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RESEARCH ARTICLE

Conditions for Producing High-Quality Dry Pelleted Feed from a Mixture of Protein Paste and Ground Feed Grain

K.S. Kuralimova[1], Yu.V. Marchenko[1], V.S. Ligacheva[1], D.V. Moskovskaya[1], A.S. Glazunov[1], S.I. Popov[1]*

[1]Don State Technical University, Rostov-on-Don, Russian Federation

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***Corresponding Author:**
spopov1957@yandex.ru

ABSTRACT

The wet fractionation technology for the green biomass of cultivated grasses and feed-grain processing waste, developed at the Research Laboratory of Green Feed Concentrates of Don State Technical University, makes it possible to obtain a paste-like protein concentrate – a nutritionally complete substitute for animal-derived proteins. To produce dry pelleted feed additives, protein paste is mixed with ground feed grain, followed by pelleting and drying. The aim of this study was to investigate the feasibility of producing pellets from this mixture by screw pressing and to determine the quality indicators of the finished product – friability and caking – as functions of mixture moisture content and component mass ratio. The experiments were conducted using a laboratory granulator with a screw working element. Protein paste with a moisture content of 85.6%, obtained by chemical coagulation of alfalfa green juice, and ground feed grain with a moisture content of 11.2% were used as the raw materials. Mixtures with moisture contents ranging from 30.5% to 58.1% and protein paste-to-ground feed grain mass ratios ranging from 1:0.5 to 1:3 were studied. It was established that the screw granulator makes it possible to produce pellets of satisfactory quality. The following mixture moisture-content limits were established: to obtain non-caking pellets with a caking index of no more than 7%, the moisture content should not exceed 40%; pellet friability below 10% is achieved at a mixture moisture content above 30%.. The resulting regression relationships can be used in the design of production lines and the selection of pelleting conditions for feed mixtures of a specified composition.

INTRODUCTION

The production of dry pelleted feed is one of the most effective methods of preparing feed additives for long-term storage and transportation. Pelleting not only reduces nutrient losses and improves the sanitary and hygienic characteristics of feed but also ensures the uniform distribution of components in livestock and poultry diets (Dolgov and Proydak, 1990; Dolgov and Popov, 1999). Pelleting feed mixtures based on nontraditional protein sources, including protein paste obtained by wet fractionation of the green biomass of cultivated grasses, is of particular relevance.

The Research Laboratory of Green Feed Concentrates of Don State Technical University has developed a technology for producing a paste-like protein concentrate from the leaf-and-stem biomass of alfalfa and feed-grain processing waste (Maltseva et al., 2022). When mixed with ground feed grain in specified proportions and subsequently pelleted and dried, this concentrate forms a nutritionally complete feed additive capable of replacing animal-derived proteins in livestock and poultry diets. Feeding trials have confirmed the high effectiveness of this additive (Popov, 1996).

However, the industrial implementation of the technology for pelleting mixtures of protein paste and ground feed grain is constrained by the lack of scientifically sound recommendations for selecting operating parameters that ensure the required quality of the finished product. Pellet quality is determined by a set of indicators, among which friability and caking are essential for evaluating product strength and integrity during transportation and distribution (Proydak et al., 1986). High friability leads to the formation of fines and feed losses, while increased caking impedes the discharge of pellets from the granulator and their subsequent dosing.

Previous exploratory studies (Proydak et al., 1986) determined the friability and caking indices of pellets produced from a mixture of ground feed grain and protein paste obtained by thermal coagulation of alfalfa green juice. However, the available literature contains no data on the behavior of mixtures containing paste obtained by chemical coagulation (Rudoy et al., 2021; Rudoy, 2023), although the coagulation method is known to significantly affect the structural and mechanical properties of the paste and, consequently, the pellet formation process.

The aim of this study was to investigate the feasibility of producing pellets from a mixture of protein paste obtained by chemical coagulation and ground feed grain using a screw granulator, as well as to establish quantitative relationships between pellet friability and caking, mixture moisture content, and component mass ratio. These relationships are required to determine appropriate pelleting conditions when designing production lines for dry pelleted feed additives.

MATERIALS AND METHODS

The experiments used green protein paste with a moisture content of 85.6%, obtained by chemical coagulation of alfalfa green juice at the budding to early flowering stage. A concentrate of low-molecular-weight acids was used as the coagulant. The coagulate was separated into protein paste and brown juice using a flotation separator.

Ground feed grain with a moisture content of 11.2% was produced by grinding barley grain in a KDU hammer mill followed by sieving in a Burat separator. The experiments were conducted using mixtures of green protein paste and ground feed grain with moisture contents ranging from 30.5% to 58.1% at a temperature of T = 293 K (20 °C). The moisture contents of the paste, ground feed grain, and their mixture were determined experimentally using a standard method.

To estimate the amount of ground feed grain required to obtain the specified mixture moisture content, calculations were performed using the following equation:

$$M_{д} = M_{п} \frac{B_{п} - B_{к}}{B_{к} - B_{д}},$$

where Md is the mass of added ground feed grain, kg; Mp is the mass of paste, kg; Vp is the paste moisture content, %; Vk is the mixture moisture content, %; and Vd is the ground feed grain moisture content, %.

The paste, ground feed grain, and their mixture were weighed using floor-mounted lever scales.

The mixture moisture content Vk, depending on the amount of ground feed grain added per 1 kg of paste, was determined using the following equation:

$$B_{к} = \frac{M_{п}B_{п} + M_{д}B_{д}}{M_{п} + M_{д}}$$

The relationships between mixture moisture content, protein paste moisture content, and the amount of ground feed grain added per 1 kg of paste are presented in Figure 1.

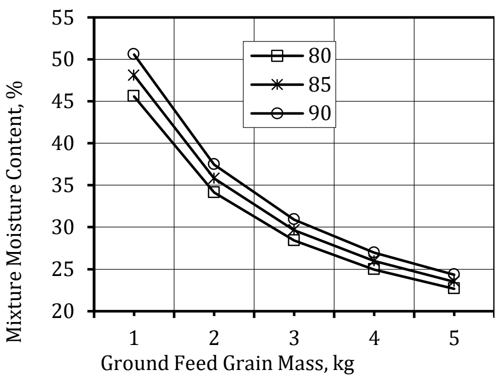

Figure 1: Mixture Moisture Content Vk versus the Amount of Ground Feed Grain Added per 1 kg of Paste

The pellet quality indicators, friability and caking, were determined as follows:

$$K = \frac{m_к}{m} 100\%;$$

$$C = \frac{m_c}{m} 100\%,$$

where K is friability, %; mk is the mass of crumbled pellets, kg; m is the total mass of pellets, kg; C is caking, %; and mc is the mass of caked pellets, kg.

Pellets with a length of less than two diameters were considered crumbled.

The experimental procedure included the following stages:
– Preparation of a mixture sample with the required moisture content based on the calculated data shown in Figure 1.
– Determination of the mixture moisture content using a standard method
– Starting the unit and feeding the mixture into the loading hopper
– Dropping the pellets from a height of 1 m after they exited the die, corresponding to the conditions under which the material is transferred from the granulator to the dryer in the actual production process, for subsequent determination of friability and caking
– Sampling and weighing the caked and crumbled pellets;
– Determination of the total mass of pellets obtained in each experiment and their moisture content at the end of the experiment.

The experiments were conducted in triplicate using mixtures with different moisture contents. According to the research program, the friability and caking of the resulting pellets were determined for the following component mass ratios: Mp/Md = 1:0.5, 1:1, 1:1.5, 1:2, and 1:3, corresponding to mixture moisture contents Vk of 58.1%, 47.4%, 40.4%, 36.0%, and 30.5%, respectively.

RESULTS AND DISCUSSION

The experimental results are presented in Figures 2 and 3 as graphical relationships between pellet friability and mixture moisture content, K = f(Vk), and between pellet caking and mixture moisture content, C = f(Vk).
The experimental data were subjected to statistical analysis, and the correlation coefficients and regression equation coefficients were calculated for the relationships K = f(Vk) and C = f(Vk). The following regression functions were considered: hyperbolic, $y = a/x + b$; power, $y = bx^a$; exponential, $y = be^{ax}$; and exponential with base a, $y = ba^x$.

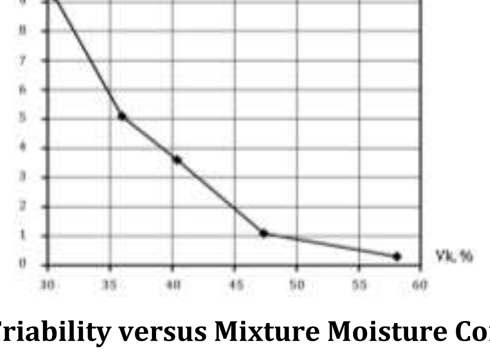

Figure 2: Pellet Friability versus Mixture Moisture Content, K = f (Vk)

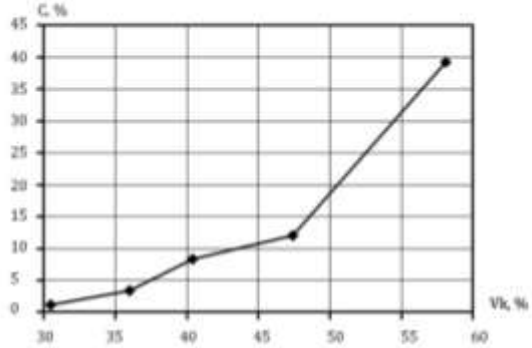

Figure 3: Pellet Caking versus Mixture Moisture Content, C = f(Vk)

The calculated coefficients of these functions for the relationships K = f(Vk) and C = f(Vk) are presented in Table 1.

Table 1: Calculated Coefficients of the Regression Equations

Type of regression	Calculated values of the function coefficients			
	a_C	b_C	a_K	b_K
y = a/x + в	$-2.23x10^3$	68.351	597.73	–10.324
y = вx^a	4.78	$1.36x10^7$	–6.091	$1.64x10^{10}$
y = вe^{ax}	0.111	0.066	–0.145	$1.083x10^3$
y = вa^x	1.117	0.066	0.865	$1.083x10^3$

The significance of the resulting regression equations was assessed using Fisher's F-test (Lvovsky, 1988).

The calculated and Critical F-values and correlation coefficients for the different regression equations are presented in Tables 2 and 3.

The data in Table 2 indicate that the dependence of pellet friability on mixture moisture content is adequately described by hyperbolic, power, exponential, and exponential functions with base a at the 10% significance level.
According to Table 3, the dependence of pellet caking on mixture moisture content is adequately described by power, exponential, and exponential functions with base a at the 2.5% significance level and by a hyperbolic function at the 10% significance level.
Analysis of the results supports the following conclusions.
– Equipment with a screw working element makes it possible to produce pellets from a mixture of protein paste and ground feed grain;
– To obtain non-caking pellets, the moisture content of the protein paste and ground feed grain mixture should not exceed 40%, at which the caking index is no more than 7%

– Pellet friability below 10% is achieved at a mixture moisture content above 30%.

Table 2: Statistical Estimates of the Regression Equations K = f(Vk)

Type of regression equation	Correlation coefficient	Calculated F-value	Tabulated F-value	Significance level
y = a/x + b	–0.9099	5.358	5.342	10%
y = вx^a	–0.9099	0.951	5.342	10%
y = вe^{ax}	–0.9099	1.638	5.342	10%
y = вa^x	–0.9099	1.638	5.342	10%

Table 3: Statistical Estimates of the Regression Equations C = f(Vk)

Type of regression equation	Correlation coefficient	Calculated F-value	Tabulated F-value	Significance level
$y = a/x + b$	0.9356	2.80	5.342	10%
y = вx^a	0.9356	27.138	15.101	2.5%
y = вe^{ax}	0.9356	26.722	15.101	2.5%
y = вa^x	0.9356	26.721	15.101	2.5%

CONCLUSION

The experimental studies confirmed the feasibility of producing pellets from a mixture of protein paste and ground feed grain using equipment with a screw working element. Quantitative relationships were established between the quality indicators of the pelleted product – friability and caking – and the mixture moisture content and component mass ratio. It was shown that, to ensure a caking index of no more than 7%, the feed mixture moisture content should not exceed 40%, while friability below 10% is achieved at a moisture content above 30%. The resulting regression equations, which adequately describe the experimental data at significance levels ranging from 2.5% to 10%, can be used to determine pelleting conditions for different ratios of protein paste and ground feed grain. The results are of practical interest to compound feed manufacturers producing pelleted feed additives based on plant protein concentrate and may serve as a basis for developing process regulations when designing the corresponding production lines.

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