THE PROSPECTIVE PROCESSING LINE FOR THE PREPARATION OF COMPLETE FEED FOR LONG-TERM STORAGE


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ABSTRACT

An important condition for increasing the livestock production efficiency and production of livestock products and reducing their cost is full-value feeding, the provision to the farm animals complete multicomponent feed mixtures. Such mixtures are much better digested by the livestock which contributes to a 10-14% increase in their production efficiency. Numerous studies have revealed that it is most practical to feed large cattle with full-value feed mixtures prepared immediately before dispensing, which is not always possible in the production conditions. This especially applies to regions where the winter is a so-called housing season for the livestock. It is extremely difficult to provide the farm animals with a full-fledged diet during that period. To avoid feed-related problems, it is necessary to create a preliminary stock of fodder with sufficiently preserved nutrients.

In the Amur Region, multicomponent silage, haylage, and different mixed feeds are used for the full-value feeding of the livestock. At the same time, the delivery of silage and haylage in low-temperature conditions is both labor-intensive and energy-intensive, since the air temperature in this period is about -25...35°C. During the transportation of these kinds of fodder, high losses are observed due to their thawing before feeding. In accordance with the above, it can be concluded that in order to provide animals with full-value feed, it is necessary to use technologies that allow maximum preservation of nutritional properties of feed and ensure its long-term storage. One of the methods that contribute to the solution of this problem is adaptive drying of feed, which results in the preservation of the maximum amount of nutrients in their contents and the reduction in labor input required to transport the mixtures to the place of feeding during the cold winter period.

The aim of the research is to increase the efficiency of preparation of livestock complete feed by developing the technology and means of mechanization for long-term storage.

To solve this aim the following research tasks were defined:

- to analyze advanced technologies and technical means for the production of feed for large cattle by reference to specific features of the food base and the natural production conditions of the Amur Region;
- to justify prospective lines of development of existing ones and develop the new technical means for the preparation of feed and agricultural crops for long-term storage.

The article in hand describes the prospective processing line for the proper preparation of the full-value feed for long-term storage which ensures the preservation of nutrients.

KEYWORDS

feed, ration, processing line, farm livestock, drying, feeding, infrared radiation.

1. INTRODUCTION

Various technological methods for the preparation of full-value feed for long-term storage have been studied by a large number of scientists around the world [1, 2, 3, 5]. Feed production implements a wide range of methods and designs for drying units. The design of this dryer should ensure uniform heating and high-quality drying of the product with appropriate control of its temperature and humidity. One more major requirement is sufficiently high performance. If these parameters are met, an efficient drying unit should also have optimal heat rates, decreased metal consumption and incur low energy and material costs. [6, 7, 8].

The currently used drying methods (Figure 1) are distinguished only by means of supplying heat. [9, 10, 11].

The most common is the convective method of supplying a thermal agent. However, in recent times, due to a significant increase in energy prices, special methods of drying (infrared and sublimation) became more widespread. In small farms, the conductive technology is an indispensable method of drying [12].

The infrared heating sees heavy use for technological purposes in a wide variety of industries.
1. MATERIAL AND METHODS

The processing procedure for preparing feed for long-term storage can be displayed as follows (Figure 2-3) [13, 14].

Depending on the season and the location of the processing complex, the grain material is transported to the sorting site by dump trucks. The grain from the vehicles or the grain-fodder storehouse is transferred to the feed graining material is transported to the sorting site by dump trucks. The grain with round holes may vary from 2.0 x 2.5 to 2.0 x 2.8, and those of the oblong holes — from 1.7 x 2.0 to 2.0 x 2.4 [15, 16].

The fine sorted grain is dumped onto the delivery screw conveyor and then transferred to the measuring hopper of the conditioning unit. The speed of the elevator varies depending on the initial moisture content of the grain material and the rotation rate of the bruising rollers. The conditioning is carried out to change the structure of the grain and reduce its initial moisture content, which in turn provides for the further reduction in the duration of the drying process.

After this operation, the fine grain is fed to the storage hopper of the thermal radiation drying unit with a convective air exchange via the screw conveyor of the elevator. The speed of the elevator screw is set within the limits necessary for the continuous operation of the drying plant. Then the dried grain from the drying unit is fed to the transport devices, which bring it to measuring hoppers.

Depending on the composition of the feed ration, the necessary protein and vitamin supplements, mineral additives, liquid components and other types of nutrients are added to the grain in the hoppers. The feed ration is selected and calculated according to the type and physiological maturity of the farm livestock.

The necessary amount of the ration components is supplied to the mixing device, where all fractions of the feed are uniformly stirred and blended. The resulting mixture is then transported to feed dispensers at the livestock feeding areas. If the feed material is meant for long-term storage, it is packaged and delivered to the storehouse [8, 13, 14].

For the coarse grain, the conditioning procedure is bypassed. It is fed directly to the thermal radiation drying unit. This separation is carried out in order to minimize energy costs and loss of nutrient properties of the initial material.

An example of an optimal combination of feed preparation technology for long-term storage and preservation of the nutritional properties of the grain material due to its drying is an infrared radiation drying unit. It is shown in Figure 4.

This drying unit (Figure 4) consists of 4 infrared heating elements (2), a movable screen plate (3), an air blower (1), a box frame (4) and a mesh air transfer duct (5) [14, 16].

During the research, the moisture content of the grain material under study was within 15...35%.

The prominent feature of the proposed drying unit is the combination of two methods of heat supply — convection and thermal radiation. It should also be noted that during heating the surface of the grain material is simultaneously cooled by the air flow created by the air blower. As a result, the moisture begins to move from the feed core to the surface, which allows for a significant increase in the drying speed [8,14, 17, 18].

The testing of the drying unit was carried out in accordance with the recommended general and particular methods using specialized programs for mathematical calculation, experimental simulation and regression analysis methods [3,4]. The following parameters were measured: the initial and the final moisture content of the grain material, the temperature of the drying agent and the grain material surface, the capacity and the power of the unit, the air flow rate and the air temperature.

The empirical and experimental studies of the post-harvest drying of grain...
material using oats as an example carried out at the facilities of the Federal budget state institution of higher professional education “Far Eastern State Agrarian University” (Russian Federation, Amur Region, Blagoveshchensk) and a large primary agroindustry center — agricultural enterprise "ORTA" confirmed the validity and correctness of the proposed drying method, as well as the need for its application in the farm livestock feeding technology.

Several studies provide the theoretical justification for the use of infrared radiation in the preparation of grain-based feed materials for long-term storage [8, 12, 14]. As a result of experimental studies, two-dimensional (Figure 5 and 6) and three-dimensional (Figures 7 and 8) graphical models of interacting dependences of the main parameters were obtained.

For this, the original regression equations were reduced to equations with one factor, and the remaining interacting values were left at constant levels. The following parameters were set as variation factors: \( x_1 \) – initial moisture content of the grain material, \( W_1 \), %; \( x_2 \) – air flow rate \( V \), m/min; \( x_3 \) – duration of drying \( \tau \), min. The following parameters were set as final values: \( Y_1 \) – final moisture content of the grain feed \( W \), %, and \( Y_2 \) – specific power of the unit \( N_{ud} \), kW·h/kg.

The experimental studies were carried out for two cases: when the thermal radiation was combined with convection and without such a combination. The data obtained during the trials are represented in Figures 6 and 7.

The bivariate analytical dependencies were built using Microsoft Excel 2010. To visualize the influence of interacting factors on the drying process of the grain-based feed material, we constructed the relevant response surfaces and the cross-sections of the response surface using MathCAD 2000 Professional.

The analysis of the relationships presented in Figures 7 and 8 proves that the drying unit combining thermal radiation with convection is a more optimal solution, as with the equal initial moisture content of the grain material of 31.4% and in the same time period, the final moisture content in the first case decreased to 11.8% and in the second case — to 12.6%. In addition, the difference in the average temperatures of the surface in those two cases was 9.95°C.

Figure 8: The response surface (a) and the cross-section of the response surface (b) of the final parameter $Y_2$ – the specific power of the unit ($N_\text{уд}$) taking into account the duration of drying ($\tau=160$ min) with the following parameters stabilized: the air flow rate ($V$) and the initial moisture content of the grain material ($W$).

Based on the analysis of the response surface graph (Figure 8), it can be concluded that with the stabilization of the air flow rate ($V$), the initial moisture content of the grain material ($W$) and constant values of the duration of drying ($\tau=160$ min), the specific power ($N_\text{уд}$) increases linearly.

4. DISCUSSION

The conducted technical and energy evaluation of the thermal radiation drying unit combined with a convective air exchange system in comparison with the convective method of heat supply during post-harvest drying of grain material showed that the duration of the drying process decreased by 28.9%, the power consumption of the post-harvest drying decreased by 52.4%, and the energy consumption per 1 kg of evaporated moisture decreased by 9.0% [5, 16, 19].

The reliability of the obtained data is confirmed by the convergence of the theoretical justifications and experimental parameters determined in the real operating conditions of the infrared heating device. The comparison of these results with the data previously obtained by the researchers proves the effectiveness of the proposed solution, which has not been considered by the applied science in its entirety before now [3,17,18,20-22].

To confirm the results of the study, we compared several drying units, similar to the proposed one in main parameters: the productivity of the unit as per evaporated moisture, the type of the grain material suitable for drying and the heating temperature of the material surface. We selected the following Russian-manufactured grain dryers: BC–10M, ACT–3, Agrohit—500.

The comparative assessment was carried out according to three main indicators: labor outlays, direct energy costs and energy costs per 1 kg of evaporated moisture.

Figure 9: Labor outlays, MJ/kg

Figure 10: – Direct energy costs, MJ/kg

Figure 11: Energy costs per 1 kg of evaporated moisture, kW·h/kg

The conducted comparative assessment shows that the proposed infrared drying unit displays minimum values for all the above energy indicators.

5. CONCLUSION

The provided materials allowed us to arrive at a definitive conclusion that the use of the thermal radiation drying unit with the combined convective air exchange for the post-harvesting processing of the grain material provides for a significant decrease in the duration of the drying process and results in lowering of costs per product unit. Consequently, the proposed drying unit is a highly efficient design implementing original ideas and a construction novelty intended for post-harvesting drying of the grain materials. The materials of the research were used for the creation of a feed reserve at the agricultural enterprise "ORTA" and several other farms of the Amur Region. The implementation of the obtained results in the production allowed to improve the time of the feed preparation, to decrease the energy costs per product unit and make a significant profit in the agricultural sector of the region.
REFERENCES


