ELECTRONIC JOURNAL OF POLISH AGRICULTURAL UNIVERSITIES

2001
Volume 4
Issue 2
Series
AGRICULTURAL ENGINEERING

GROCHOWICZ J., ANDREJKO D. 2001. THE ROLE OF PHYSICAL PROPERTIES OF LUPINE SEEDS IN THE HULLING PROCESS **Electronic Journal of Polish Agricultural Universities**, Agricultural Engineering, Volume 4, Issue 2.
Available Online http://www.ejpau.media.pl

THE ROLE OF PHYSICAL PROPERTIES OF LUPINE SEEDS IN THE HULLING PROCESS

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ABSTRACT

Nowadays the lupine varieties contain less alkaloid what makes it possible to use them as feed components in larger proportions. The purpose of this paper is to provide some new possibilities of improving lupine seed quality, by application of simple mechanical hulling method. The influence of hulling conditions on the quality of final product was analyzed. Somej factors that affect the hulling process kinds of used equipment as well as the physical properties and chemical composition of lupine seeds were discussed. The best results of hulling process was acquired on the specially adapted roller mill. Preliminary treatment of raw material also affected the hulling process in the large scale.

Key words: Lupine, seeds, hulling

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INTRODUCTION

Due to the fact that the world`s population is very rapidly increasing, the humans may have to face the problem of finding new sources of protein. One of the alternatives is obtaining the protein from lupine seeds. In some countries, especially in the South America, the protein gained from lupine seeds is used to enrich some foods. In other countries, especially those considered to be the richest, studies on the use of that kind of protein as an addition to noodles, cookies, crisps, jam or even meat products, have already been carried out for several years [8]. The use of lupine seeds for human consumption causes many different problems, mainly of technological and psychological nature. Dr R. Gross [7], who is very enthusiastic about lupine, wrote that the lupine suffered from its reputation as poor people`s foods. The lupine varieties are commonly cultivated: the blue angustifoliar lupine (*L. angustifolius*), the yellow lupine (*L. luteus*) and the white lupine (*L. albus*); there are distinct differences among these varieties in size and physical properties of the seeds. From a technological point of view, the wider use of lupine human and animal diets is limited by the presence of noxious substances (alkaloids, oligosaccharides) and a large percentage of fibre in the seed coats (low energetic value). Therefore, the studies have been conducted aiming at finding the way to eliminate these substances and consequently to produce the raw material rich in highly digestible vegetable protein. Many ways of eliminating these substances from the seeds are already known but the application of these methods on commercial scale causes many technical and economic problems. Numerous hulling methods applied to the seeds of different crops (cereals, buckwheat, rape, peas) are known as well as the various abrasive or impact dehullers used for this purpose. However, the results of investigations [2, 3, 5, 6, 9, 10, 11, 12] show that hulling of lupine seeds in such machines is rather difficult because of very close adhesion of the seed coats to cotyledons.

Hulling is a method improving nutritive value of any seeds, but because of the insufficient knowledge of the process parameters, this method has not been applied to lupine seeds until now. For such a reason the experiment were conducted to study the possibilities of separating seed coats from cotyledons of lupine seeds at the process of crushing in a roller mill.

The aim of investigation was to find out influence of different parameters on hulling process and to recommend the best of them. The same time the strength properties of seed cover at different level of moisture content were measured.

MATERIALS AND METHODS

Three species of lupine seeds commonly cultivated in Poland: white, yellow and blue were examined. Each species of lupine were represented by two varieties, as below:

- white: Bardo, Wat,
- yellow: Juno, Amulet,
- blue: Sur, Emir.

The moisture content of raw material under study was assumed to be about 10%; only case of seeds used for testing seed coat strength the moisture content ranged from 8 to 42%. As the natural moisture content was lower than assumed the seed were moistened before experiment. For that purpose weighed 5 kg seed samples were wetted with water in amounts calculated according to the formula 1:

$$M_w = \frac{W_2 - W_1}{1 - W_2} M_1 \quad (1)$$

where: M_w – mass of added water (g), W_2 – required moisture content (%), W_1 – initial moisture content (%), M_1 – mass of seeds (g)

The seeds were placed in air-tight containers. In order to unify the moisture content in the whole batch of seeds, the conditioned samples were stored for 10 days in a cooling chamber at constant temperature of 5°C, and shaken several times a day. One hour before tests the seeds were taken out from the chamber to equalize their temperature with the ambient conditions. The moisture content of seeds was determined using air-oven method according to the AACC Method 44-15A.

The granular structure of raw material was determined by sieving 100 g samples with a laboratory sifter ZBPP according to method recommended by the manufacturer. Eight sieves with square gaps of sizes from 0.4 to 6.3 mm were used. The time of actual sieving was 4 min. Every dimensional class was weighed at the accuracy of ±0.01 g. The mean for three replications was accepted as the final result. The average diameter of the particles was calculated by using the following formula:

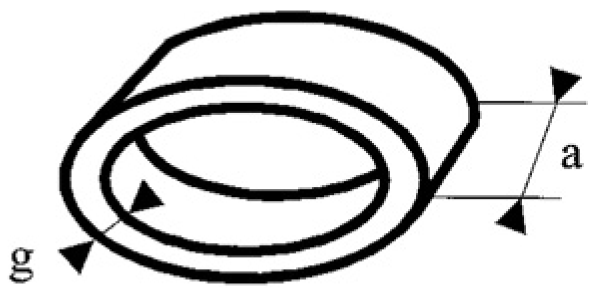
$$S = \frac{\sum_{i=1}^{8} d_i P_i}{100} \quad (2)$$

where: S – the average seeds diameter (mm), d_i – the average size of two adjacent sieves (mm), P_i – the percentage of seeds collected on particular sieve (%)

The proportion of the cotyledons and seed coats in lupine seeds was determined manually by hulling of 25 seeds and weighing them on an analytical balance at the accuracy of ±0.001 g, for each of two obtained fractions [1]. The results expressed in percentage to the whole seeds were obtained as the arithmetic mean for ten repetitions.

Strength tests for the seed coats were conducted according to adapted Dobrzański's method [4], on the samples of 10 randomly selected seeds. Before the tests the rings of 2 mm width were cut out from selected seeds (figure 1); uniform thickness of seed coats on the whole ring surface was assumed. The rings were cut out from the central part of seeds at leaving two equal endings on both sides of a seed; special set of two knives connected at 2 mm distance was used for this purpose.

Figure 1. Section through the torn seed coat: a – width (constant value equal 2 mm), g – thickness



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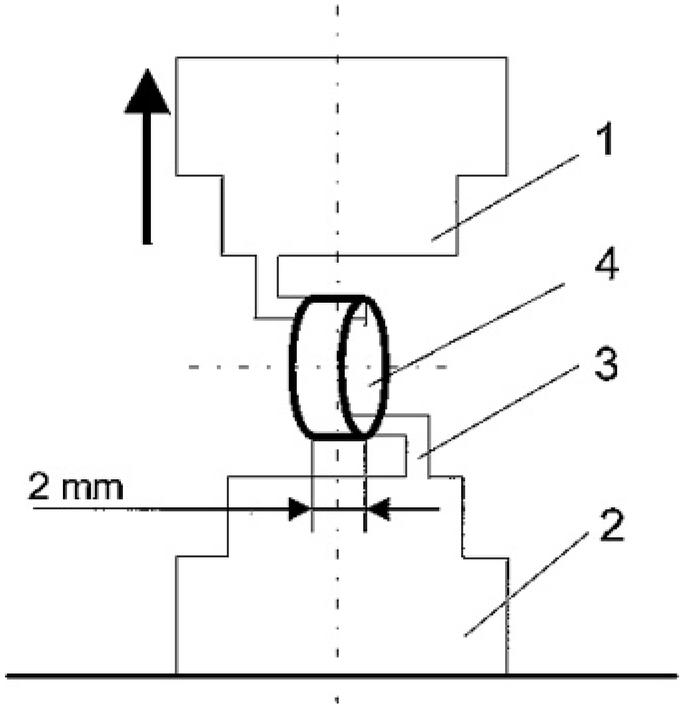
The seed coats prepared in such a way were tested for tearing on a test stand using Instron 4302 apparatus. The seed coats placed in the catches of 2 mm diameter, were teared by shifting the upper movable head at fixed velocity of 10 mm/min whence; maximum destructive force was recorded (figure 2). The tests were conducted in 10 replications; arithmetic mean for these replications were accepted as the results (table 3).

Figure 2. Scheme of tearing seed coats: 1 – upper movable head, 2 – lower stationary head, 3 – catch, 4 – seed coat torn in vertical position



Chemical compositions of whole seeds as well as the cotyledon fractions and the seed coats were analysed using: Kjeldahl's method for protein, Soxhlet's method for fat, Weende's method for the fibre.

In order to enhance the hulling process, the seeds were exposed to one of the following treatments:

- calibration of seeds;
- thermal treatment;
- humidification directly before hulling.

At the beginning the material consisted of well-formed seeds as well as too small ones which, after going through the grading gap of cylindrical roller mill, remained not hulled. In order to prevent such a situation, the lupine seeds were exposed to calibration process. 5 kg seed sample were sieved through two sieve with square gaps of 6.3 mm and 5.0 mm side dimensions. Only seeds from dimensional class within 6.3 to 5.0 mm were chosen to the tests.

Lupine seeds before testing were exposed to various temperatures. To do so, the sample of material were stored in a freezer or in a laboratory dryer at following temperatures for following time intervals:

- freezing at the temperature of –5°C, (freezing significantly weakened the bindings between seed coat and cotyledons),

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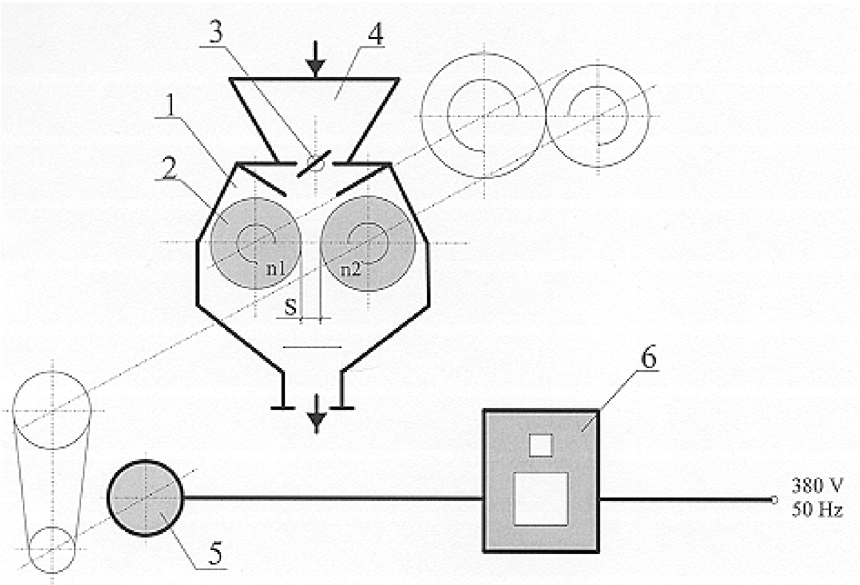
- conditioning at the temperature of 80°C for 20 min, (time of 20 min was required to get uniform heat distribution inside of seed),
- roasting at the temperature of 200°C for 10 min, (rapid vaporization water from seed coat without interfering in the cotyledon structure; higher temperature or larger exposition time could cause the expanding effect).

Hulling took place directly after the temperature treatment.

Before hulling process, the samples of 10% moisture content were moistened by dipping in water for ten minutes; next, the surplus of water was removed on the sieve of 2 mm square gaps.

The lupine seeds were hulled on an experimental stand (figure 3). The stand consisted of the two basic elements: the RUD z16 roller mill and VF61-7R44 frequency converter.

Figure 3. The experimental stand used for hulling: 1 – cylindrical mill roller, 2 – rollers, 3 – bar, 4 – feeding hopper, 5 – electric motor, 6 – frequency converter



Technical data of RUD z16 roller mill were as follows:

- motor power – 3.5 kW;
- motor rotary speed – 1500 r.p.m.,
- roller rotary speed – 400/1100 r.p.m.,
- roller length – 300 mm,
- grooving – 8 grooves/cm,
- grooving angle – 6 deg.

Before hulling the clearance between the rollers (working gap) was adjusted within the range of 2.0-4.0 mm. 5 kg lupine seed batches were processed. From hulled material 20 g samples were taken to determine the percentage of particular fractions. The effectiveness of hulling process was defined on the basic of numerical values of assumed hulling effectiveness index (formula 3):

$$E = \frac{L_1}{L_0} 100 \quad (3)$$

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where: E – hulling effectiveness index (%), L_1 – percentage of pure cotyledon fraction obtained at hulling (%), L_o – actual cotyledon content (%) calculated according to 2.4.

The final hulling product consisted of 4 fractions:

- fraction of cotyledons L_1,
- fraction of seed coats,
- floury fraction <0.5 mm (the mixture of cotyledons and seed coats),
- fraction of non-dehulled seeds.

RESULTS

Table 1 presents the measuring results for middle size lupine seeds of 10% moisture content. The data showed considerable difference in seed size among the angustifoliar lupine varieties (Emir, Sur), yellow (Juno, Amulet) and white varieties (Wat, Bardo). At average seed sizes of angustifoliar and yellow varieties on the level of 4.5 mm (range from 4.45 to 4.96 mm), the seeds of white lupine varieties were larger by 2.0 mm on an average (about 6.5 mm size).

Table 1. Average size of lupine seeds of 10% moisture content

Species	Variety	Average seed size (mm)
Blue	Emir	4.96
	Sur	4.95
White	Wat	6.42
	Bardo	6.45
Yellow	Juno	4.61
	Amulet	4.45

Data on the contents of cotyledons (by weight) in lupine seeds of 10% moisture content, are given in table 2. Determined values are similar for all tested lupine varieties ranging within 75-79% in relation to the whole seeds.

Table 2. Percentage of cotyledons in lupine seeds of 10% moisture content

Species	Blue		White		Yellow	
	Emir	Sur	Wat	Bardo	Juno	Amulet
Number of replications	10	10	10	10	10	10
Mean	77.076	76.159	78.900	77.395	75.963	77.250
Standard deviation	0.0389	0.0634	0.0684	0.1181	0.0535	0.0221
Min	77.01	76.09	78.79	77.27	75.88	77.21
Max	77.13	76.29	78.99	77.59	76.01	77.28
Range	0.12	0.20	0.20	0.32	0.13	0.07

Table 3 presents the regression equations and determination coefficients describing the changes in the values of force tearing seed coats *F*, as affected by increasing moisture content from 8.0 to 42.0%. It was found that the increase of moisture content in seeds of all tested lupine varieties caused rectilinear-like drops of tearing force *F*.

Table 3. Regression equations and R^2 value describing the changes in tearing force *F* in function of moisture *w* content ranging from 8.0 to 42.0%

Species	Variety	Regression equation	R^2
Blue	Emir	$F = 6.8 – 0.06\ w$	0.95
	Sur	$F = 6.7 – 0.06\ w$	0.96
White	Wat	$F = 7.8 – 0.08\ w$	0.93
	Bardo	$F = 7.9 – 0.07\ w$	0.94
Yellow	Juno	$F = 9.3 – 0.10\ w$	0.99
	Amulet	$F = 9.1 – 0.09\ w$	0.99

The data from table 4 show that the highest protein content in cotyledons were found in the seeds of yellow lupine, Juno and Amulet varieties (56.3 and 59.5%, respectively). Protein contents in cotyledons of remained varieties were somewhat lower, ranging from 39.8% in Wat variety to 50.2% in Emir variety. The protein content in seed coats was similar in all tested lupine varieties, ranging from 4.3% in Wat and Amulet varieties, to 5.4% in Emir variety. The distribution of protein in seeds ought to be noticed: in all considered cases the cotyledons contained above 90% protein (from 90.3% in seeds of Wat and Emir varieties, to 93.2% in seeds of Amulet variety).

Table 4. Chemical composition of lupine seeds

Species	Protein (%)			Fat (%)			Fibre (%)		
	seed	cotyledons	seed coat	seed	cotyledons	seed coat	seed	cotyledon	seed coat
Emir	39.8	50.2	5.4	6.1	7.7	0.7	4.1	1.7	12.2
Sur	35.9	43.8	4.6	5.8	7.0	0.8	3.2	1.2	11.1
Wat	32.1	39.8	4.3	9.9	12.5	0.5	2.8	1.1	8.9
Bardo	34.5	41.8	5.2	11.9	14.6	0.9	3.6	1.9	10.2
Juno	46.0	56.3	4.7	5.4	6.6	0.5	4.0	2.0	11.9
Amulet	46.8	59.5	4.3	4.1	5.2	0.5	4.4	2.1	12.3

Likewise as the protein, approximately 90% fat was concentrated in cotyledons; the highest content (95.8%) was observed in seeds of white lupine, Wat variety. Generally, the high fat content in white lupine seeds (14.6% in cotyledons and 0.9% in seed coats of Bardo variety), was lower almost by half in remained varieties, ranging from 5.2% in the cotyledons of yellow lupine seeds, Amulet variety, to 7.5% in cotyledons of angustifoliar lupine, Emir variety.

Quite opposite regularities occurred in lupine seeds in the case of the fibre. Prevailing part (approximately 90%) of the fibre was contained in the seed coats. The highest fibre concentration was found in seed costs of angustifoliar lupine, Sur variety.

Figures 4 and 5 present the effects of hulling lupine seeds subjected previously to various method of treatments. Because of unsatisfactory results of seed treatments with the temperatures of 80 and 200°C, the data obtained in these experiments were not taken into account. In both cases the indices of hulling effectiveness (E) ranged within 50-70%. Hulling process of the seeds conditioned at 80°C for 20 min was difficult because of gumming up the grooving in milling rollers (to high moisture content of external seed layers). The seeds conditioned at 200°C for 10 min were over ground at hulling (large amount of the floury fraction, <0.5 mm). Best results of hulling were obtained in the case of seeds previously moistened and frozen. The results of these experiments are presented on figures 4 and 5.

Figure 4. Comparison of the efficiency of working gap clearance at hulling process of lupine seeds exposed to wetting NR and not pre-treated NN

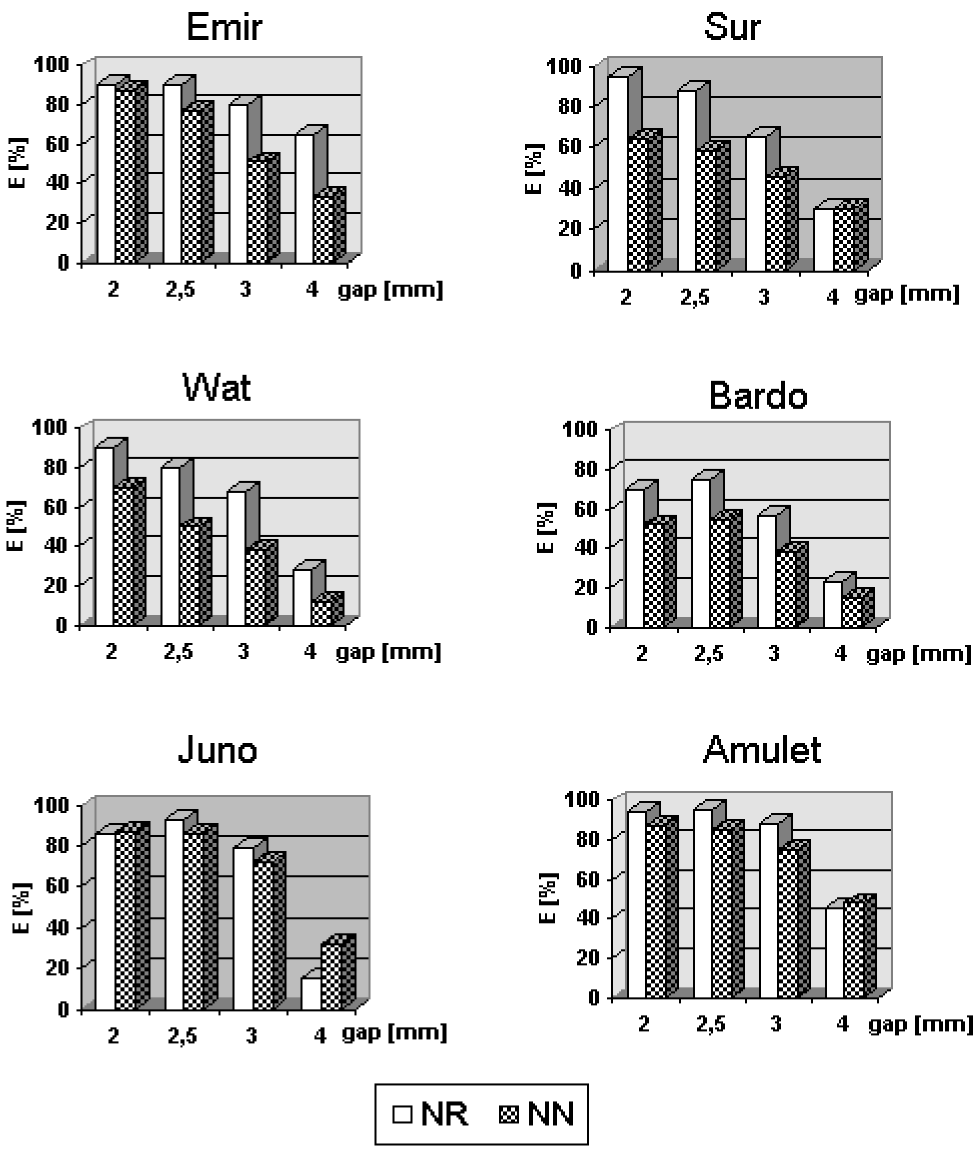
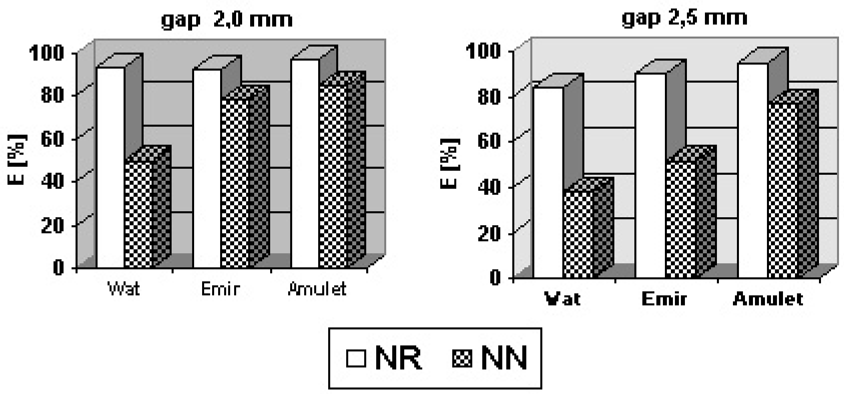


Figure 5. Comparison of hulling process efficiency of frozen NR and not pre-treated lupine seeds NN



Moistening of the seeds for 10 min before hulling in order to loose the bindings between seed coat and cotyledons and to soften the seed coat itself, improved the effectiveness of hulling. It was proved by high values of the hulling effectiveness indices *E*, as compared to these indices for seeds non-conditioned before hulling.

The relationships between the values of *E* index and working gap applied in hulling process (figure 4) should be indicated. The best hulling results were obtained in all cases when the process run at 2.0 or 2.5 mm clearance between the rollers.

Freezing was another preliminary treatment of lupine seeds. The results of these experiments are illustrated on figure 5. Because of practically identical values obtained for all the varieties of the same lupine, the diagrams presented only one curve (variety) for each lupine. The data presented on figure 5 show that the initially frozen seeds were much more susceptible to hulling process than the seeds not chilled. The indices of hulling effectiveness *E* calculated for the material initially frozen were much higher in comparison to seeds untreated in such way before hulling. That relationship appeared to be regular for hulling at both working gaps (roller clearances) 2.0 and 2.5 mm. Presumably, improving the quality of seed hulling process resulted from loosening the bindings between cotyledons and seed coats by freezing of free water in superficial sphere of the seeds.

CONCLUSIONS

On the basis of obtained results and some observations connected with the experiments following conclusions may be formulated:

1. At 10% moisture content of the material used in experiments, big dimensional differences were observed among the seeds of angustifoliar, yellow and white lupine varieties. Average dimension of the white lupine seeds was greater by almost 2 mm than the same size of angustifoliar and yellow lupine seeds.
2. The analysis of lupine seed structure showed that the cotyledons make 75-79% weight of the whole seeds. Study on chemical composition of whole lupine seeds and the products of their hulling indicated that the total content of protein in seed coats ranged from 4.3% for seeds of Amulet and Wat varieties, to 5.4% for Emir variety. Prevailing amount of the protein (about 90%) is contained in cotyledons. The highest protein

content (59.5%) was found in the cotyledons of Amulet variety seeds, while the lowest (39.8%) in cotyledons of Wat variety. The fat – similarly as protein – is distributed mostly in the cotyledons. Relatively high fat content in the seeds of white lupine is noteworthy. On the other hand, a significant reduction of fibre content in the final product is a result of hulling process. The seed coats contain about 90% of total fibre in lupine seeds.

3. The strength properties of lupine seed cover strongly depend of moisture content and decrease proportionally with increase of moisture content (table 3).

4. The roller mill of the characteristics described here, appeared to be useful to hulling lupine seeds; its easy adjustment makes this machine quite universal. Within the range of tested regulation variables the optimum setting of working gap (roller clearance) was 2.0-2.5 mm.

5. Searching the ways to improve the hulling effectiveness showed that the course of hulling was significantly affected by various preliminary processing of the seeds. From among applied preliminary seed treatments the positive influence on the results of hulling revealed:

   – the wetting of seed coats just before hulling,
   – freezing of the seeds by storage at minus temperatures.

6. There exists a need of more extensive studies to elaborate on effective method of separating the seed coats from cotyledon fraction of lupine seeds.

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