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Optimal parameters of sunflower seeds dehulling process with freezing

Introduction

Development and production of foodstuffs which ensure sufficient and healthy human nutrition is an actual topic nowadays.

One of the products of high nutritional value is sunflower seeds. Kernel of sunflower seed contains 62% of lipids and 21% of proteins which includes all essential amino acids [*Ikhno, 2004*].

Existing technology of sunflower seeds processing does not allow to utilize whole nutritional value of sunflower seeds, for instance units for sunflower seeds dehulling do not allow to remove whole hull from the kernel. As a result, after all stages of oil pressing and/or extraction, sunflower cake with content 39-40% of protein and 58% of fiber only can be obtained. Sunflower cake of that content of fiber can be used only as a feed for cattle.

Development of dehulling process that allows to obtain fully dehulled sunflower kernel is a major challenge in the industry.

Effect of dehulling significantly depends on direction, in which external forces act on the seed. If external forces act in longitudinal axis of the seeds, specific work for the hull destruction is the lowest comparing to the width and thickness directions. The values of specific work of the destruction for hull and for kernel are similar which is the reason of kernels damage and losses of oil during dehulling [*Koshevoi, 2001*]. The authors recommend to apply a number of methods of seeds treatment before dehulling to increase hulls brittleness. For this aims many different treatment techniques, such as fractionation of seeds by moisture, infrared treatment, freezing have been employed [*Lange et al., 1984; Ikhno, 2004; Shazzo, 2009*].

Lange et al. [*1984*] described effective method of sunflower seeds dehulling which includes the following stages: immersion of the seeds in the liquid nitrogen, immediate and rapid heating of the infused seeds by immersion into hot oil bath. The severe thermal stress caused the hull to split off from the seeds kernel which resulted in about 60% of dehulling process efficiency.

Perevalov et al. [*2010*] combined process of seeds pretreatment in the liquid nitrogen with dehulling process on the mechanical dehulling unit *Ikhno*-2 [1997]. During the dehulling process seed was exposed to single impact in the direction of seeds longitudinal axis due to advanced construction of the *Ikhno-2* dehulling unit. Results showed that freezing of seeds before dehulling allows to achieve 99% efficiency of the process. Additionally, technique of dehulling with freezing allows to minimize kernels damage during process and reduce losses of oil with the hull .

The first aim of this work is to estimate the influence of processes parameters (moisture of the seeds, rotor speed of the dehulling unit, temperature of seeds freezing) on the effectiveness of dehulling and kernels preservation from damage. The second aim of this work is to determine optimal parameters of the process.

Materials

Sunflower seeds used in the frame of this work were delivered by *Peresechanski Oil Producing Plant* (Kharkov). Seeds with initial moisture content 5.1% (wet-basis) were separated from the additives on the sieves.

Methods

Plan of the full factorial experiment

To estimate influence of the process parameters on efficiency of the dehulling with freezing the plan of two level full factorial experiment was elaborated. As a factors of the process were chosen: moisture content of seeds, rotor speed of the dehulling machine and temperature of seed freezing. Low and high level of variation for every factor are given in the tab. 1.

Tab. 1. Levels of variation for factors

Factor	Low level	High level
Seeds moisture content (W), % wet-basis	1.2	9.1
Rotor speed of the dehulling unit (N), rpm	1300	1700
Temperature of seeds freezing (T), ºC	-130	-30

The effect of each factor as well as effect of factors interaction on the variables such as coefficient of dehulling (C_d) and coefficient of kernel preservation from damage ($C_{k.p.}$) were estimated.

Samples preparation

To obtain 1.2% (wet-basis) seeds moisture content, samples were dried in the laboratory scale chamber dryer. Temperature of the seeds was kept below 80ºC during drying process. After every 30 min of drying samples were weighted and preliminary moisture content in the samples was determined. The final moisture content of the dried seeds was determined by drying to the constant weight in the oven at 105°C.

To obtain 9.2% (wet-basis) moisture content of the seeds the following moisturizing technique was employed. The seeds samples were placed in the wet medium (wet cotton tissue) for 30 min, then samples were weighted and preliminary moisture contentin the samples was determined. The procedure was repeated until the desirable moisture content of the seeds was achieved. The final moisture content of the wetted seeds was determined by drying to the constant weight in the oven at 105°C.

Seeds samples freezing and dehulling

The laboratory scale installation for seeds freezing consisted of vessel, detachable cap insulated with polystyrene foam, temperature controlling device (thermocouple) and doser of liquid nitrogen.

Sample of seeds (30 g) was placed in the vessel, where liquid nitrogen was fed with the feed rate 4 ml/min while needed temperature of the seeds freezing was achieved. Samples of the frozen seeds were immediately dehulled.

Dehulling of seeds was carried out in the laboratory scale *Ikhno-2* dehulling unit [1997]. Dehulled samples collecting system was organized to avoid losses of any part of the dehulled material. Cyclone with dedusting filter was attached to the outlet of the dehulling machine. Every freezing-dehulling test was performed twice.

Dehulled samples analysis

Dehulled sample was separated on the sieves (ø 3 and 2 mm) to isolate such fractions as oil dust and damaged kernel. Subsequently, the following fractions: kernel, hull, non-damaged seeds, non-dehulled seeds were isolated manually. All fractions were weighted and mass fractions were calculated and used for calculation of coefficients C_d and $C_{k.p.}$

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Coefficient of dehulling (C_d) and coefficient of kernel preservation from damage ($C_{k.p.}$) are the dimensionless values in the range of 0 and 1.0. A value of C_d close to 1.0 indicates good effectiveness of dehulling process (high content of fully dehulled kernel in the sample). A value of $C_{k.p.}$ close to 1.0 indicates that damage of kernel during the process is eliminated (high content of non-damaged kernel and low content of oil dust in the sample).

Results and discussions

Results obtained from the tests conducted according to the experimental plan are given in the tab. 2.

Tab. 2. Results of the experiment

Test no.	N, rpm	W, %w.b.	T, °C	C_d	$C_{k.p}$
1	1700	9.1	-130	0.991±0.003	0.758±0.002
2	1300	9.1	-130	0.950±0.005	0.864±0.038
3	1700	1.2	-130	0.994±0.002	0.686±0.028
4	1300	1.2	-130	0.986±0.001	0.840±0.015
5	1700	9.1	-30	0.872±0.061	0.858±0.034
6	1300	9.1	-30	0.626±0.019	0.874±0.051
7	1700	1.2	-30	0.981±0.007	0.920±0.023
8	1300	1.2	-30	0.944±0.017	0.955±0.009

Values of C_d and $C_{k.p.}$ are the mean ± standard deviation of at least 2 determinations. N is rotor speed of the dehulling unit, W is moisture content of the seeds, T is temperature of freezing.

First order regression equations were obtained for two variables C_d and $C_{k.p}$. Regression equation for C_d is

$$C_d = 0.9142 + 5.197 \cdot 10^{-5} N - 0.133 W - 4.772 \cdot 10^{-4} T + 6.353 \cdot 10^{-5} NW + 3.156 \cdot 10^{-7} NT - 8.853 \cdot 10^{-4} WT + 4.094 \cdot 10^{-7} NWT \qquad (1)$$

Regression equation for $C_{k.p}$ is

$$C_{k.p.} = 0.9751 + 1.4 \cdot 10^{-5} N - 0.012 W - 2.019 \cdot 10^{-3} T + 2.612 \cdot 10^{-6} NT + 2.612 \cdot 10^{-6} NT - 1.5 \cdot 10^{-4} WT \qquad (2)$$

The aim of regressions equations analysis was to check possibility to achieve high values of C_d as well as $C_{k.p}$ for two cases: for relatively high freezing temperatures –20°C, –30°C (to reduce process costs) and for moisture content of seeds equal to 7% which is the optimal for processing and storage [*Niewiadomski, 1979*]).

Series of the plots that represent changes of C_d and $C_{k\cdot p}$ for different temperatures, rotor speeds, and defined seeds moisture content were elaborated using regression equations. In this work plots for seeds moisture content 2% (Fig. 1) and 7% (Fig. 2) are presented.

Analysis of the plots shows that high effectiveness of the process (C_d = 0.959, $C_{k.p}$ = 0,932) can be achieved under the following conditions: temperature of freezing –20 °C, moisture content of the seeds 2%, rotor speed 1700 rpm (Fig. 1).

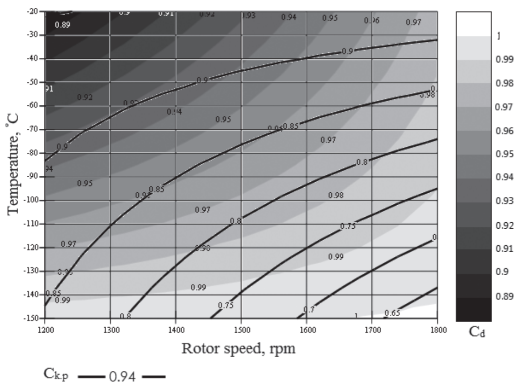

Fig. 1. Changes of C_d and $C_{k.p}$ for different temperatures, rotor speeds, and 2% moisture content of the seeds (contours in the shades of gray depict changes of C_d, contours with black solid lines depict changes of $C_{k.p}$)

Fig. 2 shows changes of C_d and $C_{k\cdot p}$ for different temperatures, rotor speeds and moisture content of seeds equal to 7%. The following parameters of the effective dehulling process (C_d = 0.999, $C_{k.p}$ 0.860) for seeds with 7% moisture content were determined: temperature of freezing –150°C, rotor speed 1300 rpm (Fig. 2).

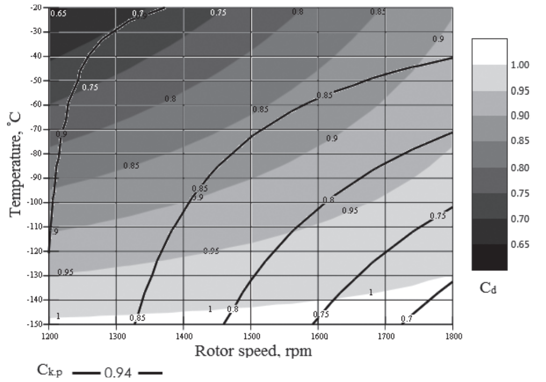

Fig. 2. Changes of C_d and $C_{k.p}$ for different temperatures, rotor speeds and 7% moisture content of the seeds (contours in the shades of gray depict changes of C_d, contours with black solid lines depict changes of $C_{k.p}$)

Since some of the theoretically determined optimal parameters (temperatures –20°C, –150°C) lie beyond the boundaries of variation of factors (Tab. 1), experimental tests for this parameters were carried out to confirm results obtained using regression equations. Comparison of calculated and experimental results for C_d and $C_{k.p}$ are given in the tab. 3. Test 11 was carried out for values of parameters which lie in center of of variation of factors.

Tab. 3. Comparison of calculated and experimental results for C_d and $C_{k.p}$

Test no.	N, rpm	W, %w.b.	T, °C	C_d		$C_{k.p}$	
				calculated.	experimental	calculated.	experimental
9	1700	2.0	-20	0.959	0.958±0.008	0.932	0.922±0.014
10	1300	7.0	-150	1.000	0.970±0.013	0.860	0.851±0.027
11	1500	5.0	-80	0.912	0.956±0.001	0.844	0.882±0.016

Values of $C_{d,}$ and $C_{k.p.}$ are the mean ± standard deviation of at least 2 determinations

Results of theoretical prediction for optimal parameters of the process are completely consistent with results of experimental tests.

Conclusions

In the frame of the work sunflower seeds dehulling process with freezing in a liquid nitrogen was analyzed. In order to estimate influence of parameters on effectiveness of the process the two level factorial plan of experiments was elaborated. Regression equations were obtained for two variables: coefficient of dehulling and coefficient of kernels preservation from damage.

Analysis of regression equations allowed to find optimal parameters for dehulling process. High efficiency of the dehulling process (C_d = 0.958, $C_{k.p}$ = 0,922) can be achieved applying relatively high temparatures (–20°C, –30°C).

Regression equations can be used for estimation of process parameters on the effectiveness of the dehulling process for the wide range of operation parameters.

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