ISSN: 0975-8585

Research Journal of Pharmaceutical, Biological and Chemical Sciences

Analysis Of The Structure The Technological Process Of Harvesting Haylage In Rolls, Packed In Film.

Sultan Nanuovich Kapov[1]*, Alexander Viktorovich Orlyansky[1], Irina Alexandrovna Orlyanskaya[1], Alexander Alexandrovich Kojukhov[1], and Vladimir Alekseevich Bogomyagkih[2].

[1]Stavropol State Agrarian University, Zootekhnicheskiy lane, 12, Stavropol 355017, Russia.
[2]Azov-Black Sea Engineering Institute, Don State Agrarian University, Lenina str. 21, Zernograd 347740, Russia.

ABSTRACT

To realize all the advantages of harvesting haylage in rolls, it is necessary to optimize the structure of the process taking into account regional specifics, the multivariance of possible technological and technical solutions, the probabilistic nature of the existing factors and the dynamics of changes in the properties of the grass mass. The purpose of the step-by-step optimization of the technology for harvesting haylage in rolls for specific production conditions is a rational choice of the technological scheme of the process of harvesting haylage using advanced high-performance feed-harvesting complexes. It is necessary to take into account the price and quality of the resulting haylage and ensure the minimum unit costs of material and energy resources for production. To solve such problems, an efficient graphical-analytical or topological approach is used to determine and evaluate indicators, which is based on the use of a structural and operator scheme for presenting the technology of harvesting haylage in coils. Such an approach allows: to establish the factors that influence the technological process; visualize the interaction of the studied processes and phenomena in conjunction with significant factors; determine the significance of the technological operations performed; optimize the structure of the process of harvesting haylage in rolls and machine complex; estimate the cost of hay production and feed loss.
Keywords: technological process, grass mass, structural and technological scheme, harvesting of haylage in rolls, the model of step-by-step optimization.

Corresponding author

INTRODUCTION

The most important feed for ruminants in the stall period is haylage. It is known that the nutritional value, quality, and cost of haylage is largely determined by the technology used, the rational choice of the technological scheme of the workpiece and the corresponding set of used forage machines and units. Especially it concerns the technology of harvesting haylage in rolls, packed in a polymer film. This technology, also called "haylage in packaging", has been successfully introduced around the world in recent decades. The main advantages of this technology are the possibility of uniformly wilting all parts of plants, reducing the period of grass mass in the field, a high degree of compaction of the mass in rolls, high-quality sealing off the feed with preservation of dry matter and carotene.

It should be noted that the technology under consideration consists of many individual technological operations that have a significant impact on all the factors of the roll production process. The main elements of the structure of this technological process are common to all regions of its use, however, when optimizing the technological scheme and choosing technical means, it is necessary to take into account the regional specifics imposed by the zonal working conditions. In addition, the choice of a rational forage production strategy is significantly influenced by the multivariance of possible technological and technical solutions, the probabilistic nature of the process of haylage harvesting, and the variability of the properties of the grass mass.

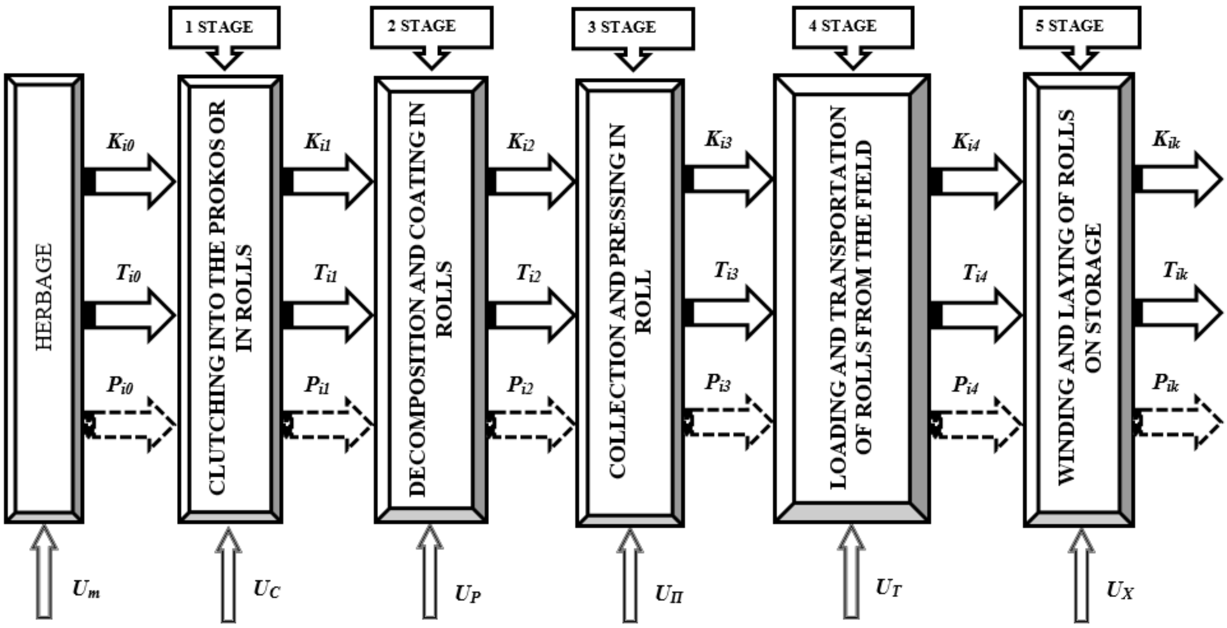
MATERIALS AND METHODS

In general, the main goal of the gradual optimization of the technology of harvesting haylage in rolls for specific production conditions is the rational choice of the technological scheme of the process of harvesting haylage using advanced forage harvesting complexes. It is necessary to take into account the price and quality of the resulting haylage and ensure the minimum unit costs of material and energy resources for production. To solve such problems, an effective graphical or topological method is the definition and evaluation of indicators, which is based on the use of a structural and operator scheme for presenting the technology of harvesting haylage in rolls. Such an approach will allow to visualize the interaction of the studied processes and phenomena in their relationship with significant factors and move on to the possibility of using the optimization model.

RESULTS AND DISCUSSION

In the studied technology, an important role is played by the need to take into account the sequence and efficiency of the impact of working bodies and machines on the material being treated (herbage and mowed grass mass) in accordance with the technological requirements for performing operations of the haylage harvesting process in rolls. Therefore, the consistent implementation of the harvesting machines each element of the technological process must meet the agrotechnical requirements and biological phases of plant development [1].

Now, many Russian farms use different technological cards, which provide for various options for the technology of haylage in rolls. The analysis shows that any variant of the technological process of harvesting haylage in rolls is carried out by sequentially performing the five main stages (Figure 1). The object of each stage of forage preparation is grass mass, the state, and properties of which vary from stage to stage (U_m, U_C, U_P, U_{PP}, U_T, U_X)with a different set of technological operations, ranging from mowing herbs to packing rolls and putting them in storage [2, 3, 4, 5]. Moreover, the implementation of technological operations of each stage is accompanied by the transfer of the properties of the grass mass from the initial state to the required one according to agrotechnical requirements. In this case, the criteria for evaluating each stage can be qualitativeK_i, technological$T_i$and economic P_i performance of fodder harvesting machines and units.



K_i – constructive - technical indicators of the machine and the units; T_i -agro technological indicators (requirements) of the operation of machines and units; P_i - economic indicators for agro technical requirements; U_m – initial state of grass mass current state of green mass, respectively, after mowing U_C, scattering U_P, pressing U_{PP}, as well as transportation $U_T$and windings U_X rolls before storage.

Figure 1: Structural-technological scheme of the harvesting the haylage in rolls

At each stage, there is a cycle of both individual and sets of sequential and parallel operations aimed at creating the conditions for the effective implementation of the technology of harvesting haylage in rolls. From the standpoint of evaluation and the formation of quality indicators, it is necessary to conduct a structural analysis of all operations of the technology of harvesting haylage in relation to the technical means used [2, 3, 4, 5]. It should be noted that the quality of transfer of grass mass from the initial state to the desired one according to agrotechnical requirements is decisive at all stages of the preparation of feed.

Then the general formulation of the task of step-by-step optimization of the technology for harvesting haylage in rolls can be formulated as follows:it is required to define a set of permissible controls (a set of operations, aggregates, operating modes, etc.)X_K,allows you to translate the properties of the plant*S*from the initial state$S_H$to the finalS_K, which achieves the desired effect, with the current state of the plant$S_I$at the end of each stage *I* depends on the previous stateS_{I-1}andcontrol parameter X_I.

Given this requirement, we write the equation of state:

$$S_I = \beta_I(S_{I-1}, X_I), \quad I = 1,2, \ldots, k, \quad (1)$$

k– number of stages (operations) in the structure of the technological process.

Such a task should be implemented using optimization methods, using the objective function:

1. $$Z_I = f_I(S_{I-1}, X_I) \quad (2)$$

Considering that the considered task is a multi-stage,

$$Z = \sum_{I=1}^{k} f_I(S_{I-1}, X_I) \quad (3)$$

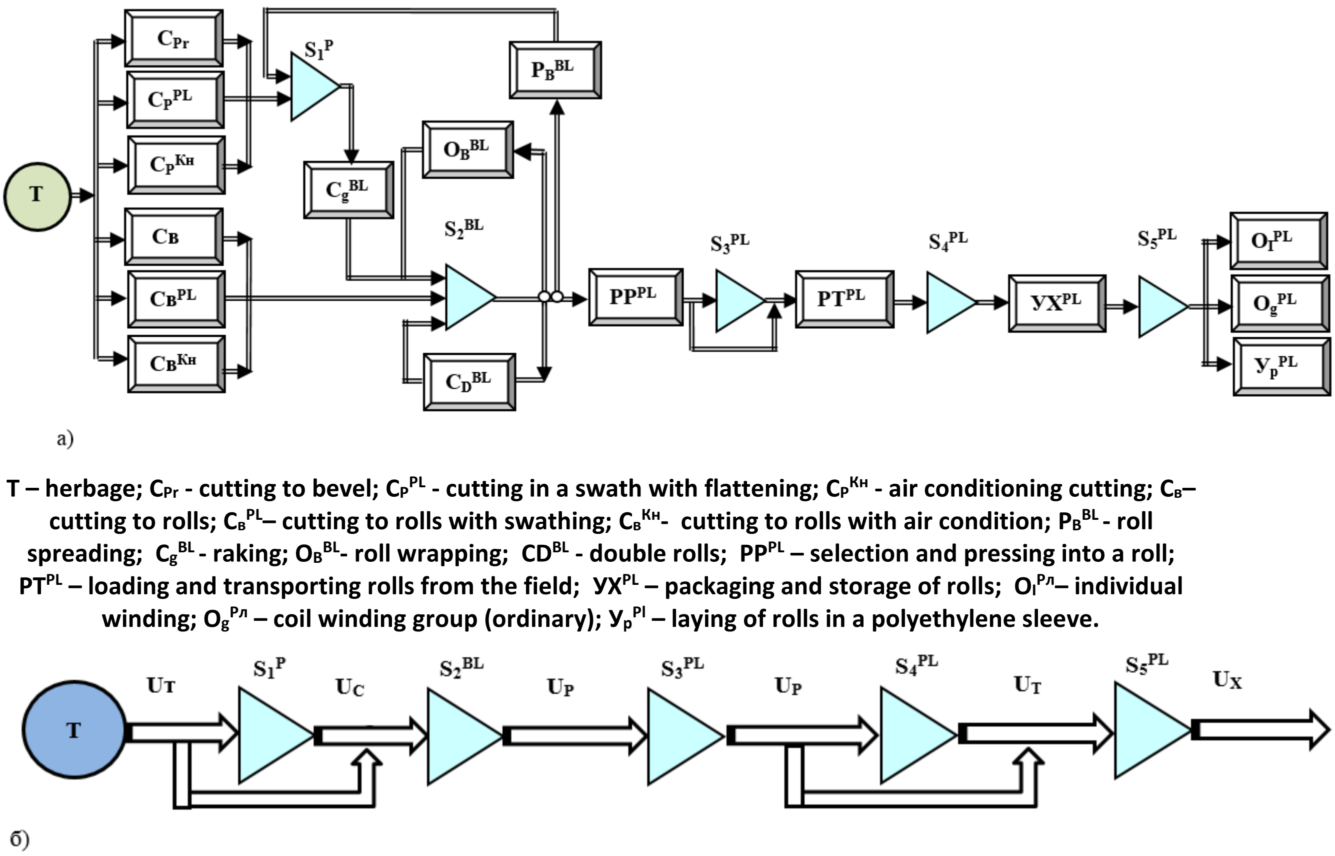
Analysis of equation (3) allows the following conclusions:

- optimization task is considered as a multi-stage process;
- value of the objective function is composed of the sum of the functions of each stage;
- Current state$S_I$each stage is determined by the previous state $S_{I-1}$and control parametersX_I;
- each stage of management X_I depends on the final number of control variables and is determined by the result of technological operations at this stage and the stateS_{I-1}.

Necessary effect on each*I*stage is achieved provided that by the beginning of the last stage, the system*S* was a conditionS_{I-1}, and at the last stage, the control was optimal and had an extreme (minimum or maximum) value:

$$Z(X_I) = \underset{\{X_I\}}{extr}\, f_I(S_{I-1}, X_I) \quad (4)$$

The task formulated in this way and the objective function obtained (4) show that the process of harvesting haylage in rolls can be implemented according to different technological options with a different set of technological operations, ranging from mowing herbs to packing rolls and placing them for storage. To carry out a structural analysis of the technology, we consider options for possible technological operations (Figure 2a), using the operator presentation form (Figure 2b).



T – herbage; C_{Pr} - cutting to bevel; C_P^{PL} - cutting in a swath with flattening; $C_P^{Кн}$ - air conditioning cutting; C_B– cutting to rolls; C_B^{PL}– cutting to rolls with swathing; $C_B^{Кн}$- cutting to rolls with air condition; P_B^{BL} - roll spreading; C_g^{BL} - raking; O_B^{BL}- roll wrapping; CD^{BL} - double rolls; PP^{PL} – selection and pressing into a roll; PT^{PL} – loading and transporting rolls from the field; $УX^{PL}$ – packaging and storage of rolls; $O_I^{Рл}$– individual winding; $O_g^{Рл}$ – coil winding group (ordinary); $У_p^{Pl}$ – laying of rolls in a polyethylene sleeve.

S_1^P and S_2^{BL} – grass conditions in swaths and felling after mowing-wilting; S_3^{PL} - state of grass mass in a roll after picking; S_4^{PL} – the state of grass mass in the roll at the stage of their transportation;S_5^{PL} – the state of grass mass in the roll at the stage of packing and storage.

Figure 2: Structural and technological analysis of the harvesting haylage in rolls

The quality of the haylage depends on the type of crop being harvested, the state of the grass stands and the agrotechnical terms of harvesting. For example, for cereals, it is recommended to start harvesting herbs in the earing phase, and for legumes - during the beginning of budding, in order to complete it at the beginning of flowering. Failure to comply with the agrotechnical terms of the beginning of the harvesting of haylage and the stretching of the time for harvesting herbs affect the quality of the feed.

The task of the first stage is to carry out the whole complex of works related to the organization of cutting operations of grass stand. In this case, an important element is the initial state of the grass stand, which is characterized by the crop being harvested, the phase of its development, the yield and moisture of the grass. At this stage, the duration of wilting of cut grass is a significant factor. Therefore, it is necessary that in a short time the mowed grass reaches the desired physiological dryness. This reduces the percentage of nutrient losses and increases the quality indicators of the resulting haylage in rolls. For this purpose, in various applied technologies of haymaking in rolls, mowing operations are performed in a swath without flattening (C_P),with ivy ($C_P^{\text{ПL}}$) or air conditioning ($C_P^{\text{Кн}}$), as well as cutting into a roll without flattening ($C_В$),with ivy ($C_В^{\text{ПL}}$)or air conditioning ($C_В^{\text{Кн}}$).

At the second stage, various technological operations are carried out to form a roll and to control the process of wilting of cut grass to achieve the necessary technological properties, based on agrotechnical requirements. So, with a high crop yield for accelerated wilting of the grass mass in the swaths and rolls, along with flattening, various operations are performed with rakes and tillers - spreading (agitating) herbs (P_B^{BL}), raking the grass (C_g^{BL}),wrapping (O_B^{BL})and,by necessary,doubling rolls (C_D^{BL}).

The mode of execution of a specific technological operation depends on the climatic conditions and the state of the grass mass.

The third stage, associated with the selection and pressing of dried grass from the rolls, begins with a moisture content of 55% so that when pressing the rolls, the moisture is in the range of 45 ... 55%. In addition, it is necessary that the packaged roll has the correct dimensions and geometric shape.

The fourth stage is related to the organization of the process of loading and transporting the haylage coils to the storage location. In addition to the well-known criteria, the assessment of the stage can be such an indicator as the total mileage of transport units during loading and transportation of rolls to the storage location [1, 6. 7]. In determining the necessary need for vehicles for the transport of coils, it is necessary that the duration from the formation to the package does not exceed the permissible limits in order to avoid overheating of the grass mass in the roll [1, 9, 10].

At the fifth stage, the rolls delivered to the storage site are packed in self-adhesive film and stored in a two-, three-layer stack on a flat open area or storage. It should be noted that, along with the individual winding of bales of haylage, ordinary packaging of rolls of haylage in plastic wrap is widely used, for example, group winding of rolls with plastic film or laying of rolls into a polymer sleeve. Due to the reduction of consumables and increased productivity of machines carrying out group winding, this type of roll packaging has great prospects [1].

The advantage of harvesting haylage in rolls is the ability to pack haylage in a special film without the addition of preservatives. Such a roll is rather well stored, has a constant weight and is convenient for dosing before feeding to animals, facilitates the work of workers.

Thus, the analysis of the technology of harvesting haylage in rolls allowed to gradually consider the structure of each stage and identify the main technological processes that can be implemented according to various technological schemes.

However, the conducted structural analysis will not be complete if we do not single out the indicators (factors) that influence the performance of each stage of the technology.

In general, the implementation of any variant of the technology for harvesting haylage in rolls begins with an assessment of the grass stand (Figure 3).

ISSN: 0975-8585

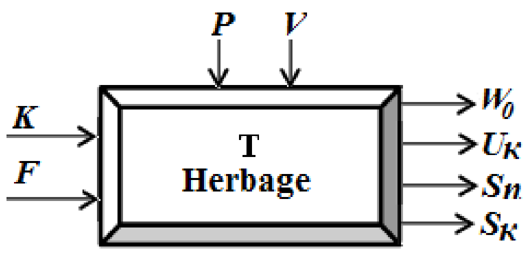


Figure 3: Herb condition

The quality of harvested haylage in a roll depends on the state of the grass stand at the initial moment and later on at all stages of fodder procurement. Input indicators (factors) that form the initial state of the grass stand are: soil conditions (***P***), weather conditions (***V***), cultivated crop (***K***) and the phase of its development (***F***). Output indicators characterizing the state of grass before mowing are: initial moisture (W_0), урожайностькультуры ($U_к$), as well as protein content (S_n) and fiber ($S_к$).

Mowing the grass and forming the rolls is an important step in the overall chain of the whole technology of feed preparation and determines the subsequent work with the canted mass. Therefore, the correct choice of the appropriate machine and units allows you to preserve the original quality of the grass as much as possible, speed up its drying and minimally injure. At the stage of timely mowing grass in the swath S_1^P or to rolls S_2^{BL} with possible scattering, raking, wrapping or twinning of the rolls, the characteristics of the state of the grass mass are determined by the duration of the wilting process. Scrolling to the desired condition contributes to the increase in the water-holding capacity of plants and is a preservative factor determining the physiological dryness of the resulting herbal environment. The output parameters characterizing this stage are the density and humidity of the grass mass, as well as the corresponding grass losses in the swath and rolls. So, for example, to accelerate the wilting of grasses, the use of grasses is used at the same time as mowing. When grass yields are up to 10 t / ha, the use of mower conditioners ensures uniform grass drying in rolls without agitating, and if the yield is higher than 10 t / ha, then rolls need to be turned or wrapped for uniform drying.

Stage of selection and pressing of dried grass from rolls S_3^{PL} provides for the displacement of air from the feed array and the formation of a roll with a density of more than 350 ... 400 kg / m^3. Such a mass density and the subsequent hermetic packing of the rolls into a film ensure the safety of the original grass quality throughout the year. In addition to density and humidity, at this stage, the relevant parameters are the mass, width and diameter of the roll [11].

After pressing follows the stage of loading and transporting the rolls from the field S_4^{PL}. Timely transportation of the rolls to the storage location prevents overheating of the packaged grass mass and prevents the appearance of undesirable biochemical and microbiological processes [1, 9, 10]. In addition, it is important that the loading and unloading of the rolls takes place neatly, without disturbing the geometrical shape and size.

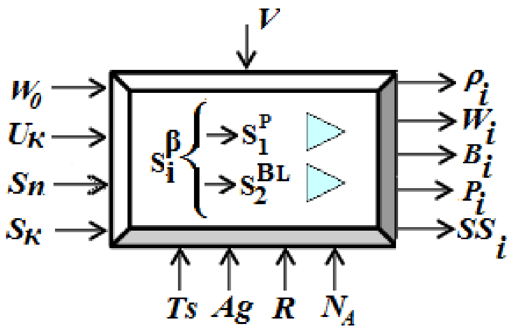
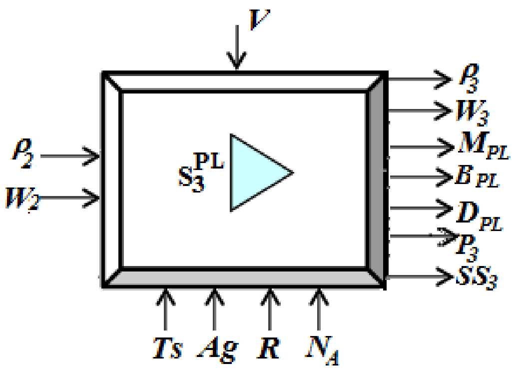
Storage rolls S_5^{PL} is a crucial stage. Although the packaged roll does not require special conditions, it is advisable to store it in a vertical position in order to better protect the end surfaces of the roll. The main task of the stage is to preserve the energy value and nutrients of the haylage in the package.

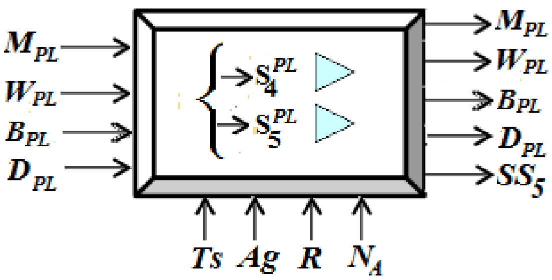
Last two stages S_4^{PL} and S_5^{PL} basically the same input and output indicators have, namely, the parameters of the formed haylage roll: mass, width and diameter.

Summing up, we note that efficient and high-quality harvesting of haylage in rolls can be organized only with the right choice of technological operations and a rational selection of the composition of machines and units at each stage. Issues of adaptation to specific production conditions are determined by many factors, first of all, the crop being harvested, the type of forage harvesters available, the volumes of billets, the distances of haylage transport, climatic conditions, etc.

To assess the components of the objective function (4) and determine the significance (share) of each operation at the stages of the technological process, it is advisable to determine the costs attributable to the technological operation both at each stage and in the whole technology.

Table 1: Input to output indicators for harvesting stages in rolls

STAGES	MODEL: INPUT / OUTPUT	INPUT INDICATORS	OUTPUT INDICATORS
Cutting grass and roll formation		***W_0*** - humidity, ***U_K*** - crop yield; ***S_n*** - protein content; ***S_K*** - fiber content; ***Ts***- cutting technology; ***Ag*** - brands of machines and units for mowing-grass wilting; ***R*** - modes of operation of units; ***N_A*** - number of units;	***ρ_i*** - grass density: in the swath (***ρ_1***), in rolls (***ρ_2***); ***W_i***- grass moisture: in the swath (***W_1***), in rolls (***W_2***); ***B_i*** - roll width (***B_2***) ; ***P_i***- feed loss in the field; ***SS_i*** – operating time /operations;
Roll selection and pressing		***W_2***- moisture content of the grass mass in the roll; ***ρ_i***- density of grass mass in the roll; ***B_2***- roll width; ***Ts***- selection and pressing technology; ***Ag*** - brands of machines and units on the selection-pressing; ***R*** - modes of operation of units; ***N_A*** - the number of units in the selection-pressing;	***ρ_i***- density of hay mass in a roll; ***W_3*** - roll moisture; ***M_{PL}*** - roll weight; ***B_{PL}*** - roll width; ***D_{PL}*** - roll diameter ***P_3*** - roll loss; ***SS_3***– operating time on selection-pressing;

Loading, transporting and packing rolls		***M****PL*** - roll weight; ***W****PL***- roll moisture; ***B****PL*** - roll width; ***D****PL*** - roll diameter ***Ts***- loading and transport scheme; ***Ag*** - brands of machines and units for loading, transporting and packing rolls; ***R*** - operation modes of units; ***N****A*** - number of units for loading, transporting and packing rolls;	***M****PL*** - roll weight; ***W****PL***- roll moisture; ***B****PL*** - roll width; ***D****PL*** - roll diameter ***SS****5*** – operating time on the transportation and packaging of haylage rolls.

With this in mind, we can propose a model that includes the objective function, systems of constraints, the scope of work, and agrotechnical deadlines for their implementation, as well as conditions for non-negativity of variables.

Objective function:

$$Z(X) = \sum_{I=1}^{k} \sum_{J=1}^{Nai} C_{IJ} \cdot X_{IJ} \rightarrow min \qquad (5)$$

With regard to the technology under consideration (with the number of operations *k* = 5), we have:

$$Z(X) = \sum_{I=1}^{5} \sum_{J=1}^{Nai} C_{IJ} \cdot X_{IJ} \rightarrow min \qquad (6)$$

or in expanded form:

$$Z(X) = \sum_{J=1}^{Na1} C_{1J} \cdot X_{1J} + \sum_{J=1}^{Na2} C_{2J} \cdot X_{2J} + \sum_{J=1}^{Na3} C_{3J} \cdot X_{3J} + \sum_{J=1}^{Na4} C_{4J} \cdot X_{4J} + \sum_{J=1}^{Na5} C_{5J} \cdot X_{5J} \rightarrow min \qquad (7)$$

I = 1,2,…,5 - number of process steps (operations); *J= 1,2,…,*N_{ai}– the number of units employed in the implementation of technological operations on the *I-th* stage; C_{IJ}– costs of the *I-th* technological operation by the *J-m* aggregate, rubles / ha; X_{IJ} – the number of *j-th* units at the *I –th* stage.

The system of restrictions imposed on the model:

$$\sum_{I=1}^{k} \sum_{J=1}^{Nai} a_{1J} \cdot X_{1J} \cdot T_{см} \geq b_{IJ} \qquad (8)$$

a_{IJ} –performance of the *J-th* unit at the *I-th* operation, ha / h;$T_{см}$ - shift duration, h; b_{IJ} –required shift production of allN_{ai}units on the I-th operation, ha. Here $b_{IJ} = \frac{V_{IJ}}{t_{IJ}}$, whereare V_{IJ} –total amount of work on each technological operation, ha; t_{IJ} –agrotechnical deadlines for each operation, days.

The condition of nonnegativity of variables: $X_{IJ} \geq 0.$

CONCLUSION

On the basis of the analysis performed, it was shown that the optimization of the technological process of harvesting haylage in rolls packed in film is a multi-stage task, the solution of which requires:

- to determine the significance of the operations performed, both at individual stages of the technological process, and throughout the technology;
- to optimize the structure of the technological process of harvesting haylage in rolls;
- to establish the main indicators (factors) that affect the process;
- estimate the cost of hay production and feed loss;
- to justify the qualitative and quantitative composition of the park forage harvesting and transport vehicles.

Summing up, we note that the most expensive haylage is not so much the one that was produced with high labor costs, but the one that was obtained with high losses of value and nutritional value. Therefore, it is the gradual optimization of technology, from the moment of cutting the grass to laying the rolls for storage in compliance with all agrotechnical requirements, which is the basis for reducing the component costs of high-quality haylage production in rolls.

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