Technology of sunflower cake preparation

I E Priporov, V S Kurasov and E E Samurganov

Kuban State Agrarian University named after I. T. Trubilin, 13, Kalinina str.,
Krasnodar, 350044, Russia

E-mail: i.priporov@yandex.ru

Abstract. For the production of sunflower cake, various technologies, which need to be improved, are used: it will increase the nutritional value of the feed which is a topical problem. To make possible the quality assessment of the protein feed, when it is prepared with components from piles of sunflower seeds in real time, the process is carried out by using multimedia devices at the stage of clearing the pile of sunflower seeds, as well as milling the prepared feed. The uniform-pitch screw value of a serial extruder is directly proportional to the first winding pitch and inversely proportional to the number of winds. By increasing the flight screw constant number, the winding pitch decreases and the processed material becomes compact. Reduction of the winding pitch aliquot to the screw is carried out exponentially. The compression ratio of sunflower seed components to obtain protein feed of a cake form with a winding pitch decrease aliquot depends on the design parameters of the extruder screw, which enables to regulate the technological process of its preparation in crumbly and granular forms. It depends on the screw winding pitch with its number, and by increasing the screw winding pitch the compression ratio is decreased, and contrariwise, with decreasing screw winding pitch the compression ratio of the processed material (sunflower cake) is increased.

1. Introduction

In order to take the livestock industry out of the crisis, a set of measures is needed, including the provision of livestock with full-rationed fodder. One of the ways to solve this problem is the creation of technologies that provide the preparation of protein feed in accordance with zootechnical requirements at the lowest material and energy costs [1].

Currently, the works of scientists and the experience of specialized farms proved that the production lines of protein feed preparation most comprehensively meet the production requirements [2, 3].

For the production of sunflower cake in relation to its features, the various technologies, which are being imposed by zootechnical requirements, are used, and need to be improved, that would increase the feed nutritional value and is a topical problem. Scientific developments on technology improvement of sunflower cake preparation are being held at the Department of tractors, automobiles and technical mechanics of Kuban state agrarian university [4].

Feeds are often not nutritionally balanced, which leads to their inefficient use [5, 6].

For the sunflower cake preparation, as an additive into a mixed fodder, the various components in its composition are used (hay, straw, molasses pulp in dry and raw forms, beet silage, etc.), which may be of a great many. The feed can be mixed in a mixer or in a disperser to obtain the wet feed.

However, high scientific achievements were made in a mechanization for providing the animals productivity growth, but it requires a plethora of unit costs. Therefore, there is an emerging issue of an
exact match between the additional costs and the resulting product, and the problem which has arisen in the world agricultural science and has been termed as “precision livestock farming”. The creation of modern means of information data processing on the basis of microcomputer technology enables to solve this problem. For example, it is possible to carry out the feeding of a concentrated feed not averaged over the herd but depending on the productivity of each animal. To conduct this, appropriate technical means and technologies, providing the use of electronic equipment, should be developed [7].

2. Materials
To ensure the possibility of assessing the quality of protein feed [8] in its preparation, a technology (figure 1) for its implementation was proposed (Pat. RF no. 2688481), in which the process of mixing and grinding at all stages of its preparation is controlled with the help of multimedia devices.

The technology of obtaining protein feed for farm animals is realized through the device (figure 1), which contains tank 1 for enrichment the feed with micronutrients, extruder 2 [9–12], mixer 3, receptacle 4 for storing and dispensing the prepared feed, air-sieve grain-cleaning machine 5, under which there is hopper 6 for storing the product of oil crops processing, air conditioner 7, shredder 8. The line has transport-dispensing device 9 installed in front of the air-sieve grain-cleaning machine 5, at its inlet and outlet there are multimedia devices located on top of it 10, to have an image of a heap of sunflower seeds before and after cleaning, multimedia devices are connected to computer 11 for mathematical processing of the images obtained.

Air-sieve grain-cleaning machine 5 has container 12 for additional processing of the material. At the same time, air conditioner 7 is installed under the extruder, the outlet of which is connected to shredder 8, under which mixer 3 is located, connected to tank 1 for enrichment with micronutrients. Under the outlet of shredder 8, additional multimedia device 13 is installed, connected to the computer 11. The disperser 14 is located above the inlet of receptacle 4 for storing and dispensing the prepared feed.

Figure 1. Device for the implementation of the method of obtaining protein feed for farm animals (general outline): 1 – tank for enrichment of the feed with micronutrients; 2 – extruder; 3 – mixer; 4 – receptacle for storing and dispensing the prepared feed; 5 – air-sieve grain-cleaning machine; 6 – hopper for storing the product of oil crops processing; 7 – air conditioner; 8 – shredder; 9 – transport-dispensing device; 10 – multimedia devices; 11 – computer; 12 – container for additional processing of the material; 13 – additional multimedia device; 14 – disperser.
3. Results and discussion
The analysis of scientific works of Kurochkin A.A., Shaburova G.V., Novikov V.V., Denisov S.V. showed that the rational parameters of extruders in the processing of various feeds are justified on the basis of theoretical studies about their movement under the effect of working bodies [13].

However, our own theoretical studies have shown that many scientists have not considered the production of cake from the components of sunflower seeds (fragments of baskets and stems, whole seeds). Therefore, the movement of the processed material (fragments of baskets and stems, sunflower seeds) on the turns of the screw extruder KMZ-2 to obtain cake is an actual problem.

At the same time, we consider 2 options for the organization of the movement of the processed material till obtaining the resulting product – sunflower cake.

1 – we believe the pitch “h” of the flight screw decreases with each wind by the value of the step “d” = const.

At n = 1 step h₁, where “n” is the number of turns on the extruder screw.
At n = 2 step h₂ = h₁ + d.
At n = 3 step h₃ = h₁ + 2d.
At n-turns, the step of the extruder screw is:

\[ h_n = h_1 + (n - 1) \cdot d, \]  

(1)

where h₁ – the step of the first turn on the screw, mm; d – the value of the step of the extruder screw coil, mm.

Reducing the step of the screw coil in the expression (1) is carried out by arithmetic progression and is found by the expression:

\[ d = \frac{h_n - h_1}{n-1}. \]  

(2)

In expression (2), the values of hₙ and h₁ must be known.

The uniform-pitch screw value of a serial extruder is directly proportional to the first winding pitch and inversely proportional to the number of winds. By increasing the flight screw constant number, the winding pitch decreases and the processed material becomes compact.

The research results coincide with the studies conducted by Frolov V. Yu., who showed that by winding pitch decreasing, the volume in the same amount of mass for the same angle of screw rotation, decreases, and hence the more compacted the treated material and the mass quickly comes to the desired concentrations [14].

2 – we believe that the step of the screw coil is diminished aliquotly (figure 2).

![Figure 2. Extruder screw with aliquotly diminishing step of the turn](image)

Determining the ratio of the second to the first turn of the step and of the subsequent to the previous ones according to the expression:

\[ \frac{h_2}{h_1} = k, \]  

(3)
\[
\frac{h_3}{h_2} = k. \tag{4}
\]

Substituting the step of the second turn on the screw \((h_2)\) from the expression (3) to the expression (4), we obtain:

\[
\frac{h_3}{h_1} \cdot k = k, \\
\frac{h_3}{h_1} = k^2. \tag{5}
\]

From the expression (5) we define \(h_3\):

\[
h_3 = h_1 \cdot k^2. \tag{6}
\]

In this way, the step of the turn “n” on the screw \((h_n)\) is:

\[
h_n = h_1 \cdot k^{n-1}. \tag{7}
\]

Analysis of the expression (7) shows that the winding pitch reduction, aliquot to the extruder screw, is carried out exponentially.

From the expression (7) we find the material compression ratio \((k)\) with the obtaining a sunflower cake:

\[
k = \sqrt[\frac{n-1}{h_1}]{h_n}, \tag{8}
\]

where \(h_n\) – step coil with “n” number of coils, mm; \(h_1\) – step of the 1-st turn of the screw, mm.

Analysis of expression (8) shows that the compression ratio of the material depends on the screw winding pitch at “n” of their number, as well as by increasing the winding pitch the compression ratio decreases, and contrariwise, by decreasing the pitch, the compression ratio of the processed material (sunflower cake) increases.

Determining the initial volume of sunflower cake, which is obtained as a result of the receipt of the processed material (fragments of baskets and stems, sunflower seeds) in the compression chamber of the extruder (figure 3) by the expression:

\[
V_0 = \left(\frac{\pi D^2}{4} - \frac{\pi d_s^2}{4}\right) \cdot h_0, \tag{9}
\]

where \(V_0\) – initial volume of sunflower cake, which is obtained as a result of receipt of the processed material (fragments of baskets and stems, sunflower seeds) in the extruder compression chamber, mm\(^3\); \(D, d_s\) – the diameter of the screw and shaft, respectively, mm; \(h_0\) – the initial step of the screw turn at the moment when sunflower seeds are fed to a screw turn, mm.
The resulting amount of product (the sunflower cake) deriving from the extrusion of the processed material defined by expression:

\[ V_k = \left( \frac{\pi D_s^2}{4} - \frac{\pi d_{se}^2}{4} \right) \cdot h_s, \]  

where \( V_k \) – final volume of the material (sunflower cake) obtained by extrusion of the processed material, \( mm^3 \); \( D_s \), \( d_{se} \) – diameters of the screw and the shaft on the ends, respectively, \( mm \); \( h_s \) – step of the last screw turn, \( mm \).

Dividing the expression (9) to the expression (10) and determining the processed material compression ratio – sunflower cake in the chamber during its release by the formula:

\[ k_k = \frac{V_0}{V_k}, \]

\[ k_k = \left( \frac{\pi D_s^2}{4} - \frac{\pi d_{se}^2}{4} \right) \cdot \frac{h_0}{h_s}, \]

\[ k_k = \left( \frac{D_s^2 - d_{se}^2}{D_s^2} \right) \cdot \frac{h_0}{h_s}. \]  

The analysis of the expression (12) permits to control the process of compression of sunflower seed components to obtain the cake depending on the design parameters of the extruder screw.

4. Conclusion
1. The technology according to patent RF №2688481 allows one to prepare a protein feed with components from the pile of sunflower seeds, and at all stages of its processing, allows one to evaluate the quality of preparing through the use of multimedia devices during the phase of sunflower seeds pile cleanup (before and after), and grinding prepared feed.
2. The uniform-pitch screw value of a serial extruder is directly proportional to the difference between pitch “n” and step revolution first and inversely – to the wind number. By increasing the flight screw constant number, the winding pitch decreases and the processed material becomes compact. Reduction of the winding pitch aliquot to the screw is carried out exponentially.
3. The compression ratio of sunflower seed components to obtain protein feed of a cake form with a winding pitch decrease aliquot depends on the design parameters of the extruder screw, which enables one to regulate the technological process of its preparation in crumbly and granular forms in real time. It depends on the screw winding pitch with its number, by increasing the screw winding pitch the

![Figure 3. The shaft of the extruder screw KMZ-2, advanced model](image)
The compression ratio is decreased; and contrariwise, with the decreasing screw winding pitch the compression ratio of the processed material (sunflower cake) is increased.

References
[1] Tishchenko M A, Tokareva A N and Khlebov Yu A 2003 Perspective technologies of cattle feeding Energy saving and energy-saving technologies in agriculture 1 81–86
[2] Per-Curan K 1975 Means for increased feed efficiency in large for increased feed efficiency in large-scale cattle production Soviet-Swedish symp. on problems in large scale cattle and pig husbandry (Agricultural college, Sweden Department of Animal Husbandry Rapport) p 31
[3] Burmaga A V 2014 Improving the efficiency of production processes of preparation and distribution of mixtures in the system of mechanized feeding of cattle, thesis abstract (Blagoveshchensk) p 39
[4] Priporov I E and Baciu T N 2019 Directions of perfection of technology of preparation of protein feed Proc. of Orenburg state agricultural university 2(76) 104–106
[5] Flachowsky G 1986 Efficient feed use in beef cattle feeding Tierzucht 12 533–536
[6] Sadov V V 2017 Substantiation of the structure and composition of technological lines for the production of animal feed in agricultural enterprises, thesis abstract (Barnaul)
[7] Kormanovskii L P 2004 Precision technology in livestock production Economics of agriculture 6 7
[8] Priporov I E 2018 Advanced technology of obtaining protein feed from sunflower seeds (cake) Bulletin of East Siberia State University of Technology and Management [in Russian – Vestnik VSGUTU] 1(68) 47–53
[9] Bandyobadhyay S and Rout R K 2001 Aquafeed extrudate flowrate and pellet characteristics from low cost single screw extruder J. of Aquatic Food Product Technology 10(2) 3–14
[10] Miller R C 1985 Low temperature extrusion: effects of cooking moisture on products characteristics J. of Food Science 50 249–253
[11] Chevanan N, Muthukumarappan K, Rosentrater K A and Julson J L 2007 Effect of die dimensions on extrusion processing parameters and properties of DDGS-based aquaculture feed Cereal Chemistry 84(4) 389–398
[12] Snabi Z et al 1999 Effects of extrusion of grain and feeding frequency on rumen fermentation, nutrient digestibility, and milk yield and composition in dairy cows J. of Dairy Science 82 1252–1260
[13] Kurochkin A A, Shaburova G V, Novikov V V and Denisov S V 2013 Methodological aspects of theoretical studies of press extruders for processing plant starch-containing raw materials XXI century: the results of the past and the problems of the present plus 6(10) 46–54
[14] Frolov V Yu 2010 Theoretical and experimental aspects of the development of technologies and technical means, preparation of concentrated feed based on soy protein (Krasnodar) p 140