parts of plants. They are Lactobacillus plantarum, Lactobacillus brevis, Enterococcus sp., which are facultative (relatively) anaerobes developing in both anaerobic and aerobic conditions. Therefore, it is necessary to create anaerobic conditions that promote the development of lactic acid bacteria and inhibit the development of microorganisms unnecessary for haylage, i.e. aerobic, mold and others.

In modern conditions, the attractiveness of silage for agricultural production is the simplicity and cheapness of this method, and this technology is the most rational and cost-effective way of harvesting and storage of feed. Preservation of fodder crops allows to preserve their quality changшгп during the growing season. In addition, it solves the problem of the mismatch between the constant need for feed and the uneven supply of plant mass.

The most important criterion for feed quality is the concentration of energy, protein and other nutrients in the dry matter. The content of crude fat and crude ash does not change during ensiling. There is only a slight increase in fat content due to fermentation acids and a decrease in the content of crude ash at high silage moisture [1].

Successful ensiling is primarily based on the development of microorganisms found in plant raw materials. If these are few, then they must be made or favorable conditions for their reproduction should be created. The biochemical processes occurring during ensiling are caused by the action of plant cell enzymes, by various microorganisms entering the silage with green grass, which are able to convert sugars contained in green mass into milk, acetic, propionic and other acids, as well as various additional elements.

There is an increase in lactic acid and suppression of ammonifiers, gas-forming, butyric and other microbes with proper fermentation. Therefore, the quality of feed is associated with the activity of lactic acid bacteria, and spoilage of silage is associated with the activity of enterobacteria, clostridia, various species of bacilli, yeast and mold [2]. The ratio between the physiological groups of microorganisms varies depending on the stage and conditions of the ensiling process.

The development of mixed microflora is observed in the first short-term phase. Lactic acid bacteria compete with all other epiphytic microflora for fermented sugar in this phase of fermentation.

Then the captured atmospheric oxygen in the raw material is used by plant enzymes, and fermentation takes place under anaerobic conditions. During spontaneous fermentation, lactic acid bacteria begin to multiply rapidly to a concentration of 109-1010 cells / g. Its share in the total plants weight fluctuates in the range of 0.01-10%. Then they begin to produce lactic acid [3]. However, in some cases, the number of lactic acid bacteria is not enough for its formation in the right amount, or the content of water-soluble carbohydrates is limited. In this case, lactic acid bacteria use lactic acid as a source of energy and convert it into acetic acid. As a result, the pH increases opening up opportunities for the development of clostridia and enterobacteria, which are harmful to fermentation, as they produce less acidic components such as acetic and butyric acids, as well as neutral substances 2,3-butanediol and ethanol or basic NH_3 and CO_2 [4].

It should be noted that lactic acid bacteria are quite unpretentious in temperature, they develop at a temperature of +5˚C. The dry matter content significantly affects their vital functions. Increasing the dry matter content by 30% or more inhibits the development of lactic acid bacteria, especially in the first crucial stage of ensiling. At a dry matter content of 26% in the feed material, the maximum number of lactic acid bacteria is formed on the third day, with its increase to 36% on the seventh day. Lactic acid bacteria dominate in a day in the freshly mown mass of easily ensiled plants [5]. A. But explained delay in the reproduction of lactic acid bacteria on the dried raw materials by the fact that they experience osmotic stress at high dry matter content. As a result, there is a decrease in the reproduction rate, it leads to a delay in the acidification of feed material and negative consequences [6].

It should be mentioned that there is no noticeable development of enterobacteria and yeast ensiling perennial legumes with a dry matter content of 30-35% [7]. According to some researchers, in these conditions plants retain moisture with a force of up to 52 atmospheres making it inaccessible to enterobacteria. The relatively low sugar content in the substrate inhibits the development of yeast. Therefore, the spoilage of raw materials with high protein content is mainly associated with butyric fermentation, its elimination should be aimed by technological techniques.

The next phase is very dynamic due to the change of different bacterial populations depending on the dry matter content, active acidity and temperature. First, fermentation of oxygen-tolerant bacteria begins with the production of acetic acid. Then acetic acid bacteria die, their number decreases and the development of the first bacteria resistant to lactic acid begins. The pH value decreases from 5.3 to 4.6. The metabolic activity of other yeasts and bacteria is blocked, and they gradually die out with a decrease in active acidity. Populations of lactic acid bacteria dominate over the previous ones, lowering the pH value from 4.6 to 3.6.

The production of aerobically stable silage requires that the pH value reaches 4.2 or less because some types of mold and yeast typical for ensiling are not sensitive to low pH values. They are able to grow and reproduce, can ferment sugar into ethanol and decompose many other products in an acidic environment with a pH below 4 under anaerobic conditions [4]. The lactic acid accumulated and converted by them provides new opportunities for the development of unwanted bacteria. This phase can continue from several days to several weeks due to the course of certain fermentation processes. Taking into account the analysis of scientific literature we should conclude the shorter it is, the higher the quality of the silage at the output.

The final phase is characterized by minimal activity of microorganisms. Many bacterial species reduce their numbers, acid-resistant bacteria remain numerous but physiologically inactive, and Clostridium and Bacilli persist in spores.

The solution of the problems of nutrient losses in the process of storage and use of silage in animal feed was discussed by the XI International Conference on Silage, held in England. The decisive factor for obtaining high-quality silage is primarily the perfect technology of silage in addition to good quality raw materials [8].

You can significantly increase the silage of high-protein crops and reduce nutrient losses during storage by drying the raw materials. Hard-to-silage crops can also be stored under anaerobic conditions if they are pre-dryed to silage (70-60%) or hay moisture (40-60%) if necessary. However, as the humidity of the raw material decreases, the amount of acids in the finished feed decreases, and the pH increases. The technology of harvesting silage from wilted grass is similar to the preparation of haylage. When harvesting silage, the mass is lesser dried. As a result, the loss of nutrients during drying is significantly lower. On the other hand, weeding involves a large amount of additional field work and requires more skillful organization of work compared to harvesting silage from freshly cut plants. The stronger the dried mass, the harder it is compacted and requires good tightness of silos [9].

Alfalfa is considered as a non-ensiled crop, which implies the impossibility of effective application of lactic acid bacteria in its ensiling [10]. That's why alfalfa is recommended to be used mainly for haymaking. It is believed that the preservation of food is ensured by so-called physiological dryness due to the unavailability of moisture contained in the plants for unwanted microbes. As a result, the feed is successfully stored regardless of the degree of acidification. They say in most herbs physiological dryness occurs when they are dried to a dry matter content of 45-50% [11].

When dried alfalfa with the dry matter content of 45-50% is loaded for storage we don't always get feed free from the accumulation of butyric acid because such wilting of plants does not lead to physiological dryness. This is indicated by the actual determination of the water activity (Wa) in the dried mass. When plants are dried to a dry matter content of 50%, water activity does not fall below 0.95, while active acidity (pH) is not normalized only when canning plant products with Wa ≤ 0.85 [11].

So, we can conclude that the need to wither alfalfa and other non-ensiled legumes to a dry matter content of 45-50%; it isn't associated with the creation of physiological dryness in plants; it is caused by the need to ensure their preservation in conditions of weak acidification. The main cause of spoilage of silage from legumes is butyric fermentation, while other species of unwanted microflora do not receive significant development. The susceptibility of pathogens of butyric acid fermentation to active acidity (pH) increases with increasing dry matter content in the ensiled mass, which in contrast to the ensiling of wilted cereals allows to ensure high safety of feed at its low active acidity.

The aim of the work is to develop a method of obtaining good quality silage from highly nutritious low-silage green mass of the most common perennial legumes, i.e. alfalfa and clover by combining silage mass with green mass of bluegrass and fairway crested grass without their preliminary drying because it significantly increases the cost of the final product. We also aimed to establish a degree of digestibility of nutrients in the forages prepared from drought-resistant cereal grasses in mono rations of ruminants.

Materials and methods of research. Referring to the literature [12, 13] on the optimal grasses harvesting to provide the highest productivity as animals feed. We determined the budding phase of perennial legumes and at the end of the tube phase, i.e. before cereals earing as optimal one. Laboratory tests were performed in 3-liter glass containers connected by the connected vessels type with a vessel of saturated salt solution. This method was used to study the technological method of making silage from drought-resistant fodder crops of wheatgrass and rye in equal proportions with perennial legumes of clover and alfalfa (50:50%). This formulation of the research scheme makes it possible to have control and research options for various factors influencing the fermentation processes (Table 1).

Table 1

The scheme of the experiment to establish the degree of ensiling of the green mass of newly created drought-resistant cereals

Experiment variant	Variant characteristics
I – control	Green mass of bluegrass + alfalfa
II – experimental	Green mass of bluegrass + alfalfa + EM-A crop (2 ml of diluted solution (1:1000) + 20 ml of water.
III – experimental	Green mass of fairway crested grass + alfalfa
IV – experimental	Green mass of bluegrass + red clover

Green mass of cereals and legumes was laid in a container with a density of 506 kg / m^3 in I, II and IV variants and 480 kg / m^3 in III variant.

Physiological experiments to determine the degree of digestibility of basic nutrients and nitrogen balance in the ruminants` body were performed from rolled bluegrass hay and fairway crested grass haylage. The experiments were conducted by the method of groups with preparatory and recording periods; each group consists of 3-4 heads. The preparatory period of experiments on sheep lasted for 10 days, the recording period of experiments on sheep lasted for 6-7 days, and the transitional period of experiments on sheep lasted 6-7 days lasted for 3 days (Table 2).

Table 2

Scheme of the experiment to establish the digestibility of bluegrass hay and fairway crested grass haylage by sheep

Group of animals	Number of animals, heads	Characteristics of feeding
Experimental-I	3	Basic diet (BD) + wheat bran + sunflower meal + salt + bluegrass hay
Experimental -II	4	Basic diet (BD) + fairway crested grass haylage + salt

The recording period of the experiment included a transition period during which the animals were completely transferred to the planned mode of the experiment. The planned and previously specified regime of the experiment was carefully followed during the recording period, all planned records and sampling for chemical analysis were conducted. The digestibility and metabolism were studied simultaneously. That's why all urine was collected during the main period and its nitrogen content was determined.

During the preparatory period, sheep received a basic diet that included the studied feed.

Research results and their discussions. The obtained research data show that the longest duration of fermentation processes for the release of fermentation gases was observed in the first variant; it is 50 days against 41 days in the second, third and fourth variants. Only 30% of the total amount of fermentation gases was released for the first 12 days in the first variant, it indicates a low-intensity and stretched type of fermentation processes The intensity of fermentation processes increased by 59% stimulating the fermentation processes by making EM-A (effective microorganisms — activated) at a dose of 2 ml of solution diluted (1:1000) per 1510 g of raw material ensiled with 20 ml of water in the second variant. The dry matter content in the silage of both variants was 35.4 % and 34.7 % respectively. One gram of dry matter released 24.5 ml of gases in the silo of the first variant, one gram of dry matter released 15.3 ml in the second variant; it is by 37.5% less than in the first variant (Table 3).

Table 3

Indicators of fermentation intensity in grass silage

Indicator	Experiment variant			
	I	II	II	IV
Fermentation days:				
total	50	41	41	41
first intensive days	12	12	12	12
Fermentation gases released, ml:				
total	13,160	7,995	7,480	14,435
intensive period, (12 days)	3,970	7,110	6,200	12,950
%	30	89	83	90
Dry matter content:				
total, g	538	524	619	633
%	35.4	34.7	43	32.9
Fermentation gases released, ml:				
1 g of silage	8.7	5.3	5.2	9.6
1 g of dry matter	24.5	15.3	12.1	22.8

The increase of dry matter content to 43% in the silage mass of the third variant due to the cereal component of the green mass of fairway crested grass with a dry matter content of 49.2% verse 37.9% of the bluegrass green mass of the second and first variants provided a reduction gases emission from 1 g of dry matter of silage to 12.1 ml, or 50% less than in the first variant.

In the fourth variant, the silage of the green mass of bluegrass and clover provides 90% fermentation processes for the first 12 days with the release of 22.8 ml of fermentation gases per 1 g of dry matter indicating a satisfactory selection of components in the silage.

Analyzing the organoleptic indicators of silage quality (table 4), it should be noted that all variants preserved loose structure of silage with a brown-green tinge and a pleasant odor after 134 days of storage, it characterizes the silage as satisfactory feed [14].

It was found that the high content of dry matter in the green mass of bluegrass (37.8%) and (49.2%) fairway crested grass provides conditions for obtaining good quality silage at equal ratios of cereal and legume components (1: 1) from the green mass of alfalfa and clover.

The application of effective activated microorganisms (EM-A) during ensiling reduces the release of fermentation gases from 1 g of silage by 39.1%. According to organoleptic and biochemical parameters, the silage in the control and experimental variants meets the requirements of a good silage made of green mass of perennial grasses, it is indicated by the pH level. This value is not indicative on itself, but there is a relationship between pH and fermentation quality. The pH values are in the range of 4.6-6.9 with poor and very poor fermentation quality. The pH level varies between 3.4 and 5.0 with a very good quality of fermentation [15].

Table 4

Organoleptic indicators of grass silage quality after 134-day storage

Experiment variant and its characteristics	Organoleptic characteristics
I – Green mass of bluegrass + alfalfa	The structure is preserved, crumbly, brown-green color, pleasant smell of high-quality silage, sour.
II – Green mass of bluegrass + alfalfa + EM-A crop	The structure is preserved, crumbly, brown-green color, pleasant smell of high-quality silage, not sharp.
III – Green mass of fairway crested grass + alfalfa	The structure is preserved, crumbly, brown-green color, pleasant smell of high-quality silage, slightly acidic.
IV – Green mass of bluegrass + red clover	The structure is preserved, crumbly, the color is dark brown-green, the smell is pleasantly sour.

It is important to know the content and the ratio of organic acids to characterize the quality of silage. According to the biochemical indicators data of silage quality (Table 5), lactic acid fermentation prevailed in all variants. The level of lactic acid ranged from 58.7% in the first variant to 70% and more in the second and third variants.

Targeted ensiling took place with minimal loss of nutrients. The proportion of acetic acid does not exceed 25% of all acids characterizing the silage of good quality. A small amount of butyric acid was synthesized in the first and fourth variants.

The butyric acid was not detected in the variant of green mass and of fairway crested grass and alfalfa at a dry matter level of 39.8%. In the first and fourth variants its concentration was respectively 3.0-5.9% of the organic acids amount corresponding to the 0.11- 0.17 g per kg of dry matter (DM) at the rate of 3.0 g per kg of DM. The concentration of ammonia ranged from 37 to 45 mg%.

Table 5

Biochemical indicators of silage quality

Experiment variant	pH	Acid content, %				Ammoniac, mg%	% total acid	
		lactic	acetic	acetic	total		lactic	acetic
I	4.25	1.15	0.50	0.06	1.96	39.1	58.7	25.5
II	4.35	2.07	0.50	-	2.83	37.4	73.1	17.7
III	3.87	1.67	0.45	-	2.34	45.05	71.4	19.2
IV	4.4	1.09	0.43	0.11	1.85	40.8	58.9	23.2

The ratio of silage components should be based on the principle of 30-40% dry matter content in the ensiled mass at which the probability of very high quality fermentation is greatest.

The EM-A crops application provides a targeted flow of lactic acid fermentation in the second experiment variant; they make possible to obtain high-quality silage by organoleptic characteristics with a dry matter content in the ensiled mass of 30-40%.

It was found that the sheep of the first experimental group ate feed rations without residues. It included 1 kg of bluegrass hay, 100 g of wheat bran, 100 g of sunflower meal and 11 g of salt. The average daily water consumption was 1.7 liters. The digestibility of dry matter was 48.8%, organic matter was 51.86%, crude protein was 51.98%, crude fat was 57.2%, crude fiber was 59.64% and nitrogen-free extractives (NER) was 47.21%; nitrogen retention was 3.58 g, it is 19.17% of the accepted and 36.56% of the digested nitrogen (Table 6).

Table 6

Digestive factors of essential nutrients and nitrogen retention (n=3; M±m)

Indicator	Digestibility ratio	
	Experiment I	Experiment II
Dry matter, %	48.8±2.1	71.3±35.6
Organic matter, %	51.86±1.75	73.1±36.5
Crude protein, %	51.98±1.82	67.6±33.8
Crude fat, %	57.2±1.7	61.5±30.7
Crude fiber, %	59.64±2.22	67.5±33.7
NER, %	47.21±2.04	78.6±39.3
Ash, %	10.81±3.29	40.9±20.5
Nitrogen retention, g:	3.58±0.95	12.73±0.25
accepted, %	19.17±5.09	54.7±1.1
digested, %	36.56±9.73	77.6±1.1

It was found that the experimental sheep of the second group consumed haylage as mono-feed harvested from fairway crested grass green mass with small residues from 337 g to 648 g per day (8.4 % and 16.2%).

The obtained results show that the digestibility of the main nutrients in the mono-ration of fairway crested grass (4 kg per day) is 71.3% of dry matter, 73.1% of organic matter, 67.6% of crude protein, 61.5 % of crude fat, 67.5% of crude fiber, and 78.6% of nitrogen-free extractives (NER) with nitrogen retention is 12.73 g, which is 54.7% of the accepted and 77.6% of the digested one.

Conclusions

1. The application of green mass of bluegrass and fairway crested grass in equal proportions with the green mass of alfalfa, or meadow clover provides a good quality silage by increasing the dry matter content in the ensiled mass to optimal one (not less than 30-40%).
2. The EM-A crops application in green mass of bluegrass and alfalfa ensiling creates a targeted lactic acid fermentation providing high-quality organoleptic and biochemical silage with a higher content of lactic acid in it (73.1%), which is 24.5% higher than control option.
3. Consumption and digestibility of the main nutrients of the diet including hay from wheatgrass and fairway crested grass are high with a positive nitrogen balance in the animals` body.

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