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PEELING OF WHITE LUPINE GRAIN IN ROLLER MILLS

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In cereal production, there are a number of methods for grain peeling. The process of peeling lupine grain having a specific form, which differs from the spherical one, includes grain crushing, sieve screening, and pneumatic separating. Independent variables characterizing the processing conditions include the gap between the rollers, grain moisture content, the speed of the rollers, and their slippage. Roller mills (crushers) were used for crushing. The rotational speed of the rollers was 300 and 600 min^{-1}. During pneumatic separation, the air speed in the pneumatic duct corresponded to 7.5 m/s. It has been established that the gap between the rollers and the grain moisture content significantly affect the quality indicators of the ground product. As a result of the experiments, it has been found that an increase in the gap in the range of 1.0…2.5 mm and an increase in the grain moisture content from 8 to 13.2% result in the increased output of middlings and the average size of particles. However, the number of core particles with shell remnants increases too, and the output of tailings (mainly, shells) decreases after pneumatic separation. The output of marketable kernel middlings was about 70%. The technological process of white lupine grain peeling is based on the traditional equipment of cereal production. The results obtained suggest the possibility of the primary processing of white lupine grain with such crushers to produce kernel middlings of the required fractional composition.

Key words: white lupine, peeling, crusher, crushed grain material, shells.

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ОБРУШЕНИЕ ЗЕРНА БЕЛОГО ЛЮПИНА НА ВАЛЬЦЕВЫХ СТАНКАХ

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В крупяном производстве существует ряд методов обрушения зерна. Процесс обрушения специфической формы зерна люпина, отличной от сферической, включает операции дробления зерна, просеивание на решетах и пневмосепарирование. Независимыми варьируемыми переменными, характеризующими режимы обработки, являются зазор между вальцами, влажность зерна, скорость вращения вальцов, их проскальзывание. Для дробления использовались вальцовые станки (дробилки). Скорость вращения вальцов составляла 300 и 600 мин$^{-1}$. При пневмосепарировании скорость воздуха в пневмоканале соответствовала 7,5 м/с. Установлено, что зазор между вальцами и влажность существенно влияют на показатели качества измельченного продукта. В результате проведенных экспериментов установлено, что с ростом зазора в диапазоне 1,0…2,5 мм и увеличения влажности с 8 до 13,2% выход крупки и средний размер частиц увеличиваются, однако возрастает доля частиц ядра с остатками оболочек, и снижается выход относов (в основном оболочек) после пневмосепарирования. Выход товарной крупки ядра составил около 70%. Технологический процесс обрушения зерна белого люпина основан на традиционном оборудовании крупяного производства. Полученные результаты позволяют говорить о возможности первичной переработки зерна белого люпина на подобных дробилках с получением крупки ядра необходимого фракционного состава.

Ключевые слова: белый люпин, обрушение, дробилка, крупка, оболочки.

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Introduction. Biological, feed, and technological features of white lupine make it popular on the market for vegetable protein. Lupine growing is also a necessary link in preserving the country's food security [1, 2]. That's why white lupine is considered not only as an import-substituting alternative to soybeans, but also as a crop, the cultivation of which is of interest to producers in connection with the use by plants during vegetation of biological nitrogen and tripe-substituted soil phosphates [3-5].

White lupine is most widely used in fodder production [6-8]. Its use in compound feeds, taking into account the peculiarities of the structure of white lupine grain, is advisable after the separation of the shell (peeling). In this regard, grain separation into anatomical parts can be considered the first stage of processing. Fig. 1 shows the products of primary processing.

a *b* *c* *g* *d*

Fig. 1. Products of primary processing of white lupine grain in a roller mill:
a, b, c – middlings of three fractions; g – whole grain; d – shell

Рис. 1. Продукты первичной переработки зерна белого люпина на вальцовом станке:
a, b, c – крупка трех фракций; g – целое зерно; d – оболочка

The specific shape of white lupine seeds does not allow separating the shells, which constitute 14…19% of the grain mass, without destroying the kernel. However, crushing leads to the formation of two fundamentally different products:

– crushed kernel in the form of particles of an irregular shape and a various size freed from the shell (middlings);

– more or less crushed shells of a flaky form.

These two phases can be separated with a pneumatic separator, since middlings have higher density and floating speed as compared with the shells. It should be noted that in this case, part of the powdery fraction of the kernel crushing products also gets to the fraction of tailings.

For small enterprises, it is advisable to use machines of low productivity [9]. When organizing a larger production, use should be made of roller machines (crushers).

The purpose of the study is an experimental evaluation of the efficiency of using roller machines in the process of separating white lupine kernels from their shell (peeling).

The object and methods of research. White lupine seeds of the "Degas" variety were used as an experimental material. The seeds were crushed with longitudinal-cutting rollers (diameter 250 mm, cutting pitch 3.3 mm, α = 20°, β = 70º). The rollers were installed according to the "tip to the tip" scheme. To ensure the effect of grinding the grains during peeling, rollers had a different rotation speed: 300 and 600 min^{-1}. The gap between the rollers was set using a kit of probes with an accuracy of 0.05 mm.

After grinding, the product passed through the "Petkus" laboratory pneumatic separator at an air speed in the pneumatic duct of 7.5 m/s.

To determine the fractional composition of the grinding products, laboratory sieves with round holes and scales were used (an accuracy of 0.01 g); with load weight of 100 g.

Seed moisture content was determined according to GOST 13586.5-93 (Grain. Method for determining moisture content).

As a result of search experiments, it has been found that the main factors significantly affecting the quality indicators of a crushed product are the gap between the rollers and moisture content [10].

Results and discussion.

The output of middlings. Middlings, i.e. crushed core-free shell, are the main product of peeling. The overall amount of middlings in relative units (r/u) after pneumatic separation, depending on the gap between the rollers during grain crushing, is presented in Fig. 2.

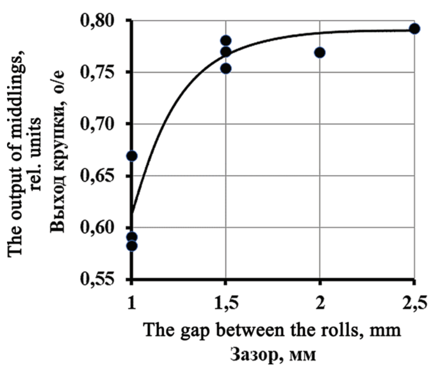

Fig. 2. The output of middlings depending on the gap between the rolls

Рис. 2. Выход крупки в зависимости от зазора между вальцами

The change in the output at the stated processing procedure occurs due to the variation of the proportion of bran and shells in the middlings (after winnowing). Preliminary experiments showed that an increase in the gap in the range of 1.0…2.5 mm results in the increased middlings output. This is caused both by a decrease in the relative share of the winnowed bran, and an increased proportion of the large fraction, the particles of which still keep shell elements.

The purest fraction shall have particle sizes of 2…4 mm. The relationship between the output of this fraction (relative to the output of middlings) and the gap between the rollers is shown in Fig. 3. The moisture content of the fraction was 10.8%, the ratio of the roller speed with slippage was 300/600 min^{-1}.

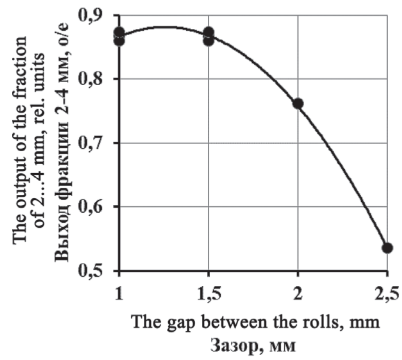

Fig. 3. The output of the fraction of 2…4 mm (relative to the total grain mass) depending on the gap between the rollers

Рис. 3. Выход фракции 2…4 мм (относительно общей массы крупки) в зависимости от зазора между вальцами

Depending on the gap, the fractional composition of middlings and the average particle size change. Fig. 4 and 5 present empirical functions and the distribution density (by mass) of middlings obtained after screening on sieves with round holes.

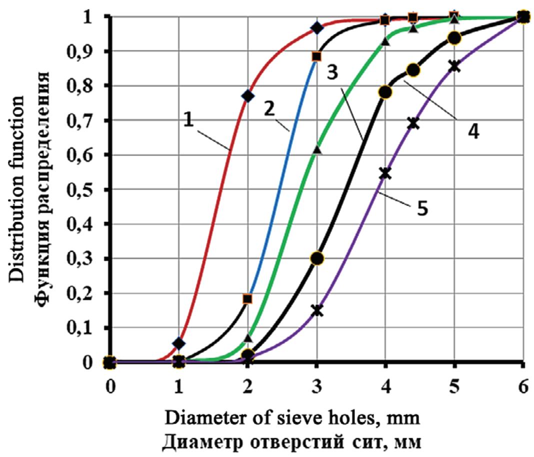

Fig. 4. Empirical functions of the distribution of middlings at the gap between the rollers, mm:
1 – 0.5; 2 – 1.0; 3 – 1.5; 4 – 2.0; 5 – 2.5

Рис. 4. Эмпирические функции распределения крупки при зазоре между вальцами, мм:
1 – 0,5; 2 – 1,0; 3 – 1,5; 4 – 2,0; 5 – 2,5

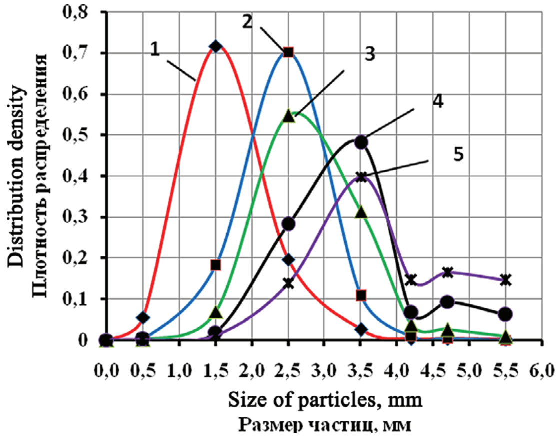

Fig. 5. Empirical density of the distribution of middlings at the gap between the rollers, mm:
1 – 0.5; 2 – 1.0; 3 – 1.5; 4 – 2.0; 5 – 2.5

Рис. 5. Эмпирические плотности распределения крупки при зазоре между вальцами, мм:
1 – 0,5; 2 – 1,0; 3 – 1,5; 4 – 2,0; 5 – 2,5

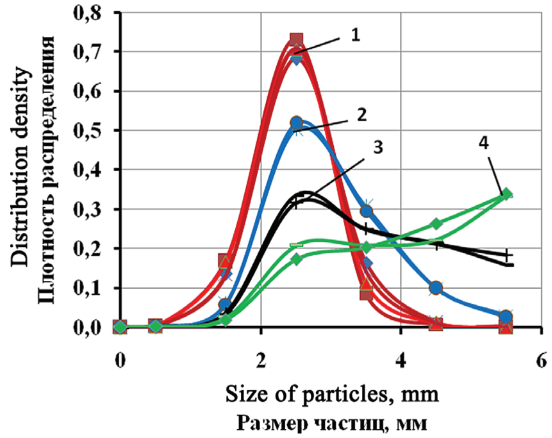

Fig. 7. Empirical distribution density of middlings (at the gap between rollers of 1 mm) with moisture content:
1 – 8%; 2 – 10.5%; 3 – 11.7%; 4 – 13.2%

Рис. 7. Эмпирическая плотность распределения крупки (зазор между вальцами 1 мм) при влажности:
1 – 8%; 2 – 10,5%; 3 – 11,7%; 4 – 13,2%

It was initially assumed that an increase in the gap resulted in an increased share of large fractions, and a decreased share of the smaller ones, i.e. the average particle size grew almost linearly with an increase in the gap. At the same time, an increase in standard deviation was noticed.

The effect of the moisture content. The output of crushed grain material increases as grain moisture content increases (Fig. 6). This is associated with a decrease in the proportion of the produced crushed grain material and an increase in the proportion of a large fraction particles with the remnants of shells.

In these tests, due to the variation of grain moisture content, the rotational speeds of the rollers relative to each other are changed by 450 and 600 min^{-1}. In this regard, an increase in the average size and standard deviation of particles was observed.

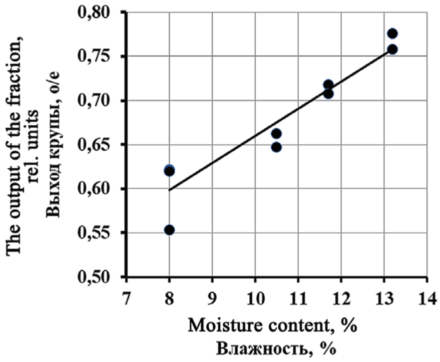

Fig. 6. The output of middlings depending on the grain moisture content at the slipping rotation speed of the rollers of 450/600 min^{-1}

Рис. 6. Выход крупки в зависимости от влажности зерна при частоте вращения вальцов с проскальзыванием 450/600 мин$^{-1}$

As moisture content increases, a significant violation of the symmetry of the empirical distribution density is observed (Fig. 7).

The symmetry of distribution density is characterized by the third-order moment. As humidity increases, a sharp increase in the third order moment is observed. A visual analysis of the crushed grain material with different moisture content showed that an increase in moisture content of a fraction of more than 4 mm in size resulted in the increased proportion of particles with shell residues.

The output of tailings. Tailings are a light fraction of crushed products obtained by winnowing with pneumatic separators. This fraction consists of shells and small kernel particles. Fig. 8 shows the proportion of the overall relative output after pneumatic separation in the pneumatic duct at an air speed of 7.5 m/s.

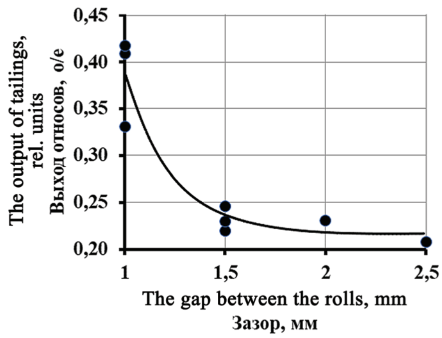

Fig. 8. The output of tailings depending on the gap between the rollers (at roller speed with slippage of 300/600 min^{-1}, and moisture content of 10.8%)

Рис. 8. Выход относов в зависимости от зазора между вальцами (частота вращения вальцов с проскальзыванием 300/600 мин$^{-1}$, влажность 10,8%)

In the fraction triage with a particle size of 2…3 mm, a certain amount of shells was observed, and a lot of kernel bran were observed in the sifted material.

As the gap increases, the output of tailings decreases, since the share of sifted bran decreases, i.e. its relative mass decreases, and a part of shells remains on the particles of the coarse grain material.

It is obvious that the obtained relative values and their composition largely depend on the air speed during pneumatic separation. The higher it is, the more effective the removal of the membranes is, but at the same time, larger kernel particles are carried away, which reduces the output of crushed grain material.

As moisture content increases, the particle density in the tailings increases too (with equal geometric characteristics), therefore, the floating speed increases, and the relative value of tailings at a constant air speed in the pneumatic duct decreases (Fig. 9).

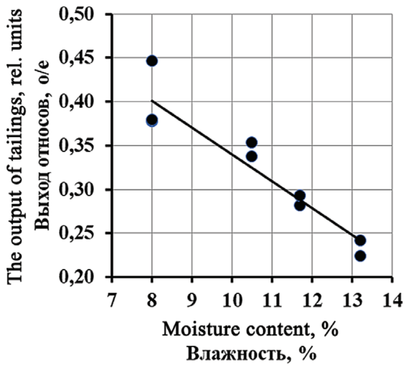

Fig. 9. Influence of moisture content on the output of tailings (at an air speed in the pneumatic duct of 7.5 m/s, a gap of 1 mm, and a roller slippage speed of 450/600 min^{-1})

Рис. 9. Влияние влажности на выход относов (скорость воздуха в пневмоканале 7,5 м/с, зазор 1 мм и частота вращения вальцов с проскальзыванием 450/600 мин$^{-1}$)

Thus, the gap between the rollers and the grain moisture content have a major impact on the fractional composition of crushed products, the degree of separation of the kernel and shells, and, accordingly, their aerodynamic characteristics.

Preliminary pneumatic separation moves the powdery fraction of the kernel to tailings, and there remains an extracted fraction with a particle size of less than 2 mm.

With large gaps and high moisture content in the coarse fraction of the crushed grain material, there is insufficiently crushed output as there still remain large kernel particles with shell elements.

Conclusion

Primary processing of white lupine grain is possible using roller crushers to obtain the necessary fractional composition. However, additional equipment and the development of a process line are required to obtain shell-free crushed grain middlings.

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Contribution

Zverev S.V., Stavtsev A.E., Tsigutkin A.S., Aldoshin N.V., Alipichev A.Yu. carried out the experimental work, on the basis of the results summarized the material and wrote the manuscript. Zverev S.V., Stavtsev A.E., Tsigutkin A.S., Aldoshin N.V., Alipichev A.Yu. have equal author's rights and bear equal responsibility for plagiarism.

Conflict of interests

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ПАРАМЕТРЫ И РЕЖИМЫ РАБОТЫ ПНЕВМАТИЧЕСКОЙ СИСТЕМЫ УСТРОЙСТВА ДЛЯ ДЕКАПИТАЦИИ КАРТОФЕЛЯ

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Получение экологически чистой картофельной продукции без дополнительного применения агрохимикатов позволяет осуществлять технологический приём обезглавливания, что стимулирует потенциал растения и способствует увеличению листовой поверхности. Суть обезглавливания заключается в удалении апикальной части стеблей, что провоцирует развитие боковых побегов. Картофель имеет как вертикальные, так и отклоненные стебли, перед обрезкой верхнюю часть следует довести до режущего аппарата, а поскольку стебли растения легко травмируемые, то этот подвод должен быть очень деликатным. В связи с этим предлагается обратить внимание на возможность подъёма стеблей картофеля на нож режущей машины при обезглавливании с помощью всасывающего воздушного потока, что позволяет выполнять операцию с минимальным трением растения о поверхность без повреждения стеблей и листьев. Обоснована методика определения параметров пневматической системы подъёма стеблей картофеля. Установлено, что для обеспечения подъёма стеблей с перепадом высот побегов 0,10…0,15 м при обезглавливании картофеля используют устройство, диаметр устья всасывающей трубы которого составляет 0,35 м, скорость воздуха – 10…15 м/с соответственно.

Ключевые слова: картофель, устройство для удаления верхушек, безнапорный срез, режущая кромка, скорость агрегата.