TECHNICAL SCIENCES
Abbrev.: Techn. Sc., 2011, 14(1)

THE EFFECT OF THE IMPURITY CONTENT OF BUCKWHEAT NUTLETS ON PRODUCT PURITY AFTER CLEANING IN A GRADER WITH INDENTED POCKETS

Zdzisław Kaliniewicz

Department of Heavy Duty Machines and Separation Processes
University of Warmia and Mazury in Olsztyn

Key words: buckwheat, wild radish, impurity content, grader.

Abstract

This study analyzed four mixtures of buckwheat nutlets and wild radish siliques with impurity content (wild radish siliques) of 2.5, 5.0, 7.5 and 10.0%. Buckwheat nutlet yield, the efficiency of wild radish silique removal, the efficiency of mixture separation and product purity were determined at two depth settings of indented pockets (2.4 and 2.8 mm), three factors of static load of the cylinder with the mixture (0.1, 0.2 and 0.3 of full load) and five angles of the working edge of the trough (10, 20, 30, 40 and 50°). The obtained results indicate that the impurity content of raw material significantly affects the purity of the separated product.

WPŁYW STOPNIA ZANIECZYSZCZENIA SUROWCA ZIAREN GRYKI NA CZYSTOŚĆ PRODUKTU PO CZYSZCZENIU W TRYJERZE Z WGŁĘBIENIAMI KIESZONKOWYMI

Zdzisław Kaliniewicz
Katedra Maszyn Roboczych i Procesów Separacji
Uniwersytet Warmińsko-Mazurski w Olsztynie

Słowa kluczowe: gryka, rzodkiew świrzepa, stopień zanieczyszczenia, tryjer.

Abstrakt

Do badań wykorzystano cztery mieszaniny ziaren gryki i łuszczyn rzodkwi świrzepy o udziale: 2,5, 5,0, 7,5 i 10,0% składnika zanieczyszczającego – łuszczyn rzodkwi świrzepy. Wyznaczano uzysk ziarna gryki, skuteczność wydzielania łuszczyn rzodkwi świrzepy, skuteczność rozdzielania mieszaniny i czystość produktu na dwóch głębokościach wgłębień kieszonkowych (2,4 i 2,8 mm), przy trzech wskaźnikach statycznego obciążenia cylindra mieszaniną (0,1, 0,2 i 0,3 pełnego obciążenia) oraz pieciu kątach ustawienia roboczej krawędzi rynienki (10, 20, 30, 40 i 50°). Stwierdzono, że stopień zanieczyszczenia surowca wpływa istotnie na czystość produktu czyszczenia.

Symbols:

c – purity of separated product,
s – depth of indented pockets, mm,
q_s – factor of static load of the cylinder with mixture,
z – impurity content of raw material, %,
α – setting angle of the working edge of the trough, °,
ε – efficiency of mixture separation,
ε_1 – buckwheat nutlet yield,
ε_2 – efficiency of wild radish silique removal.

Introduction

Wild radish siliques constitute a group of impurities that are difficult to remove from buckwheat nutlet mixtures. The silique content of threshed buckwheat nutlets may be as high as 6% (SEMCZYSZYN, FORNAL 1990), accounting for 40% to 70% of total useless impurities. Under the repealed Polish Standard PN-R-65023:1999, which is yet to be replaced with an updated version, seed material was grouped into three quality classes (I – 98%, II – 98% and III – 96%). The admissible quantity of other plant seeds in the raw material was determined by the purity class. The number of other plant seeds in 1 kg of seed material was set at up to 50 seeds in super elite (SE) and elite (E) seed, up to 100 seeds in original (O) seed, up to 200 seeds in primary reproduction seed (I ods.) and certified seed (Okw), and up to 340 seeds in uncertified single-variety seed (No) and uncertified seed of unknown variety (N).

Wild radish siliques can be effectively removed from seed material in a grader with indented pockets (KALINIEWICZ 2000). To date, the grader's separation efficiency was analyzed at a constant impurity content of the purified material. The effect of impurity content on the purity of the separated mixture of buckwheat nutlets and wild radish siliques has not been investigated. According to the proposed hypothesis, the impurity content of buckwheat nutlets cleaned in a grader with indented pockets determines the purity of the resulting product.

The objective of this study was to determine the boundary content of impurities – wild radish siliques – in seed material purified in a grader with indented pockets which guarantees 95% buckwheat nutlet yield for a given product quality class.

Materials and Methods

The experimental material comprised nutlets of buckwheat cv. Luba and wild radish silique segments harvested in a farm estate near Olsztyn. The relative moisture content of the investigated mixture components was 12.3%

and 11.9%, respectively, with a corresponding thousand seed weight and thousand silique weight of 25.38 g and 21.43 g, respectively. The resulting mixture comprised buckwheat nutlets as the main component and wild radish siliques as the impurity. The percentage quantitative content of impurities in the mixture was 2.5%, 5.0%, 7.5% and 10.0% (percentage content by weight – 1.9%, 4.2%, 6.4% and 8.6%).

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

1) constants:
– horizontal inclination angle of cylinder axis – 2^o,
– distance from the working edge of the trough to cylinder surface – 6 mm,
– cylinder's kinematic indicator – 0.25,
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^o, 20^o, 30^o, 40^o and 50^o,
– content of wild radish silique segments z = 2.5%, 5.0%, 7.5% and 10.0%,
3) results:
– buckwheat grain yield ε_1,
– efficiency ε_2 of wild radish silique removal,
– efficiency ε of mixture separation,
– purity c of the cleaned product.

Only two cylinders with a different depth of indented pockets recommended for buckwheat cleaning were used in the experiment (KALINIEWICZ 2000). The full load exerted by the mixture on the cylinder was determined on the assumption that all indented pockets can be filled with both buckwheat nutlets and wild radish siliques. Subject to the impurity content of the mixture, cylinder load varied from 175.4 to 177.7 kg h^{-1} for indented pocket depth s = 2.4 mm and 156.1 to 158.1 kg h^{-1} for indented pocket depth s = 2.8 mm.

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 two fractions, buckwheat nutlets and wild radish siliques. Every fraction was weighed on AM 500 laboratory scales with a measuring precision of 0.01 g.

Buckwheat grain yield ε_1 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_2 of wild radish silique removal was estimated based on the ratio of the weight of wild radish siliques removed to the waste container and the total weight of wild radish siliques in the trough and in the waste container. The efficiency ε of mixture separation was determined from the formula (GROCHOWICZ 1994):

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

The purity c of the cleaned product was determined as the ratio of the weight of buckwheat nutlets removed to the trough and the total weight of buckwheat nutlets and wild radish siliques in the trough.

Experimental results were processed with the use of Winstat and Statistica software.

Results and Discussion

Linear correlation coefficients between variables are presented in Table 1, indicating that all independent variables are not correlated. The investigated qualitative indicators of the separation process (dependent variables) were significantly correlated with the setting angle of the grader trough. The efficiency of wild radish silique removal was highly correlated with the depth of indented pockets. The factor of static load of the cylinder with mixture was also significantly correlated with the efficiency of wild radish silique removal. It should be noted that the impurity content was significantly correlated only with the purity of the cleaned product.

Table 1

Coefficients of linear correlations between variables

Variable (factor)	s	q_s	α	z
s	1.000	0.000	0.000	0.000
q_s	0.000	1.000	-0.000	-0.000
α	0.000	-0.000	1.000	0.000
z	0.000	-0.000	0.000	1.000
ε_1	0.101	-0.064	**-0.833**	0.040
ε_2	**-0.496**	**0.162**	**0.732**	-0.071
ε	**-0.108**	-0.002	**-0.675**	0.016
c	**-0.411**	0.079	**0.200**	**-0.552**

Critical value of correlation coefficient – 0.103
Adopted level of significance – 0.05
Source: author's calculations

Table 2 presents the statistical parameters of the adopted indicators and the results of one-way analysis of variance verifying the statistical hypothesis that the mean values obtained in each treatment are equal. The presented data also suggest a drop in product purity with an increase in the impurity content of the separated material. The above seems to be a logical consequence of the observation that the impurity content of the raw material has no significant effect on buckwheat nutlet yield and the efficiency of wild radish silique removal.

Table 2

Statistical parameters of dependent variables grouped according to the impurity content of the mixture

Variable	Impurity content	Mean	SD	Coefficient of variation	Test results
ε_1	$z_{2.5}$ $z_{5.0}$ $z_{7.5}$ $z_{10.0}$	0.734 0.737 0.755 0.769	0.343 0.345 0.340 0.343	46.67 46.83 45.03 44.62	F = 0.205 $p(F)$ = 0.893 no significant differences
ε_2	$z_{2.5}$ $z_{5.0}$ $z_{7.5}$ $z_{10.0}$	0.849 0.865 0.847 0.827	0.117 0.121 0.131 0.148	13.75 13.96 15.51 17.96	F = 1.280 $p(F)$ = 0.28 no significant differences
ε	$z_{2.5}$ $z_{5.0}$ $z_{7.5}$ $z_{10.0}$	0.583 0.601 0.603 0.596	0.281 0.288 0.281 0.276	48.18 47.90 46.71 46.36	F = 0.092 $p(F)$ = 0.965 no significant differences
c	$z_{2.5}$ $z_{5.0}$ $z_{7.5}$ $z_{10.0}$	0.995 0.992 0.987 0.980	0.003 0.005 0.011 0.012	0.33 0.49 1.14 1.22	F = 53.541 $p(F)$ = 0.000 $z_{2.5}, z_{5.0} > z_{7.5}, z_{10.0}$** $z_{2.5} > z_{5.0}$* $z_{7.5} > z_{10.0}$**

F – calculated value of the test statistic
$p(F)$ – probability that the calculated value of test statistic F is exceeded
* – statistically significant differences at α = 0.05
** – statistically significant differences at α = 0.01
Source: author's calculations

The next stage of the experiment involved a multivariate regression analysis using a second-order polynomial model with stepwise elimination of non-significant variables and polynomial degree for buckwheat nutlet yield and the purity of the cleaned product. The following functions were determined with the percentage of explained variability of 95.62 and 68.72, and the standard deviation of residuals of 0.072 and 0.006, respectively:

$$\varepsilon_1 = (24.993 \cdot \alpha - 1.016 \cdot \alpha^2 + 6.114 \cdot s \cdot \alpha + 693.800) \cdot 10^{-3} \qquad (2)$$

$$c = (7.751 \cdot z - 2.127 \cdot s^2 - 0.137 \cdot z^2 - 0.019 \cdot \alpha^2 - 4.909 \cdot s \cdot z + \\ - 3.591 \cdot s \cdot z + 0.400 \cdot s \cdot \alpha + 0.041 \cdot z \cdot \alpha + 1001.339) \cdot 10^{-3} \qquad (3)$$

It has been assumed that buckwheat nutlet loss cannot exceed 5%. In view of the above, equation (2) was used to determine the allowable range of trough setting angles for every indentation depth which was below 28° for $s = 2.4$ mm and below 32° for $s = 2.8$ mm.

Assuming that wild radish siliques are the only impurity in the mixture and that siliques, whose thousand segment weight is identical to that determined in raw material, have not been completely removed, product purity may reach the following boundary values for buckwheat nutlets of the following quality class:

– super elite (SE) and elite (E) seed – $c = 0.9989$,

– original (O) seed – $c = 0.9978$,

– primary reproduction (I ods.) seed and certified seed (Okw.) – $c = 0.9957$,

– uncertified single-variety seed (No) and uncertified seed of unknown variety (N) – $c = 0.9927$.

The above values and the determined setting angles of the working edge of the trough were input in equation (3) to calculate the admissible (boundary) impurity content of raw material which guarantees seed yield of a given quality class (disregarding the material's sowing value). The resulting data, shown in Figure 1, indicate that super elite and elite seed may be obtained when the angle of the working edge of the trough is higher than 14° for pocket depth $s = 2.4$ mm and higher than 19° for pocket depth $s = 2.8$ mm. The above parameters guarantee the lowest buckwheat nutlet loss during separation. At 5% buckwheat nutlet loss, the boundary content of wild radish siliques in the material is 5.1% and 1.8% for the above pocket depths, respectively. In seed material of the lowest quality class, the boundary impurity content of the mixture separated in a grader with indented pockets may be as high as 8.9% for pocket depth $s = 2.4$ mm and 5.0% for pocket depth $s = 2.8$ mm.

Conclusions

1. The results of a correlation analysis indicate that the content of wild radish silique impurities in buckwheat nutlets significantly affects the purity of seed material cleaned in a grader with indented pockets. The impurity content of seed material has no significant effect on buckwheat nutlet yield, the efficiency of wild radish silique removal and the efficiency of mixture separation.

2. Wild radish siliques are most effectively separated from buckwheat nutlets in a grader with indented pockets with a depth of 2.4 mm when the

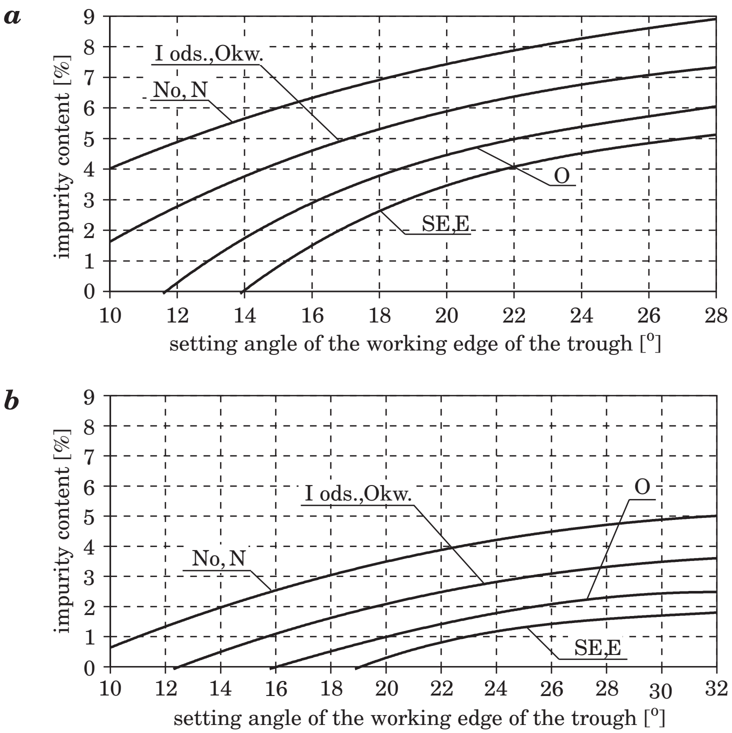

Fig. 1. Boundary content of wild radish silique impurities in buckwheat nutlets before cleaning in a grader with indented pockets that guarantees the production of seed material in the following quality classes: a – s = 2.4 mm, b – s = 2.8 mm; SE – super elite seed, E – elite seed, O – original seed, I ods. – primary reproduction seed, Okw. – certified seed, No – uncertified single-variety seed, N – uncertified seed of unknown variety

Source: developed by the author.

working edge of the trough is set at a maximum angle of 28°. The above parameters guarantee minimal buckwheat nutlet yield of 0.95 (buckwheat nutlet loss does not exceed 5%). The investigated grader may be applied to produce super elite seed provided that the impurity content of the material does not exceed 5.1% at the highest setting of the working edge of the trough.

Translated by ALEKSANDRA POPRAWSKA

Accepted for print 19.11.2010

References

GROCHOWICZ J. 1994. *Maszyny do czyszczenia i sortowania nasion*. Wyd. Akademii Rolniczej. Lublin. ISBN 83-901612-9-X.

KALINIEWICZ Z. 2000. *Modelowanie tryjerów z wgłębieniami kieszonkowymi w aspekcie poprawy skuteczności czyszczenia nasion gryki*. Rozprawa doktorska. Wydział Budownictwa, Mechaniki i Petrochemii Politechniki Warszawskiej w Płocku. Maszynopis.

KALINIEWICZ Z., RAWA T. 2004. *Wyniki eksperymentalnej weryfikacji apriorycznego modelu matematycznego rozdzielczości tryjera do gryki*. Inżynieria Rolnicza, 3(58): 211–218.

Materiał siewny, nasiona roślin rolniczych. PN-R-65023:1999. Wydawnictwo Normalizacyjne, Warszawa.

SEMCZYSZYN M., FORNAL Ł. 1990. *Analiza skuteczności pracy urządzeń czyszczących stosowanych w liniach technologicznych czyszczenia ziarna gryki. II. Wyniki badań jakości pracy urządzeń czyszczących*. Acta Acad. Agricult. Techn. Olst., Aedif. Mech., 21: 111–121.