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THE PRODUCTION OF BIOLOGICALLY ACTIVE FEED ADDITIVES BASED ON GRAIN-CONIFEROUS MIXTURES

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Abstract

The article in hand describes the process of producing pelleted biologically active supplements based on grain-coniferous mixtures. It also describes the design of a pelleting press and lists the results of the testing. The implementation of the proposed pelleting machine will allow solving the main problem of compacting such mixtures. It gives the opportunity to produce pellets without active drying of the raw material. The grinding of the grain-coniferous mixture takes place in the working zone of the screw conveyor of the press. In the Amur Region, despite the sufficient logging of coniferous trees, the bulk of resulting needles and twigs is not used for further processing. The fir needles and pine needles contain an ample quantity of vitamins and minerals. They are also available during the winter period, characterized by lack of other green fodder. Consequently, the coniferous needles and branches can serve as an excellent means of replenishing deficiencies in rations with biologically active substances. It is quite difficult to produce pellets with high coniferous content using matrix-molding presses without grinding these materials and adding binding agents. Therefore, the main task of the conducted studies is to determine the possibility of obtaining pelleted biologically active supplements based on grain-coniferous mixtures. It has been experimentally established that the application of the pelleting press of the proposed design enables the production of such pellets according to with the set zootechnical requirements.

Key words: Coniferous needles, coniferous twigs, pellets, compaction, vitamines, hardness, nutritional properties, press machine

Introduction

An important condition for increasing the livestock production efficiency and production of livestock products and reducing their cost is full-value feeding. When compiling an optimal feed ration with a high biological value which would fully satisfy the nutritional needs of the livestock it is necessary to take into account their vitamin and mineral requirements. However, the livestock rations are not sufficiently supplied with vitamins. A possible solution to this problem is the use of vitamin products or premixes. Serious disadvantages of the majority of synthetic feed additives are their complexity and high cost. Natural sources play the main role in the provision of livestock with vitamins. They are the green fodder, hay, silage, haylage, grass meal and others (Andreeva, 2011; Konovalenko, 2011; Yakimenko *et al.*, 2012). Vitamins are the most important metabolism regulators, which normalize the metabolism, promote the assimilation of nutrient elements of the feed and boost immunity. Scientists are constantly engaged in the search, development, and approbation of new, cheaper, environmentally friendly and safe feed additives based on forest biomass (Axe, 1995; Meijer, 2003; Ernst *et al.*, 2006; Okhrimenko *et al.*, 2011; 2011b; Kozina and Tabakov, 2013, Bekezhanov *et al.*, 2018. One of the important sources of natural vitamins and minerals is the technical greenery of coniferous species. Thanks to its high vitamin content and availability in the winter period, when other green fodder is absent, the conifers can help to replenish dietary deficiencies with biologically active substances. The phytoncides present in the needles and the bark of the conifers can destroy various microbes: streptococci, staphylococci, diphtheria, and pertussis. They can serve as a means of prevention and treatment of a number of animal diseases. One kg of green coniferous needles contains the following substances: pine - 60-130 mg of carotene, 3,000 mg of vitamin C, 20 mg of

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vitamin K, 5 mg of vitamin B2; fir -50-120 mg of carotene; 2,500 mg of vitamin C, 12 mg of vitamin K, 5 mg of vitamin B2. The use of pine and fir needles as a vitamin supplement in the amount of 0.1-0.2 kg per head per day increases the daily weight gain in pigs by 13- 5% compared to the weight gain in farm animals that did not receive the additional feed (Kiriakidis *et al.*, 1993; Veselevskiy, 1998). The world has developed many effective methods and techniques for processing green mass. The needles are harvested in autumn and winter because at this time the content of resinous substances which are harmful to the body in the technical greenery is minimal. During this period, the needles are rich in valuable, biologically active elements, which is why harvesting coniferous foliage and feeding it to the livestock fresh is especially beneficial (in October-March). The ground coniferous green can be mixed with the root crops, silage, beet pulp, concentrated feedstuffs and other fodder (Behnke, 2005; Dooley *et al.*, 2011; Antonova *et al.*, 2014).

Many domestic and foreign researchers consider pelleting one of the most effective methods of processing the foliage of firs and pines. It allows preserving nutrients and vitamins, moreover, the pellets are more conveniently transported and more easily distributed by mechanical means (Tadmor and Klein, 1970; Vermeulen *et al.*, 1971; Viriyayuthakorn and Kassahun, 1984; Guy and Horne, 1988).

When producing pellets from forest raw materials, a slight decrease in fiber, protein, and carotene content is observed. Nevertheless, no significant changes in components occur (Tomchuk and Tomchuk, 1973). The pellets must comply with zootechnical requirements, the most important of which are physical and mechanical properties, such as hardness and the time of conversion of monoliths into a homogeneous mass. The conducted analysis of the domestic and foreign sources shows that the known methods of pelleting do not allow the production of pellets of specified hardness from needles with natural moisture content without preliminary grinding and the addition of binding substances (Mount III *et al.*, 1982; Flachowsky, 1986; Van Lengerich *et al.*, 1989; Meijer, 2003). The aim of the study is to search for new technical solutions allowing to obtain pressed feed additives from coniferous foliage compliant with zootechnical requirements.

Material and methods

The optimal technological solution for the production of pelleted biologically active additives is presented in the Russian Federation Patent RU 2275827. The basic diagram of the pelleting press is represented in fig. 1.

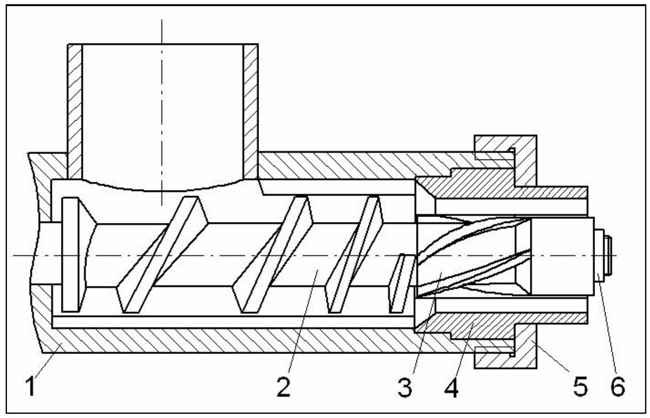

Fig.1: Basic diagram of the pelleting press: 1- body; 2- screw conveyor; 3-multiple-thread part; 4- drawing die; 5 & 6- nut

When studying the pressing process, we used coniferous needles, twigs and grain material.

The proposed pelleting press allows producing pellets without the active drying of the source raw material; the foliage is ground in the working zone of the screw conveyor of the machine. The work process is as follows: the prepared feed mixture from the hopper is fed into the loading neck, picked up by the screw conveyor and then is simultaneously compacted and ground during its transport. After that, the mixture enters the drawing die and moves inside it due to the pressure of the screw and the driving force generated by the multiple-thread part. It is squeezed and rubbed further. The formation of monoliths begins in the drawing die. The final stage of this process takes place in the plain section of the bushing. After that, the pellets exit from the grooves of the drawing die. To limit the length of the pellets, a cutter is installed on the screw shaft after the bushing (Yakimenko, 2013; Petrochenko *et al.*, 2014; 2016).

The testing of the pelleting process was carried out in accordance with the recommended general and particular methods using specialized programs for mathematical calculation, experimental simulation and regression analysis methods. The following parameters were measured: the friability of the pellets, the press performance, soaking capacity of the pellets, the power supplied for the pressing process, the initial and the final moisture content of the source raw material. To measure the above parameters, specialized laboratory instruments and apparatus were used. The data obtained during the experiment was processed via known methods of mathematical statistics with the use of information technologies.

Results

The empirical and experimental studies of the mixture pressing process carried out at the Far Eastern State

Agrarian University (Blagoveschensk, Amur Region, Russian Federation) and the subsidiary farming unit of OOO "DOM" confirmed the validity of the proposed method for producing biologically active feed additives based on grain-coniferous mixtures. The research also justified the possibility and the need for its application in the farm livestock feeding technology. Studies (Yakimenko and Petrochenko, 2006; Petrochenko *et al.*, 2008; Docenko *et al.*, 2017) provide theoretical foundations for the use of a screw pelleting press for the production of feedstuff of different types. The research objectives included determination of the optimal operating conditions and design parameters of the press machine. The conducted experimental studies allowed to establish that the pressing process is significantly influenced by the rotation speed of the screw (fig. 2), the moisture content of the base mixture (fig. 3), and the length of the die orifice (fig. 4).

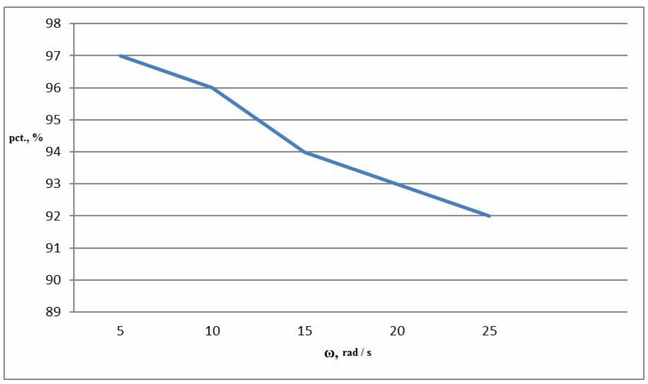

Fig. 2. The graphical dependency between the rotation speed of the screw and the hardness of pellets.

As can be seen in the figure, with the increase in the rotation speed of the screw the hardness of the monoliths decreases. This is explained by the decrease in the relaxation time due to the increase in the mass overflow rate in the forming channel of the die.

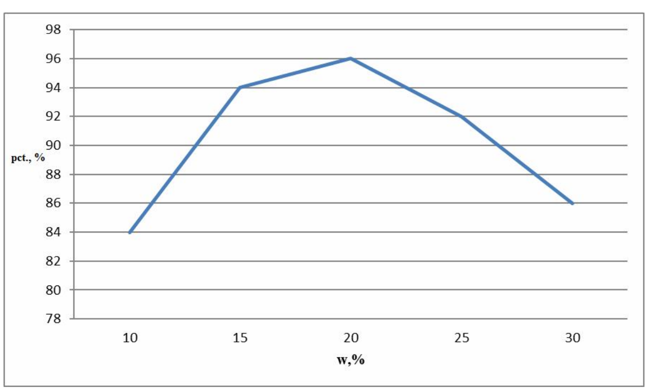

Fig.3: The graphical dependency between the moisture content of the base components and the hardness of pellets.

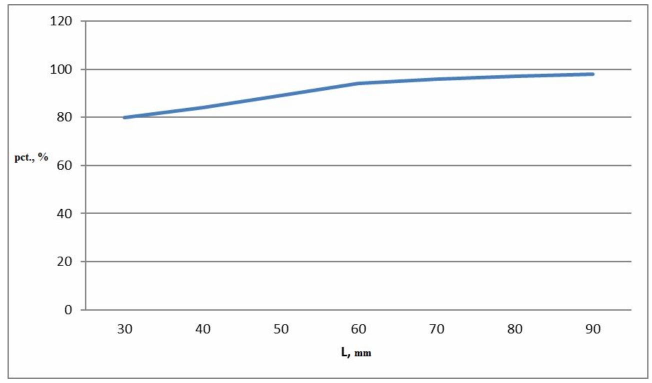

Fig. 4: The graphical dependency between the length of the die orifices and the hardness of pellets.

The hardness of pellets depends on the redistribution of moisture between the components of the mixture and the gluten conversion degree, which directly depends on humidity content. While the excess moisture increases the elasticity of the mass, the water, in this case, prevents proper compaction. If the moisture content of the mixture is too low, the friction between the mass and the internal surface of the press increases, which is followed by the increase in the energy consumption and the deterioration of conditions for redistribution of binding agents in the mixture. In its turn, it negatively affects the uniformity of the components in the pellets.

The length of the forming channels of the drawing die has the greatest effect on these parameters with a significant nonlinearity, which is explained by the nonlinear increase in the frictional forces acting on the feed material while moving along the length of the channels. This

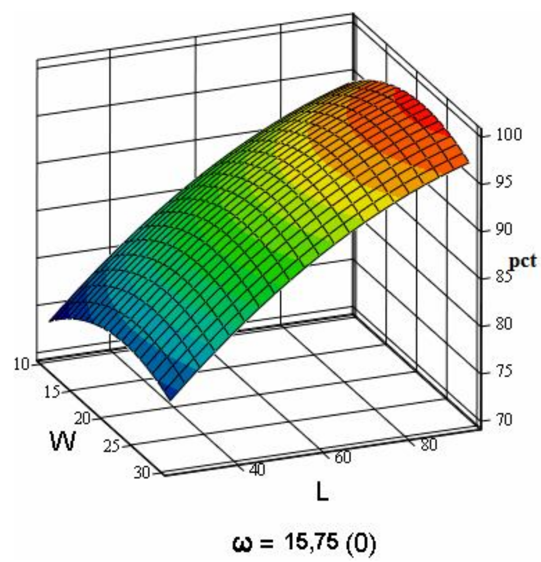

Fig. 5: The influence of the moisture content of the base components of the mixture and the lengths of the channels of the die on the hardness of pellets at ω=15.75 rad/s.

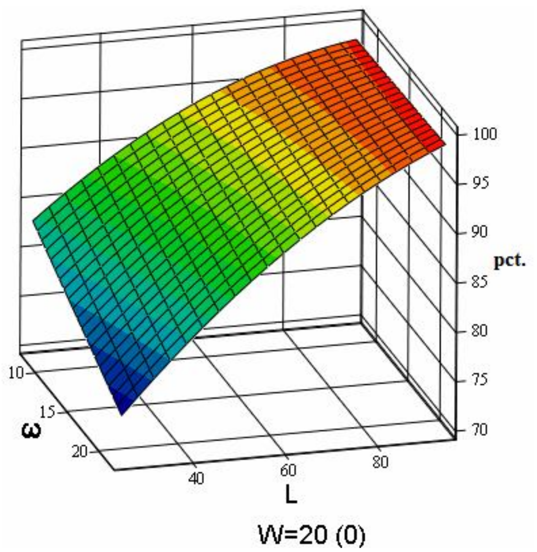

Fig. 6: The influence of the moisture content on the hardness of the pellets at W=20%

confirms the empirical conclusions that the increase in the frictional force of the feed material in the forming channels of the die occurs according to a function similar to the progression, depending on the length of the channel.

The specific energy consumption of the pressing process (Y1, W·h/kg) and the hardness of the resulting pellets (Y2,%), the screw rotation rate (ω, rad/s), the moisture content (W, %), and the length of the channels (L, mm) were chosen as output parameters.

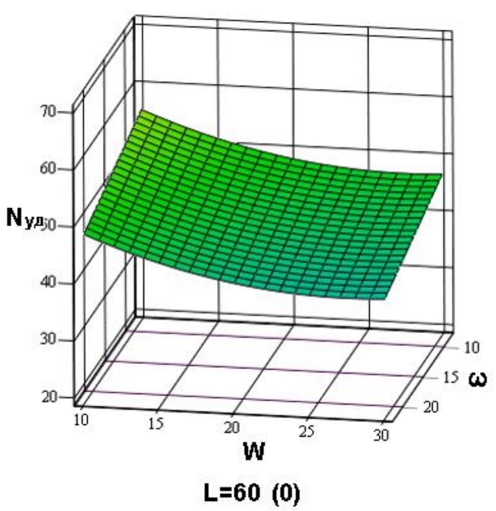

Fig.7: The influence of the rotation rate of the pelleting press screw and the moisture content of the mixture on the specific power of pressing.

During the generation of response surfaces in Mathcad 2000 Professional, only two factors were variable, while the third one was stable.

The analysis of the presented dependences shows that the minimum value of the specific power (25.83 W-h/kg) is reached when L=23 mm, W=27.4%, ω=22.13 rad/s. In this case, the hardness of pellets amounts to 81%. The maximum hardness (98%) is achieved at L=90 mm, W=23.6%, ω=9.38 rad/s; with the specific power of 65.6 W-h/kg. The authors have conducted a multifactorial experiment to establish the following acceptable values of the factors under study: the length of the forming channels of the die L=64 mm; the moisture content of the base mixture W=24%; the rotation rate of the screw ω=22 rad/s.

Discussion

The technical and energy evaluation of the use of the screw pelletizer showed that the hardness of the resulting pelleted biologically active supplements based on the grain-coniferous mixtures meets the main requirements. The acceptable values of the output parameters of the pressing process are as follows: the specific power Nyπ=40 W-h/kg; the hardness Пр=90%.

The reliability of the obtained data is confirmed by the convergence of the theoretical justifications and experimental parameters determined in the real operating conditions. The comparison of these results with the data previously obtained by the researchers [6, 19, 24] proves the effectiveness of the proposed solution, which has not been considered by the applied science in its entirety before now.

The comparative assessment was carried out according to several main parameters: the performance of the units, the equipment driving power, the specific power of pressing and mass (fig. 8).

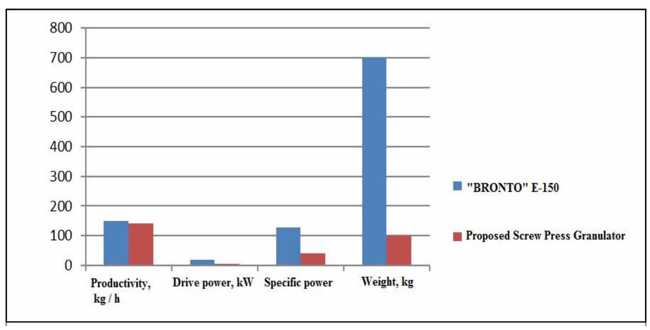

Fig. 8: Technical parameters of the equipment.

As compared to the stock configuration of the BRONTO E-150 press machine, the proposed screw pelleting press for the production of pelleted biologically active supplements from grain-coniferous mixtures displays lower values for all the above-listed indicators.

Conclusion

Based on the above, we conclude that the proposed screw pelleting press can be used for producing pelleted biologically active feed additives based on grain-coniferous mixtures. The resulting pellets meet the standard zootechnical requirements; the design of the press allows to obtain pellets without preliminary grinding of the needles and their drying thanks to the redistribution of moisture between dry and wet components of the mixture with the lowest energy consumption. The mixing ratio of the grain part which can consist of wheat, barley, oats and corn, and the coniferous part, consisting of needles and twigs harvested in winter and having the initial moisture content of 45-55%, shall be selected on the basis of their gluten and moisture content. The amount of the coniferous component can reach 30-33% when used in combination with wheat and corn, and 26-30% in a mixture with barley and oats. In order to produce hard pellets compliant with the zootechnical requirements, it is important to determine the optimum length of the forming channels of the die. For pellets of 8 mm in diameter the length of the channels shall be 64 mm, for 3-4 mm pellets a 52 mm channel is optimal. The pellets of more than 12 mm in diameter are produced at the lower limit of hardness. This indicates the necessity to introduce additional binding agents into the composition of biologically active additives. Such agents can be hay, soy straw, dried vegetables, etc. The influence of these components and their ratio in the composition of the finished product, as well as the use of fish and meat-and-bone meal, will be topics for further research. Consequently, the proposed device is a highly efficient design implementing original ideas and a construction novelty intended for producing feed pellets from grain-coniferous mixtures. The results of the studies were implemented and are successfully used in feed production technology by the subsidiary farming unit of OOO "DOM" and several other agricultural enterprises of the Amur Region.

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