

Development of energy-saving methods of waste processing as a tool for transformation of the social and economic systems

Valeria Kireeva^{1*}

¹Don State Technical University, 1 Gagarin sq., Rostov-on-Don, 344003, Russia

Abstract. The article deals with the problems of preservation of leafy mass of legume family high-protein agricultural crops, the disadvantages of the crop high-temperature drying in fodder production. One presents the results of studying the possibility of reducing the moisture content in plants mechanically, using the resulting waste (press residues) as a raw material for silage preparation applying the energy-saving bioconversion method. The results of developing the method of alfalfa press residues ensilaging with introduction of a mixture of strains of lactic acid bacteria cultures are presented. The chemical composition of the vegetable stock and resulting silage was analysed, the feed and caloric values were determined for introduction into animal diets.

1 Introduction

In conditions where competitiveness of the national economy need to be improved based on innovative development, the factors capable of influencing the transformation of the economic system are gaining currency. In the opinion of researchers [1], the initial stage of a new system of economic relations is the transition period, during which the fundamentals of the contemporary system of the economic relations are formed. The energy-saving technologies, alternative energy sources, information and communication technologies, intellectual capital, knowledge-intensive industries may be such fundamentals of the innovative economic system.

In this regard, the development of energy-saving technologies of integrated use of plant resources, full or partial disposal of the resulting wastes with preparation of multi-purpose products are getting of particular importance [2, 3].

When procuring the fodder, the green mass after mowing and chopping becomes a favourable and available medium for development and accumulation of many species of microorganisms living on it - bacteria, yeast, mold and other microfungi, that during their living activities actively decompose nutrients contained in destroyed plant cells, which is the reason of decreased feed value of the biomass [4].

* Corresponding author: valeriakireeva@gmail.com

In fodder production, to reduce the vegetable stock humidity to the level required for storage, the falling through in the open air is used [5, 6] or high-temperature drying processes are used.

The main purpose of drying technologies applied for fodder procurement is not only the dehumidification of the vegetable stock used but maximum preservation of properties of the contained substances.

The use of high-temperature drying provides other advantages - there is no dependence on possible adverse weather conditions, the continuity of the procurement process is ensured.

At the agricultural enterprises the high-temperature drying is used for procurement of fodder from plants legume crops in form of grass meal that are impossible or hard to ensilage.

As compared to the traditional method of the field curing, this method ensures the reduced nutrient losses.

The grass meal made of leaves and stems of fodder plants, especially seeded legume grasses, drayed at a high temperature is characterized by high nutritional value as to the content of complete proteins, vitamins, organic acids, carbohydrates, physiologically active substances that have positive effect on the animal organism, fertility, improving the quality of the resulting animal products (meat, milk).

For that reason, high-temperature drying the fodder with gases heated to high temperatures is still relevant in fodder production but is energy demanding - to get 1 t of the grass meal made of green crop up to 0.35 t of liquid fuel or up to 400 cub.m of gaseous fuel need to be spent.

In the technology developed by the researches [7] for fractionation of legume crops herbage to get the protein concentrates, the crop humidity is reduced by pressing using various press devices.

The pressing of leaves and stems results in formation of wastes (alfalfa residues after pressing) that find no application but have certain feed value. The attempts to produce the grass meal from the press residues did not have widespread acceptance due to high energy intensity of the process.

The use of press residues as a raw material that is suitable thanks to its reduced humidity for ensilage seems relevant.

When processing the crop, the alfalfa residues after pressing are contaminated with spores of microorganisms living on stems and leaves and entering the biomass with dust from the environment [8].

To suppress them, it is necessary to add the preserving agents of a chemical or biological nature to the stored crop.

For the purpose of preservation of the fodder intended for winter feeding of animals, many plant crops belonging to different families are used. More than 1 t/ha of vegetable protein may be obtained from the herbage of legume family cultures (alfalfa, clover) for 3 cuttings per season. The cost of herbage protein is 2.5-5 times less than that of cereal protein.

Multiple researches confirmed the advantages of application of biological preserving agents as compared to chemical ones [9].

Among biological preparations, the use of fermented-milk starters in fodder production gain widespread currency due to their environmental compatibility, high efficiency and relatively low cost [10, 11].

At present the biopreservation is mostly based not on one crop - the use of one type of microorganisms producing the organic acids, but on the mixed culture of representatives of one or more different taxonomic groups. With the appropriate selection of cultures and

compliance with the preservation technology conditions, the production of high-quality fodder is guaranteed.

The purpose of the study was to develop the energy-saving method of disposal of wastes from processing of leafy mass of legume family fodder grass by bioconversion resulting in high-quality fodder for farm livestock.

2 Methods

The green matter of cultivated blue-hybrid alfalfa of the 1st cut at the budding stage was used in the study [12].

The alfalfa vegetative organs were processed using the herbage fractionation method, where it was divided into solids - alfalfa residues after pressing and green juice intended for preparation of protein concentrates [7].

The wastes (alfalfa residues after pressing) formed as a result of pressing were disposed of by ensilaging with administration of the specially selected mixture of lactic acid bacteria cultures.

The optimal modes of alfalfa residues after pressing fermentation, chemical composition of the resulting silage were determined, the preservation of its feed and caloric value during the storage was examined.

Chemical analysis of the derived product - the protein, fibre, fat, ash content was determined based on the conventional methods.

The content of easy hydrolysable carbohydrates (sugars) was determined by staining solutions with an anthrone reagent.

In order to increase the fermentation efficiency, the starter material was used - consortium of strains of lactic acid bacteria of *Lactobacillus* genus: *L. plantarum*, *L. acidophilus*; *L. casei* (in equal proportions).

To prepare the alfalfa starter, molasses (2% sugar), biotin (0.5%), meat and bone meal (0.9%), NaCl - 6.0% were added to the sterile extract of the press residues.

The lactic acid bacteria seed material was added in amount of 4% of the substrate volume and was incubated at $t = 40^{\circ}\text{C}$ within 6 hours.

Then, the culture medium was neutralized with caustic soda solution to the initial acidity of the vegetable matter.

The derived bacterial starter contained 950-1,000 mln microbial bodies (mb) of lactic acid bacteria per ml of suspension.

The crop prepared for ensilaging was enriched with a suspension of the mixture of lactic acid bacteria strains at the concentration of $1 \cdot 10^9$ MB / ml in amount of 15 ml and 150 ml of suspension per sample (1% and 10% of the crop respectively), followed by thorough mixing.

The crop was put into sealed vessels, tramped down, closed with covers and stored at a temperature of $14 \pm 1^{\circ}\text{C}$ for 6 months.

Upon expiration of the observation period, one controlled the fodder appearance, determined the quantity of microbial bodies (mb) of lactic acid bacteria and bacterial population that is undesirable (harmful) for the fodder.

3 Results

In experiments on the preparation of fodder for ruminants, the following methods were used to reduce the material moisture content: wilting of alfalfa green matter and its mechanical drying to obtain the press residues.

In experiments one used the alfalfa residues after pressing with dry ingredients content of 29.77%, and for control purposes - the green matter wilted in a traditional way to dry ingredients content of 30.74%.

In experiments for silage preparation, one placed in storage the biomass made of wilted and pressed alfalfa green matter using anaerobic fermentation with the starter material made up of a mixture of lactic acid bacteria of *Lactobacillus* genus.

These strains of lactic acid bacteria were selected based on the fact that their predominant amount is observed in different stages of ensilaging and has positive effect on the fodder fermentation rate at all stages of ensilaging [13].

These strains, in comparison with other microorganisms used for the preparation of starter materials applied in fodder production for its ensilaging, have a higher rate of reproduction, suppression of vital processes and limitation of the development of putrefactive bacteria and other undesirable bacterial population.

It is known that lactic acid bacteria have antibiotic effect on putrefactive and other spore-forming bacteria found in silage and weaker antibiotic effect on the *Echerichia coli* group.

Moreover, they may generate the required quantity of organic acids (mainly lactic acid) that are necessary for pH reduction within shorter period.

Since the wilted herbage was dry, poorly compacted mass, the cultural suspension was introduced in amount of 1% and 10% of the raw material weight.

During external examination of containers with fodder, carried out on a weekly basis, in some variants of fermentation in containers with wilted herbage, the mold was found in the fodder, that emerged by the end of the fourth month of storage.

The degree of damage of the wilted herbage fodder was 10-12% of the raw materials' weight.

In the number of experiments with the use of alfalfa residues after pressing, no mold fungi growth was observed.

The study of the dynamics of hydrolysis of easy hydrolysable carbohydrates showed that vital activity of bacteria led to their decomposition and depletion as compared to non-treated wilted herbage and press residues.

There were almost no differences in the change of pH in the fermented wilted herbage and alfalfa residues after pressing.

At the end of the storage period, the presence of butyric acid bacteria and signs of fodder decay were registered in the silage made of wilted herbage stored without starter material except for mouldy areas.

In the silage made of wilted green matter, inoculated with 1% of lactic bacteria starter, pH was 4.3, insignificant quantity of yeast colonies was noted.

In the silage made of wilted green matter, enriched with 10% lactic bacteria suspension, there were no physical signs of mold formation, pH was 4.0, occasional yeast colonies were noted.

The acidity of the silage made of alfalfa residues after pressing with the addition of bacterial starter culture suspensions in amount of 1% and 10% suspension decreased to pH 4.2, no butyric acid bacteria were found.

Yeast and putrefactive microorganisms were not sown.

This is consistent with the data available in the literature stating that in the first few days of fermentation silage there is rapid proliferation of lactic bacteria cells that ensure the pH reduction and suppression of undesirable bacterial population - putrefactive and fungal.

The use of microbial starter as preserving agent - an association of lactic acid bacteria strains promoted the improved preservation of silage nutrients made both from the wilted herbage and press residues.

In the experiments, one used the initial wilted alfalfa with the crude protein content of 18.1% and alfalfa residues after pressing immediately after pressing with the crude protein content of 17.15%.

The performed analysis showed that introduction of starter material contributed into increased efficiency of the ensilage fermentation.

With a sharp increase in the number of lactic acid bacteria cells, water-soluble carbohydrates of the crop were fermented with the formation of organic acids, mainly lactic and acetic, in the ratios necessary for effective ensilaging.

As a result, the pH level decreased and there was steady stabilization of the fodder nutrients.

The chemical composition and caloric value of fodders obtained through microbiological transformation of the initial wilted crop and alfalfa residues after pressing are presented in the table 1.

Table 1. Chemical composition (% ACB), and caloric value of fodders obtained through microbiological transformation.

| Silage made of raw materials | Content in ACB, % | | | | | Fodder unit. |
|---|-------------------|--------------|---------|---------------|------|--------------|
| | protein | fibre | ash | carbohydrates | fat | |
| Initial wilted alfalfa crop | 16.34 | 24.37 | 10.12 | 4.64 | 4.45 | 1.112 |
| Wilted crop with introduction of 1% of lactic bacteria suspension | 16.47 | 24.22 | 9.86 | 3.77 | 4.42 | 1.125 |
| Wilted crop with introduction of 10 % of lactic bacteria suspension | 16.48 | 24.22 | 9.87 | 3.84 | 4.42 | 1.125 |
| Initial alfalfa residues after pressing | 15.67 | 35.20 | 9.57 | 4.45 | 3.78 | 0.972 |
| Alfalfa residues after pressing with introduction of 1% of lactic bacteria suspension | 16.17 | 34.93 | 9.35 | 3.79 | 3.63 | 0.953 |
| Alfalfa residues after pressing with introduction of 10 % of lactic bacteria suspension | 16.17 | 34.93 | 9.37 | 3.79 | 3.59 | 0.953 |
| Standard for 1(2) grade silage | min. 15(13) | max. 28 (31) | 10 (11) | | | 0.77 (0.65) |

The loss of nutrients in the initial wilted green matter with introduction of the starter made of lactic bacteria suspension was less than in the crop stored without a preserving agent.

The protein loss in the fodder made of wilted crop with introduction of 1% and 10% of microbial starter was 8.4-8.43%.

Evaluation of the fodder caloric value showed that in terms of gross energy, the silage from the wilted herbage with introduction of lactic bacteria was at the level of the herbage stored without starter material - GE 18.34 MJ / kg; the value of the exchange energy was

higher than in the untreated herbage and amounted to 11.78 and 11.71 MJ / kg, respectively.

The number of fodder units in the silage with microbial starter was also higher as compared to the herbage without microorganisms.

The preservation of nutrients in the ensilaged alfalfa residues after pressing fermented with lactic bacteria preparation also exceeded the corresponding value in variants with the wilted green matter.

The protein losses in the fodder amounted to 5.61-5.64 % and were less than in the series of control experiments, demonstrated the improved quality of the derived product - silage.

In terms of content of the fodder units and energy value, the silage obtained by bioconversion of the alfalfa residues after pressing was inferior to the fodder made of the wilted green matter, which was due to the lower content of nutrients in the initial press residues and the wilted herbage.

The preservation of nutrients in silage with introduction of 1% and 10% differed insignificantly, which indicates that 1% of bacterial cultures is enough for microbial biotransformation of the fermented herbage.

The content of fermentation products during storage of the fodder made of wilted herbage and the press residues of alfalfa was higher in the silage than in the residues after pressing placed without introduction of the bacterial culture.

When determining the content and ratio of fermentation products, it was established that the addition of a suspension of the mixture of bacterial strains resulted in the increase in the content of the total of organic acids in the silage in comparison with the biomass placed without microbial starter.

The butyric acid was present in the silage made of the initial raw materials, but wasn't found in the silage derived from anaerobic fermentation.

The total of organic acids in the silage made of wilted herbage was 2.28-2.47%, the share of lactic acids was 64.48-64.75%.

For the silage made of alfalfa residues after pressing, the values were 2.54-2.61% and 65.48-65.77%, respectively.

Better values of nutrient preservation in the fermented herbage as compared to that stored without the use of bacterial additives is probably due to the fact that pH reduction during biotransformation took place earlier and ensured the retardation and suppression of putrefaction of protein and other substances.

The finished silage had an olive green colour, the smell of pickled vegetables, the structure of the original crop.

4 Conclusion

The obtained results made it possible to make the following conclusions.

In terms of organoleptic characteristics, the feed and energy value, the fodder made of alfalfa residues after pressing, preserved with the introduction of starter consisting of the mixture of lactic bacteria corresponded to the requirements for grade 2 silage adopted in the Russian Federation.

The preservation of nutrients in the ensilaged alfalfa residues after pressing fermented with lactic bacteria preparation exceeded the corresponding value in variants with the wilted green matter.

The developed method contributes to the solution of the waste disposal problem in crop agriculture [2, 3].

The preparation used for preservation, in contrast to chemical preservatives, is not toxic, which meets the requirements for improving the personnel safety at agricultural enterprises [14, 15].

The method of ensilaging the alfalfa crop processing wastes based on fermentation with the mixture of cultures of lactic acid bacteria ensures the production of high-quality fodder for farm livestock, reduction of expenses and energy resources.

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