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ANALYSIS OF THE EFFICIENCY OF CEREAL GRAIN AND BUCKWHEAT NUTLET SEPARATION IN A GRADER WITH INDENTED POCKETS

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K e y w o r d s: buckwheat, cereal grain, indicators of separation efficiency.

A b s t r a c t

This study describes the impact of indented pocket depth, the factor of static load of the cylinder with mixture and the setting angle of the working edge of the trough on buckwheat nutlet yield, the efficiency of cereal (wheat, rye, barley and oat) grain removal and the efficiency of mixture separation. The highest cleaning efficiency was reported in respect of indented pockets with a depth of 2.4 mm, the factor of static load of the cylinder with mixture of 0.2 and the setting angle of the working edge of the trough of 30°. At the above grader parameters, buckwheat nutlet yield, cereal grain removal and mixture separation efficiency reached 0.95, 0.83 and 0.78 respectively.

ANALIZA SKUTECZNOŚCI SEPARACJI ZIARNIAKÓW ZBÓŻ I ORZESZKÓW GRYKI W TRYJERZE Z WGŁĘBIENIAMI KIESZONKOWYMI

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S ł o w a k l u c z o w e: gryka, ziarniaki zbóż, wskaźniki efektywności rozdzielania.

A b s t r a k t

W pracy określono wpływ głębokości wgłębień kieszonkowych, wskaźnika statycznego obciążenia cylindra mieszaniną i kąta ustawienia roboczej krawędzi rynienki na uzysk orzeszków gryki, skuteczność wydzielania ziarniaków zbóż (pszenicy, żyta, jęczmienia i owsa) oraz skuteczność rozdzielania mieszaniny. Najlepsze efekty czyszczenia uzyskano dla wgłębień kieszonkowych o głębokości 2,4 mm, wskaźnika statycznego obciążenia cylindra mieszaniną 0,2 i kącie ustawienia roboczej krawędzi rynienki 30°. Przy tych parametrach tryjera uzysk orzeszków gryki wynosi 0,95, skuteczność wydzielania ziarniaków zbóż 0,83, a skuteczność rozdzielania mieszaniny 0,78.

Introduction

Threshed buckwheat nutlets contain various impurities, mostly wild radish siliques and cereal kernels (SEMCZYSZYN, FORNAL 1990). The effectiveness of graders equipped with a cylinder with indented pockets in the process of removing wild radish siliques from buckwheat raw material has been discussed in many publications (KALINIEWICZ, RAWA 2002a, 2002b, 2004). Yet to date there has been no study investigating the above grader's effectiveness in separating buckwheat nutlets from cereal kernels.

The objective of this study was to determine the impact of selected working parameters of a cylindrical grader with indented pockets on the efficiency of removing cereal kernels from the grain mixture where buckwheat nutlets constitute the main fraction.

Materials and Methods

The investigated material comprised nutlets of buckwheat cv. Luba with mass fraction of 80%, while the remaining fraction (20%) consisted of grain of 4 principal cereals: wheat cv. Nawra, rye cv. Bojko, barley cv. Blask and oat cv. Deresz, each accounting for 5% of the fraction. The relative moisture content of the investigated mixture components was as follows: buckwheat – 12.3%, wheat – 12.6%, rye – 11.8%, barley – 12.1% and oat – 11.5%. A high impurity content was adopted mainly due to the need to minimise measuring errors.

The study was conducted on a test stand presented in the work of KALINIEWICZ and RAWA (2004). It comprised a K-292 laboratory grader manufactured by Petrus, equipped with two cylinders with a length of 480 mm and internal diameter of 240 mm, each with indented pockets (KALINIEWICZ, RAWA 2002a, 2002b) with different indentation depth. The experiment was conducted in three replications with the following parameters:

1) constants:
   - horizontal inclination angle of cylinder axis – 2°,
   - distance from the working edge of the trough to cylinder surface – 6 mm,
   - cylinder's kinematic indicator – 0.25,
   - impurity content of buckwheat raw material – 20%,
2) variables:
   - working depth of indented pockets s = 2.4 mm and 2.8 mm,
   - factor of static load of the cylinder with mixture q_s = 0.1, 0.2 and 0.3,
   - setting angle of the working edge of the trough α = 10°, 20°, 30°, 40° and 50°,

3) results:
   - buckwheat nutlet yield ε_1,
   - efficiency ε_{2p} of wheat grain removal,
   - efficiency ε_{2z} of rye grain removal,
   - efficiency ε_{2j} of barley grain removal,
   - efficiency ε_{2o} of oat grain removal,
   - efficiency ε_2 of impurities removal,
   - efficiency ε of mixture separation.

The cylinder was filled with the mixture for around 60 s before every experiment. After the feeder and the grader were stopped, the trough and the waste container were removed and emptied. As the trough and the waste container were fitted back in place, the feeder and the grader were activated for 1 minute and the proper measurement was conducted. The waste which accumulated in the trough and in the waste container was separated into 5 fractions: buckwheat nutlets, wheat, rye, barley and oat kernels. Every fraction was weighed on laboratory scales with measuring precision of 0.01 g.

Buckwheat nutlet yield was determined based on the ratio of the weight of nutlets removed to the trough and the total weight of nutlets in the trough and in the waste container. The efficiency ε_{2i} of cereal grain removal was estimated based on the ratio of the weight of grain of every cereal species removed to the waste container and the total weight of cereal grain in the trough and in the waste container. The efficiency ε_{2i} of impurity removal was determined based on the ratio of the total weight of cereal grain removed to the waste container and the total weight of cereal grain in the trough and in the waste container. The efficiency of mixture separation ε was determined with the application of the formula (GROCHOWICZ 1994):

$$\varepsilon = \varepsilon_1 - (1 - \varepsilon_2) \tag{1}$$

Experimental results were processed with the use of Winstat and Statistica software. The functions describing dependent variables were determined by a multivariate regression analysis using a second-order polynomial model with stepwise elimination of non-significant variables and polynomial degree.

Results and Discussion

The highest efficiency $\varepsilon = 0.78$ (Fig. 1) of separation of the five-component mixture was reported in respect of indented pockets with a depth of s = 2.4 mm at the factor of static load of the cylinder with mixture of q_s = 0.3 and the setting angle of the working edge of the trough of $\alpha = 30^{\circ}$. Buckwheat grain loss did not exceed 5% (ε_1 = 0.95), and impurity removal efficiency reached ε_2 = 0.83. The elimination efficiency of barley and oat kernels was slightly above the average, while below average results were observed in respect of wheat and rye kernels. A similar trend was observed within the entire range of variation of the analysed factors. A comparison of the obtained data with the results of other research studies indicates that graders with indented pockets may be effectively used to clean buckwheat material of grain impurities. The efficiency of mixture separation on a precision cleaning line in a buckwheat processing plant (SEMCZYSZYN, FORNAL 1990) reached only 0.36. It should be noted, however, that the analysed mixture had a different composition – in addition to cereal kernels, it also comprised Tatarian buckwheat, bluebottle and vetch seeds, wild radish siliques as well as other organic and mineral impurities. KONOPKA (2006) separated a mixture consisting of buckwheat nutlets, kernels of four principal grain species and wild radish siliques in a separator whose cylindrical surface comprised adequately spaced circular-section rods. In the variant involving a separator with grooves, mixture separation efficiency reached around 0.63 with buckwheat loss of up to 14%. The highest efficiency of elimination was reported in respect of barley grains, and the lowest – in rye grains. When a separator without grooves was applied to separate a fraction with a thickness of 3.1 ÷ 3.5 mm, mixture separation efficiency increased to 0.92 and the loss of buckwheat nutlets was minimised to 6%.

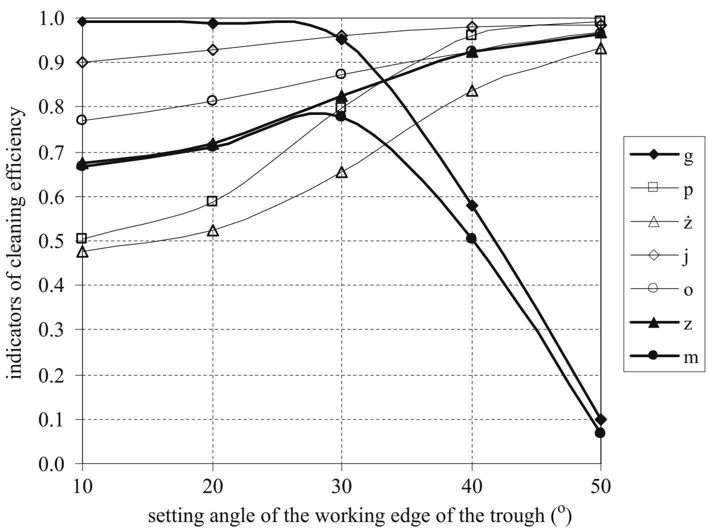

Fig. 1. Buckwheat nutlet yield (g) ε_1, efficiency ε_{2p} of wheat grain removal (p), efficiency ε_{2p} of rye grain removal (ż), efficiency ε_{2j} of barley grain removal (j), efficiency ε_{2o} of oat grain removal (o), efficiency $\varepsilon 2$ of cereal grain removal (z), efficiency ε of mixture separation (m) subject to the setting angle α of the working edge of the trough for indented pockets with a depth of s = 2.4 mm and the factor of static load of the cylinder with mixture of q_s = 0.2

Source: Author's calculations.

Straight-line correlation coefficients between dependent and independent variables are presented in Table 1. Within the analysed range of variation, the above coefficients ranged from 0.154 to 0.803. The investigated qualitative indicators of the separation process are most closely related to the setting angle of the grader trough. On the one hand, a higher setting angle reduces buckwheat nutlet yield and mixture separation efficiency, while on the other – it increases grain removal effectiveness. At the analysed level of significance, buckwheat nutlet yield is profoundly affected only by the setting angle of the working edge of the grader trough, and the efficiency of mixture separation – by the depth of indented pockets. There was no significant correlation between the efficiency of wheat grain removal and the factor of static load of the cylinder with mixture. In the remaining cases, correlation coefficients where higher than the critical value.

Table 1

Coefficients of straight-line correlation between variables

	ε_1	ε_{2p}	ε_{2z}	ε_{2j}	ε_{2o}	ε_2	ε
s	0.154	-0.529	-0.576	-0.475	-0.478	-0.526	-0.388
q_s	-0.162	0.347	0.385	0.433	0.504	0.427	0.267
α	-0.803	0.716	0.674	0.526	0.598	0.663	-0.319

Critical value of correlation coefficient – 0.361
Adopted level of significance – 0.05
Source: Author's calculations.

Since only two cylinders recommended for buckwheat cleaning were used in the experiment (with a different depth of indented pockets), second-order regression equations were developed separately for each cylinder. The functions describing qualitative indicators of the separation process within the analysed range of variation of independent factors are presented in Table 2. All equations are statistically significant at a level of 5%. The highest percentage of explained variation was recorded for the efficiency of rye grain removal (98.2) in the cylinder with s = 2.4 mm indented pockets, and the lowest for the efficiency of mixture separation (27.9) with the application of indented pockets with a depth of s = 2.8 mm. A comparison of the two tested cylinders shows greater consistency with the data specific for s = 2.4 mm indented pockets in respect of buckwheat nutlet yield, the efficiency of wheat and rye grain removal and the efficiency of mixture separation, while lower consistency was reported in respect of the efficiency of barley and oat grain removal and the efficiency of impurity removal. The above equations also indicate that despite an occasionally non-significant correlation between the factors, variable data may enter the equation in the form of a second-order effect or an interaction.

Table 2

Regression equations for qualitative indicators of the separation process

s [mm]	Regression equation	% explained variation	Standard deviation of residuals
2.4	$\varepsilon_1 = 0.04\alpha - 0.001\alpha^2 - 0.02q_s \cdot \alpha + 0.72$	96.91	0.07
	$\varepsilon_{2p} = 5.75q_s + 0.03\alpha - 6.28q_s^2 - 0.06q_s \cdot \alpha - 0.59$	97.50	0.05
	$\varepsilon_{2z} = 4.68q_s + 0.02\alpha - 5.39q_s^2 - 0.04q_s \cdot \alpha - 0.43$	98.18	0.04
	$\varepsilon_{2j} = 0.01\alpha + 0.75$	41.47	0.09
	$\varepsilon_{2o} = 0.03q_s \cdot \alpha + 0.66$	51.87	0.11
	$\varepsilon_2 = 5.27q_s + 0.02\alpha - 6.99q_s^2 - 0.05q_s \cdot \alpha - 0.26$	96.48	0.04
	$\varepsilon = 0.05\alpha - 0.001\alpha^2 + 0,15$	76.47	0.13
2.8	$\varepsilon_1 = 0.04\alpha - 0.001\alpha^2 - 0.02q_s \cdot \alpha + 0.67$	93.07	0.08
	$\varepsilon_{2p} = -0.02\alpha + 0.0004\alpha^2 + 0.05q_s \cdot \alpha + 0.11$	95.31	0.08
	$\varepsilon_{2z} = -0.02\alpha + 0.0004\alpha^2 + 0.04q_s \cdot \alpha + 0.16$	96.78	0.05
	$\varepsilon_{2j} = 0.05q_s \cdot \alpha + 0.38$	61.73	0.17
	$\varepsilon_{2o} = 0.06q_s \cdot \alpha + 0.26$	70.41	0.15
	$\varepsilon_2 = 2.48q_s + 0.0003\alpha^2 - 0.02q_s \cdot \alpha - 0.22$	97.45	0.05
	$\varepsilon = 1.20q + 0.08$	27.88	0.16

Adopted level of significance – 0.05
Source: Author's calculations.

Conclusions

1. The conducted experiment shows that a cylindrical grader with indented pockets may be applied in the separation process to improve the purity of buckwheat material. The highest impurity removal efficiency was reported in respect of barley kernels, and the lowest – in respect of rye kernels.
2. Within the analysed range of variation of indentation depth, the factor of static load of the cylinder with mixture and the setting angle of the working edge of the trough, the last parameter had the greatest impact on the qualitative indicators of the separation process. In the investigated case, the correlation coefficient ranged from 0.53 for the efficiency of barley grain removal to 0.80 for buckwheat nutlet yield.
3. The developed regression equations may be used to model the processes of separating buckwheat nutlets from impurities due to the high (in most cases) percentage of explained variation and relatively low standard deviation values of the residuals.

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