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LOW-WASTE TECHNOLOGY OF FODDER GRASS PROCESSING

Valeria V. KIREEVA[1]

Abstract: *The article describes the peculiar features of plant processing for the conservation of fodder made of the leafy mass of hard-to-ensilage legume family cultures in agricultural complex, deficiencies of the traditional treatment of the feedstock. The current technology of mechanical fractionation of legume grasses suggests the production of the basic product - the protein concentrate. The by-products are press residues - grass pulp and protein-free liquid, which are production wastes. The purpose of this work was to develop a comprehensive method of plant resources' use with waste disposal and application in fodder production. The novelty of the work is the method of combining the dehydration of the vegetative organs of the hard-to-ensilage sown legume fodder grasses through mechanical pressing and drying and the use of the resulting wastes - the press residues as raw material for fodder preparation. The humidity of the press residues was to be reduced to the level required for making haylage by using the method of low-temperature final drying in experimental unit - continuous-action direct-heated drier. The results of studying the possibility of reducing the humidity of the press residues by low-temperature direct-heated drying and using it as raw material for haylaging are presented in the article. The temperature and time ranges for the material drying in direct-heated drier were established. The chemical composition of the vegetable stock and resulting haylage was analysed, and the composition of the fermentation products, the feed and caloric values, and the potential safety for animal organisms were determined. The suggested method ensures the comprehensive processing of the herbage with waste disposal and production of high-quality animal fodder. In terms of quality parameters and environmental safety, the obtained fodder conformed to the regulatory requirements to the haylage to be used in cattle stock diet.*

Key words: *sown legume grasses, mechanical drying, press residues, direct drying, haylaging.*

[1] Don State Technical University, 1 Gagarin square, Rostov-on-Don, 344000, Russia;
Correspondence: Valeria V. Kireeva; email: kireeva.dstu@bk.ru.

1. Introduction

The comprehensive low-waste processing of the green matter of agricultural plants is one of the most important issues of modern crop growing.

In agricultural crop growing, the problem of disposal of large volumes of plant wastes characterized by a certain degree of feed value is still unsolved. The reason for the extensive use of the traditional and non-traditional technologies for haylage making from different types of plant processing wastes at agricultural fodder production enterprises within recent years is that fodder preparation makes it possible to obtain more nutrients from the same area of soil, to reduce the quantity of additional components that need to be introduced into traditional diets while reducing the cost of animal products as compared to the use of silage, hay.

For the purpose of the preservation of the fodder intended for the winter feeding of animals, many plant crops belonging to different families are used. The most valuable of them are the legume family plants. 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. However, these cultures are classified as hard-to-ensilage due to the high protein content and high humidity. The field drying of the cut green matter is traditionally used in fodder production to reduce such humidity. The cut green matter is dried in the field to 55-60% humidity with periodic turning. The dried matter is delivered to storage facilities where it is compacted and kept in airproof conditions. The timely completion of drying and herbage humidity reduction is essential. With the free and bound water content in plant tissues of above 60%, the ensilage-type fermentation takes place. Following the moisture content reduction to 40%, the field losses of nutrients reach 20% and those of provitamin A - carotene - 60-70% and more. This method has some disadvantages - dependence on weather conditions and high field losses during turning, selection of dried herbage.

In order to reduce the feedstock humidity to the level required for haylaging, artificial drying processes [2] may be used. Low-temperature direct drying [2, 13] is a method of vegetable stock humidity reduction that is widely used in fodder production, applied, in particular, for vegetable drying. The application of this drying method is considered efficient for herbage dehydration to 35-40%.

The artificial drying of the grass green matter is performed in hay and forage centres in drum-type drying units of different models. Their advantage for the drying process is the permanent steady speed of moving into the drying drum inlet chamber of the crop material having different humidity.

When drying the fine-cut green matter of the cultures with excessive humidity, the drying drum chamber is equipped with a beater. This is done to keep the moving green matter being dried in suspension, thus reducing the energy costs for its heating from 210 to 125 kcal per 1 kg.

In order to reduce the energy costs for the artificial drying of the green matter of plants, the direct drying in the drum-type drying units of different models is combined with the use of devices ensuring the final drying of the herbage using super

high frequencies (SHF). SHF installations are used in food industry enterprises to reduce the humidity of fruit and vegetables. These installations are combined with dryers of other types and they are safe for the maintenance staff.

In fodder production, the high-temperature drying of leafy fodder crops is used to get the grass meal for the purpose of adding to the combination fodder in the form of protein and vitamin supplements. In such a case, the herbage drying mode is selected regardless of the type of vegetable stock and is set to make the herbage with 10% humidity, as in case of higher moisture content there may be the growth of microfungi, which are capable of producing carcinogenic toxins, and in case of lower moisture content the oxidation rate increases and the vitamins in the biomass are destroyed.

The losses of biologically active components during storage are reduced, as a rule, by granulating the grass meal using the traditional granulating plants as well as granulating and pelletizing machines. The granulating and pelletizing machine allows the pressing of the dry cut into pellets. Granules and pellets are of high temperature, which is connected with the need for prompt cooling ensured by forced blowing with the atmosphere air supplied to the feeders through the forced blowing system.

The main purpose of the drying technologies applied for fodder procurement is not only the dehumidification of the vegetable stock used, but the maximum preservation of the properties of the contained proteins and biologically and physiologically active substances - organic acids, vitamins, carbohydrates, sugars [9, 12].

When storing the grass meal one shall keep in mind that the carotene pigment (provitamin A) is subject to fast oxidation under the influence of atmospheric oxygen. To limit the contact of the dried grass meal with the air, it must be stored in airproof paper bags, or granulation shall be used.

Carotene stabilization in the dried herbage is achieved by the application of chemical antioxidants preventing carotene oxidation [14]. Among the large number of antioxidants tested and widely used in fodder production, the most efficient is ethoxyquin or santohin, which, however, is characterized by quick oxidation in the light and high cost.

To obtain the grass mill, the natural grass stands of the improved pastures, legume crops - alfalfa, clover, sainfoin, vetch, and other perennial and annual grasses, agricultural crop growing and vegetable growing wastes - cabbage leaves, tops of the table and sugar beets and other root crops, can be used.

The fodder produced by artificial drying of leafy herbage is as good as many cereal crops in terms of nutrient value. The artificially dried meal contains 15-20% digestible protein, 200-300 mg/kg of carotene, and 08-0.9 fodder units.

A significant disadvantage of the conservation of green vegetable fodder using high-temperature drying is high energy consumption. For this reason, it is more economical to make the meal of high-protein cultures that contain vitamins, microelements and are low in fibre, which makes it possible to cover the production costs.

Alternative processing - bioconversion is applied to ensure the use of wastes in agricultural vegetable and crop growing. The essence of the bioconversion process

is that raw plant substrates, considered as waste, contain complex polysaccharides - pectins, cellulose, hemicellulose, which are destroyed and decomposed into simple structures - monomers under the action of complex enzyme preparations [6].

The objective of researchers developing advanced technologies of fodder production is the use of processes that do not require high energy costs.

In order to reduce the humidity of high-protein vegetable stock, there is the fodder grasses mechanical fractionation technology based on pressing. At the time of pressing, the leafy herbage is divided into press residues (pulp) and cellular green fluid. The fluid is used to produce protein concentrates to feed animals in the winter season [4, 5].

The key stage is the mechanical reduction of crop humidity (pressing) determining the efficiency of the finished product yield and energy costs for drying.

When implementing the technology, the by-products, press residues, are generated - grass pulp and supernatant protein-free liquid - brown fluid.

In agricultural practice, it is suggested to dry the pulp in high-temperature driers to make the grass meal, and to evaporate the brown fluid in vacuum evaporators for subsequent use in microbial synthesis, which is associated with high material and energy costs. For that reason, these products are not used and are classified as wastes and, as a rule, removed to the dumping ground.

The technology of green matter mechanical drying using pressing provides opportunities for feeding agricultural ruminants with fodder made of the green matter in plants, which are not eaten well when introduced in their diets.

The use of green matter mechanical drying technology is expedient, especially in agroecosystems located in close proximity to industrial enterprises and production facilities, and subject to the increased anthropogenic load.

In order to introduce the comprehensive processing of herbage into the practice of agricultural fodder production, the methods of disposal of the generated by-products without significant energy costs and with high-quality environmentally friendly fodder must be developed. The most economical method to dispose of the press residues is haylaging. According to available literature data, it is not always possible to make haylage of the pulp generated from alfalfa, which is a hard-to-ensilage culture. However, it contains a considerable quantity of freely soluble carbohydrates required for the growth of lactobacteria ensuring the effective fermentation of the biomass [1, 7, 11]. Therefore, studying the possibility of using the herbage processing wastes - the press residues as raw material for haylaging after the reduction of its humidity using the low-temperature final drying was of interest.

The purpose of our study was to find the opportunity to make fodder of alfalfa pulp following the additional reduction of humidity through gentle low-temperature drying.

The relevance of the study was based on the need to dispose of wastes generated in the course of processing of vegetable stock using low-temperature final drying and production of high-quality fodder, which may ensure the increased efficiency of the plant resources' use and environmental protection.

2. Materials and Methods

The purpose of the study was to develop the resource-saving method of comprehensive processing of herbage of sown legume grasses with disposal of wastes - the press residues dehydrated with low-temperature drying with subsequent haylaging.

The new-mown green herbage of "Manychskaya" breed alfalfa of the 1st cut at the budding stage was used in the experiments.

The alfalfa vegetative organs were processed using the method of herbage fractionation. It was subject to mechanical pressing with division into cellular fluid used for the production of protein fodder additive and press residues (pulp) being a production waste [4, 5].

The generated wastes (press residues) were disposed of by reducing the humidity with low-temperature drying with subsequent haylaging. The final drying of the press residues was carried out with artificial low-temperature direct drying to the level required for haylage making.

The humidity of the press residues was reduced on the experimental multilevel conveyor-type low-temperature continuous-action drier with intermediate air heating at each level.

The unit was developed based on the СПК–4Г–15 steam conveyor-type dryer used in food and agricultural production.

The drier consisted of a chamber with conveyer belts installed in five levels one above the other. The heaters were installed in the chamber to heat and supply the air to the conveyor belts with the material being dried.

The lead drums were driven by the common chain wheel gear from the power-drive station, including the speed variator to adjust the belt speed and, consequently, the drying exposure.

The press residues were delivered to the processing chamber of the unit with the layer thickness of 2.5-3.0 cm and were dried within 15-25 minutes. The temperature in the drying unit chamber was 48-60°C.

The optimal modes of drying the press residues were determined - the period of drying to the level required for haylage making.

The humidity level was controlled by drawing samples at certain intervals. In the course of drying, the material was stirred and homogenized with the turners installed in the chamber. After low-temperature drying, the press residues were placed in glass containers for storage. The storage period was 6 months, following which the chemical composition, the composition of the fermentation products, the fodder nutritional value, and the potential safety of the fodder were determined using generally accepted methods.

The biochemical characteristics of the finished haylage were determined by the following parameters:

- Dry matter content;
- Nutrient content – protein, fat, fibre, water-soluble carbohydrates (sugars);
- Silage calorific value;
- Scidity - pH;
- Content and correlation of fermentation products - organic acids (acetic, lactic, and butyric);
- Amount of the released ammonia nitrogen.

Organoleptic evaluation was carried out by means of fodder inspection during the daytime in normal diffused daylight. Based on the smell, the presence or absence of mold or rot formation as a result of the

violation of the established haylaging modes or careless storage of the fodder, the preliminary impression about the overall condition of the fodder product was created.

The quality of the resulting fodder was considered in comparison with that produced using the traditional agricultural technologies of fodder production (Hay and haylage [3]).

3. Results

The experiments on the biotransformation of press residues were carried out by haylaging after its final drying. For final drying, the alfalfa pulp with different initial humidity was used: 60-63% (experiment variant I); 65-67% (experiment variant II); 71-73% (experiment variant III). The material was processed until the humidity level reached 50-55%.

The experiments showed that the multilevel conveyor-type drying unit with intermediate air drying at each level ensured the drying of the press residues within acceptable time periods (16-20 minutes).

When processing the pulp in the turners, the drying rate increased 1.8-2 times as compared to the unprocessed pulp due to structural changes in the material. The obtained results proved that the final drying of the material with the initial moisture content of 60.27-60.03% to the level required to make the haylage takes 10 minutes, with the initial humidity of 65.47-67.03% - 14 minutes; with the humidity of 70.24-73.0 % - 18 minutes.

Chemical composition and caloric value of the initial press residues and prepared fodder Table 1

Product	Content in dry matter [%DM]				Energy yield [MJ/ kg]	
	protein	fibre	fat	ash	gross	metabolic
Initial press residues	16.37	35.48	3.77	9.57	18.55	9.61
Fodder from the initial press residues	13.57	35.54	3.05	9.34	17.23	8.19
Fodder from the press residues after final drying	15.45	36.27	3.61	9.29	18.52	9.37
Standard value for haylage [3]	at least 15.0	29.0	-	10.0	21.0	9.2

The selected variant of press residues for haylage making was based on the fact that in case of different initial humidity of the material, the final drying time differed by a comparatively insignificant value. At the same time, the herbage press ratio was achieved with a single pressing, and, as stated above, ensured the highest protein content in it. Therefore, in subsequent experiments the alfalfa pulp after minimum dehydration with the initial humidity of 72.24 % (dry matter - DM = 27.76 %) was selected, the humidity of which was reduced to 52.73% (DM = 47.27 %) after drying within 18 minutes.

In the control variant, the press residues were haylage without final drying.

Based on the information obtained in

the course of the study, it was established that after humidity reduction through alfalfa herbage pressing the content of nutrients was reduced as a result of their removal together with the green fluid.

In the fodder made of the initial press residues, the concentration of protein and other nutrients was not high, and it was below the standards established for high-quality fodder.

Based on the obtained results, it was established that during the press residues haylaging within the entire storage period the reduction in the content of protein and other nutrients took place in all variants of the experiments. The best results in terms of the preservation of nutrients in the fodder were registered in the test samples (Table 1).

The reduction in protein and nutrient content in the experimental variant of the fodder was less pronounced than in the control fodder made of the initial press residues.

When carrying out the toxicological assessment of the obtained fodder, the residual content of heavy metal ions and organochlorine pesticides used in agricultural crop growing was determined (Table 2).

Residual content of heavy metal ions Table 2

Product	Content in dry matter [mg/ kg DM]					
	Cu	Pb	Cd	Hg	Zn	As
Initial press residues	9,2	0,63	0,17	0,012	43,4	0,024
Fodder from the initial press residues	8,4	0,55	0,08	0,01	41,7	0,017
Fodder from the press residues after final drying	8,2	0,51	0,06	0,01	41,5	0,017
Standard value for haylage [3]	10,0	1,0	0,1	0,03	50,0	0,2

4. Discussion

The examination of the changes in the chemical composition during the fodder storage showed that protein loss in the test samples was 5.6%, which was much less than the losses in the reference sample (17.1%).

The press residues are characterized by lower nutrient content than the herbage. However, the press residues have some advantages - the cellular structure of the herbage is damaged, due to which the pressed herbage is better compacted; the sugar-protein ratio changes in the direction of increase in the content of water-soluble carbohydrates. This may probably be due to deactivation under the thermal action of proteolytic and other ferments contained in the herbage destroying the initial nutrients in the fodder.

During pressing the cellular fluid gets more protein and the press residues retain more sugars, which is a favourable condition for lactic fermentation and better biomass attenuation.

The parameters of the obtained fodder calorific value - the content of gross (18.52 MJ/kg) and metabolic energy (9.37 MJ/kg) were higher than in the reference sample and met the requirements established in the Russian Federation for heavy beasts haylage.

When conducting the chemical analysis of fermentation products in the haylage, it

was found that the amount of lactic acid formed was more than 55% of the total amount of organic acids, which ensured the decrease in pH to 4.3 and corresponded to the available literature data and established requirements for haylage [3, 6, 8].

No ammonia nitrogen was registered.

Butyric acid bacteria were suppressed in full and butyric acid content in the crop material was not registered.

No mold formation in the fodder took place, which was probably due to the suppression of the fungal flora under the thermal action during drying and its destruction during lactic fermentation [10, 15].

In the course of bioconversion, the development of pathogenic flora and unwanted bacterial and fungal flora is suppressed and parasites are destroyed in defective raw substrates.

Unwanted bacterial flora dies as pH rate decreases to 4.3-4.5. In the experiments carried out, the rapid acidification of the herbage led to its death and prevented the increase in the loss of nutrients due to such acidification and deterioration of the fodder quality.

When implementing the advanced technologies of crop cultivation in agricultural practice, the anthropogenic load on biocenoses increases: technogenic pollution with industrial and transport wastes, agrochemical plant protection products in agriculture (various pesticides).

In the course of the production of any type of fodder, especially from non-traditional raw materials, the main requirement in fodder production, i. e. safety, must be met.

It was established that natural and anthropogenic pollutants entering the leafy mass and produced fodder from the air and soil are the most dangerous. They include different pesticides, insecticides, numerous types of mineral and organic fertilizers; antibiotics, residual amounts of compounds of heavy metals and toxic elements extensively used in agriculture

When carrying out the toxicological assessment of the obtained fodder, the residual content of heavy metal ions - copper, lead, cadmium, mercury, zinc, arsenic [16], and organochlorine pesticides used in agricultural crop growing was determined.

The residual amount of toxic substances was determined according to the requirements to the vegetable stock used in fodder production.

As a result of the toxicological analysis, it was established that the values of the above parameters for the original leafy mass, press residues, and the fodder produced from it did not exceed the established requirements.

The fodder was yellow and green, had a good smell, non-smearing consistency, it preserved the natural vegetable structureand the protection of the environment.

5. Conclusion

The results prove that the combination of mechanical pressing of green matter with the method of direct low-temperature drying enables the optimized preparation of material for haylage making when producing fodders for using in the diets of livestock.

In terms of food and calorific value, qualitative and quantitative composition and correlation of fermentation products, and of the potential safety parameters the obtained fodder conformed to the

established regulatory requirements to the haylage to be used in the cattle stock diet.

Fodder cheapening due to the replacement of expensive animal-based protein components with cheaper ones made of vegetable stock is an important factor for the fodder production development at agroindustrial complex enterprises.

The developed method for the disposal of wastes of green matter of the sown legume fodder grasses through haylaging after artificial direct low-temperature drying ensures comprehensive low-waste processing of vegetable stock and preparation of fodder characterized by high food and calorific value.

This technology allows fodder production from high-quality hard-to-ensilage cultures (haylage) and ensures fuel economy.

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