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TWO MATHEMATICAL FORMULAS FOR ASSESSING SEED SEPARATION EFFICIENCY

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A b s t r a c t

Two mathematical formulas for assessing the efficiency of seed mixture separation were analyzed. Increases in the crop seed yield and the efficiency of impurity separation were accompanied by higher seed separation efficiency regardless of the adopted formula. One of the examined formulas carried more information, and it could be used to determine the improvement in the purity of the separated product relative to the raw material. The difference in the analyzed formulas' ability to determine the efficiency of seed separation was minimized when the separation process was more efficient, i.e. when the value of partial indicators of separation efficiency was closer to 1. Both formulas could be successfully used to describe seed separation efficiency because in most practical applications, the error generated by the evaluated formulas did not exceed 1.5%.

Symbols

a – share of crop seeds in a sample of purified seeds,
a_p – share of crop seeds in the separated product,
a_o – share of discarded crop seeds,
b – share of impurities in a sample of purified seeds,
b_i – share of impurities of the i^{th} species in a sample of purified seeds,
b_p – share of impurities in the separated product,
b_o – share of discarded impurities,
b_{oi} – share of discarded impurities of the i^{th} species,
c – purity of purified seeds,
c_p – purity of the separated product,
z – crop seed loss,
ε_1 – crop seed yield,
ε_2 – efficiency of impurity separation,
ε_{2i} – efficiency of separating impurities of the i^{th} species,
ε – efficiency of seed mixture separation.

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Introduction

In Poland, 75% of total crop acreage is dedicated to the production of cereal seeds. Other seed-producing plants include grasses, legumes, industrial crops, vegetables, culinary and medicinal herbs and ornamental plants. In addition to the main species, most field treatments contain other plant species which contaminate the main crop after harvest to a varied degree. Such impurities include the seeds of both crop plants and weeds (GROCHOWICZ 1994, PIETKIEWICZ, WIERZBICKI 1988, SEMCZYSZYN, FORNAL 1990). Seeds harvested from very clean and well-maintained treatments may contain organic (plant stems, leaves, husks, etc.) and mineral impurities (sand, gravel). In some cases, those impurities cannot be fully separated from crop seeds (SEMCZYSZYN, FORNAL 1990, RAWA, SEMCZYSZYN 1988, WIERZBICKI et al. 1991).

Seed mixtures have to be purified to meet qualitative requirements. Purification processes lead to a certain loss of crop seeds which are discarded together with impurities (CHOSZCZ, WIERZBICKI 1994, KALINIEWICZ 2011, GROCHOWICZ 1994, SEMCZYSZYN, FORNAL 1990). This does not pose a serious problems when weakly developed, broken or infected seeds are discarded. In many cases, separation leads to the elimination of healthy and plump seeds which are well suited for consumption or sowing (KALINIEWICZ et al. 1994, PIETKIEWICZ, WIERZBICKI 1988).

The results of the separation process can be described with the use of various indicators, such as product purity, crop seed yield, crop seed loss, separation efficiency of one or all types of impurities and efficiency of mixture separation. The latter concerns the entire seed mixture, and it should be the most comprehensive source of information for the user of a given separation device. The efficiency of seed mixture separation has been calculated by various authors with the use of two different formulas. The formulas could differ in their ability to accurately determine the efficiency of mixture separation.

The objective of this study was to evaluate the ability of two mathematical formulas to describe changes in seed purification parameters.

Theoretical assumptions

Indicators of seed separation quality can be determined based on the share (by number or weight) of different seed species in the mixture. The determination of the weight of every mix component and the calculation of the respective indices is an easier and a less time-consuming method. The number of separated seeds can be determined when purity standards for a given product define the maximum allowable number of contaminating seeds.

The purified mixture contains crop seeds as well as various impurities. Mixture purity can be determined with the use of the following formula:

$$c = \frac{a}{a + b} \tag{1}$$

As a result of separation, the first and second set are halved. One half is transferred to the separated product, and the other half is discarded. Therefore:

$$a = a_p + a_o \tag{2}$$

$$b = b_p + b_o \tag{3}$$

The separated product may be characterized by the following indicators:
– purity

$$c_p = \frac{a_p}{a_p + b_p} \tag{4}$$

– crop seed yield

$$\varepsilon_1 = \frac{a_p}{a} = \frac{a_p}{a_p + a_o} \tag{5}$$

– crop seed loss

$$z = 1 - \varepsilon_1 = \frac{a}{a_p + a_o} \tag{6}$$

The objective of the separation process is to eliminate impurities from raw material. The efficiency of separating a specific impurity is determined with the use of the following formula:

$$\varepsilon_{2i} = \frac{b_{oi}}{b_i} \tag{7}$$

and the efficiency of separating all impurities:

$$\varepsilon_2 = \frac{\Sigma b_{oi}}{\Sigma b_i} = \frac{b_o}{b} \tag{8}$$

For the separation process to be described by a single indicator, it has to account for both crop seed yield and the effectiveness of impurity separation. The following formula has been proposed by GROCHOWICZ (1994):

$$\varepsilon' = \varepsilon_1 - (1 - \varepsilon_2) \tag{9}$$

According to RAWA (1992, 1994), the efficiency of mixture separation can be determined with the use of the following formula:

$$\varepsilon'' = \varepsilon_1 \cdot \varepsilon_2 \tag{10}$$

The choice of the above formula was probably dictated by its widespread use, for example in calculations of the overall efficiency of technical devices (ADAMKIEWICZ, JARZĘCKI 2009, HETMAŃCZYK, WINCHULA 2012, KOJTYCH et al. 1998, KRAWCZYK 2010, KUCZEWSKI, MISZCZAK 1996, LISOWSKI, PANEK 2004, OSIŃSKI 2012, SZULC, KOCZARA 2005). To date, the information content and the ability of formulas (9) and (10) to determine the efficiency of mixture separation has not been compared in literature.

Experimental design

The experiment was designed for a hypothetical mixture of seeds containing 90% crop seeds and 10% seeds of contaminating plant species. The following change scenarios were analyzed to determine correlations between indicators of the separation process:

a) variant I – the share of crop seeds in the separated product increases (from 0.4 to 0.9) with an increase in the share of discarded impurities (from 0 to 0.1),

b) variant II – the share of crop seeds in the separated product is constant (0.8) and the share of discarded impurities increases (from 0 to 0.1),

c) variant III – the share of crop seeds in the separated product increases (from 0.4 to 0.9) and the share of discarded impurities is constant (0.07),

d) variant IV – the share of crop seeds in the separated product decreases (from 0.9 to 0.4) and the share of discarded impurities increases (from 0 to 0.1),

e) variant V – the share of crop seeds in the separated product decreases (from 0.9 to 0.1) proportionally to an increase in the share of discarded impurities (from 0 to 0.1).

Results and Discussion

The simulated separation values of a hypothetical seed mixture were presented in Tables 1 to 5. In the analyzed variants, the purity of the separated product ranged from 80% to 100%. The above indicated that case scenarios with highly unfavorable and incorrect separation parameters were also analyzed because the separated product was characterized by lower purity than the raw material. The classification of the separated fractions should be reversed, and if the resulting seed loss were excessive, a given separation process should be abandoned.

Table 1

Indicators of seed mixture separation efficiency – variant I

a_p [–]	a_o [–]	b_p [–]	b_o [–]	c_p [–]	ε_1 [–]	ε_2 [–]	ε' [–]	ε'' [–]
0.40	0.50	0.10	0	0.800	0.444	0	–0.556	0
0.45	0.45	0.09	0.01	0.833	0.500	0.100	–0.400	0.050
0.50	0.40	0.08	0.02	0.862	0.556	0.200	–0.244	0.111
0.55	0.35	0.07	0.03	0.887	0.611	0.300	–0.089	0.183
0.60	0.30	0.06	0.04	0.909	0.667	0.400	0.067	0.267
0.65	0.25	0.05	0.05	0.929	0.722	0.500	0.222	0.361
0.70	0.20	0.04	0.06	0.946	0.778	0.600	0.378	0.467
0.75	0.15	0.03	0.07	0.962	0.833	0.700	0.533	0.583
0.80	0.10	0.02	0.08	0.976	0.889	0.800	0.689	0.711
0.85	0.05	0.01	0.09	0.988	0.944	0.900	0.844	0.850
0.90	0	0	0.10	1	1	1	1	1

Source: own calculations.

Table 2

Indicators of seed mixture separation efficiency – variant II

a_p [–]	a_o [–]	b_p [–]	b_o [–]	c_p [–]	ε_1 [–]	ε_2 [–]	ε' [–]	ε'' [–]
0.80	0.10	0.10	0	0.889	0.889	0	–0.111	0
		0.09	0.01	0.899	0.889	0.100	–0.011	0.089
		0.08	0.02	0.909	0.889	0.200	0.089	0.178
		0.07	0.03	0.920	0.889	0.300	0.189	0.267
		0.06	0.04	0.930	0.889	0.400	0.289	0.356
		0.05	0.05	0.941	0.889	0.500	0.389	0.444
		0.04	0.06	0.952	0.889	0.600	0.489	0.533
		0.03	0.07	0.964	0.889	0.700	0.589	0.622
		0.02	0.08	0.976	0.889	0.800	0.689	0.711
		0.01	0.09	0.988	0.889	0.900	0.789	0.800
		0	0.10	1	0.889	1	0.889	0.889

Source: own calculations.

Table 3

Indicators of seed mixture separation efficiency – variant III

a_p [–]	a_o [–]	b_p [–]	b_o [–]	c_p [–]	ε_1 [–]	ε_2 [–]	ε' [–]	ε'' [–]
0.40	0.50			0.930	0.444		0.144	0.311
0.45	0.45			0.938	0.500		0.200	0.350
0.50	0.40			0.943	0.556		0.256	0.389
0.55	0.35			0.948	0.611		0.311	0.428
0.60	0.30			0.952	0.667		0.367	0.467
0.65	0.25	0.03	0.07	0.956	0.722	0.700	0.422	0.506
0.70	0.20			0.959	0.778		0.478	0.544
0.75	0.15			0.962	0.833		0.533	0.583
0.80	0.10			0.964	0.889		0.589	0.622
0.85	0.05			0.966	0.944		0.644	0.661
0.90	0			0.968	1		0.700	0.700

Source: own calculations.

Table 4

Indicators of seed mixture separation efficiency – variant IV

a_p [–]	a_o [–]	b_p [–]	b_o [–]	c_p [–]	ε_1 [–]	ε_2 [–]	ε' [–]	ε'' [–]
0.90	0	0.10	0	0.900	1	0	0	0
0.85	0.05	0.09	0.01	0.904	0.944	0.100	0.044	0.094
0.80	0.10	0.08	0.02	0.909	0.889	0.200	0.089	0.178
0.75	0.15	0.07	0.03	0.915	0.833	0.300	0.133	0.250
0.70	0.20	0.06	0.04	0.921	0.778	0.400	0.178	0.311
0.65	0.25	0.05	0.05	0.929	0.722	0.500	0.222	0.361
0.60	0.30	0.04	0.06	0.938	0.667	0.600	0.267	0.400
0.55	0.35	0.03	0.07	0.948	0.611	0.700	0.311	0.428
0.50	0.40	0.02	0.08	0.962	0.556	0.800	0.356	0.444
0.45	0.45	0.01	0.09	0.978	0.500	0.900	0.400	0.450
0.40	0.50	0	0.10	1	0.444	1	0.444	0.444

Source: own calculations.

Table 5

Indicators of seed mixture separation efficiency – variant V

a_p [–]	a_o [–]	b_p [–]	b_o [–]	c_p [–]	ε_1 [–]	ε_2 [–]	ε' [–]	ε'' [–]
0.90	0	0.10	0	0.900	1	0	0	0
0.82	0.08	0.09	0.01	0.901	0.911	0.100	0.011	0.091
0.74	0.16	0.08	0.02	0.902	0.822	0.200	0.022	0.164
0.66	0.24	0.07	0.03	0.904	0.733	0.300	0.033	0.220
0.58	0.32	0.06	0.04	0.906	0.644	0.400	0.044	0.258
0.50	0.40	0.05	0.05	0.909	0.556	0.500	0.056	0.278
0.42	0.48	0.04	0.06	0.913	0.467	0.600	0.067	0.280
0.34	0.56	0.03	0.07	0.919	0.378	0.700	0.078	0.264
0.26	0.64	0.02	0.08	0.929	0.289	0.800	0.089	0.231
0.18	0.72	0.01	0.09	0.947	0.200	0.900	0.100	0.180
0.10	0.80	0	0.10	1	0.111	1	0.111	0.111

Source: own calculations.

The efficiency of mixture separation calculated from formula (10) is equal to zero or is higher than zero, whereas separation efficiency determined based on formula (9) takes on both positive and negative values. Negative values were obtained in separation variants where the purity of the separated product deteriorated. In this case, the separation process is reversed. Owing to the number of discarded crop seeds, discarded material was characterized by higher purity than the material accumulated in the main container of a hypothetical separation device.

The discussed indicators had identical values when crop seed yield or the efficiency of impurity separation or both indicators were equal to 1. The efficiency of mixture separation calculated based on formula (9) was lower than that determined with the use of formula (10).

When both indicators of mixture separation efficiency were higher than 0.5, the resulting difference in indicator values did not exceed 12.5% (Fig. 1). Under relatively satisfactory separation conditions (crop seed loss of up to 10% and efficiency of impurity separation higher than 80%), the maximum difference between indicators of separation efficiency calculated with both formulas is 0.02, and the resulting error did not exceed 3%. Both formulas can be used to determine the analyzed indicator when crop seed yield and the efficiency of impurity separation are high because in most practical applications (CHOSZCZ, WIERZBICKI 1994, PIETKIEWICZ, WIERZBICKI 1988, RAWA 1992, 1994, SEMCZYSZYN, FORNAL 1990), the value of the separation efficiency indicator is higher than 0.8.

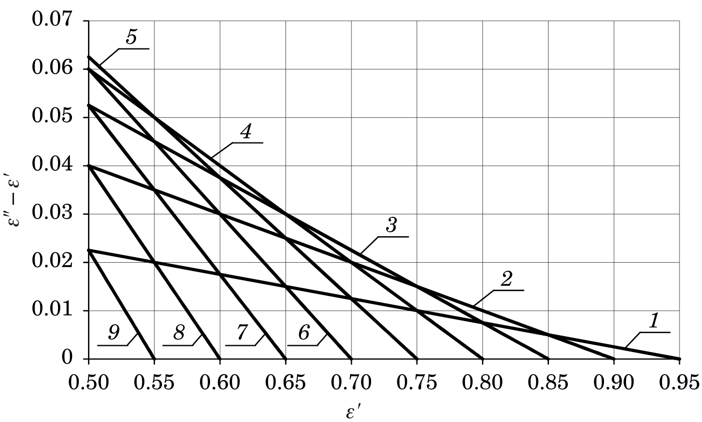

Fig. 1. Differences in the values of indicators of seed mixture separation efficiency calculated with the use of two mathematical formulas for crop seed yield of: 1 – 0.95, 2 – 0.90, 3 – 0.85, 4 – 0.80, 5 – 0.75, 6 – 0.70, 7 – 0.65, 8 – 0.60, 9 – 0.55

Source: own study.

Conclusions

1. A mathematical formula determining the efficiency of mixture separation, construed as the difference between crop seed yield and the share of impurities in the separated product, takes on both positive and negative values. Negative values indicate that the separation process has been reversed.

2. A mathematical formula for determining the efficiency of mixture separation, construed as a product of crop seed yield and the efficiency of impurity separation, always takes on positive values regardless of whether the separation process has been reversed.

3. The difference in determinations of separation efficiency (the minimum value of the indicator of separation efficiency is 0.5) performed with the use of both mathematical formulas is maximum 8%, and it decreases with an improvement in separation quality.

4. Both mathematical formulas can be applied to evaluate separation processes because in most practical applications, the minimum value of the indicator of separation efficiency is 0.8 and the resulting error does not exceed 1.5%.

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References

Adamkiewicz A., Jarzęcki Ł. 2009. *Comparative analysis of operational properties of propulsion systems of RoPax type ships*. Eksploatacja i Niezawodność, 2: 52–62.

Choszcz D., Wierzbicki K. 1994. *An analysis of the efficiency of currently applied processing lines for winnowing rape and mustard seeds in separating field bedstraw* (Galium aparine) seeds. Acta Acad. Agricult. Techn. Olst., Aedif. Mech., 25: 71–80.

Grochowicz J. 1994. *Maszyny do czyszczenia i sortowania nasion*. Wyd. AR, Lublin.

Hetmańczyk I., Winchula Ł. 2012. *Hybrid drive for agricultural vehicles*. Inżynieria Rolnicza, 2(137): 77–88.

Kaliniewicz Z. 2011. *The effect of the impurity content of buckwheat nutlets on product purity after cleaning in a grader with indented pockets*. Technical Sciences, 14: 5–12.

Kaliniewicz Z., Konopka S., Rawa T. 1994. *Problems of the buckwheat grain cleaning*. Materiały III Ogólnopolskiej i II Międzynarodowej Konferencji Naukowej „Rozwój teorii i technologii w technicznej modernizacji rolnictwa”, Olsztyn: 252–256.

Kojtych A., Szawłowski M., Szymczyk W. 1998. *Pracownia techniczna*. 1. Wyd. WSiP, Warszawa.

Krawczyk D. 2010. *The basic factors influencing energy consumption in offices*. Budownictwo i Inżynieria Środowiska, 1: 137–142.

Kuczewski J., Miszczak M. 1996. *Podstawy konstrukcji maszyn rolniczych i leśnych*. Wyd. SGGW, Warszawa.

Lisowski E., Panek M. 2004. *CFD modeling of vane pump vanes operation*. Eksploatacja i Niezawodność, 2: 36–41.

Osiński Z. 2012. *Podstawy konstrukcji maszyn*. Wydawnictwo Naukowe PWN, Warszawa.

Pietkiewicz T., Wierzbicki K. 1988. *Analysis of efficiency of rape seeds winnowing in the state corn plants*. Acta Acad. Agricult. Techn. Olst., Aedif. Mech., 18: 111–119.

Rawa T. 1992. *A study of the buckwheat grain clearing effectiveness*. Acta Acad. Agricult. Techn. Ols., Aedif. Mech., 22, Supplementum A.

Rawa T. 1994. *An analysis of the efficiency of buckwheat seeds winnowing in a trieur*. Acta Acad. Agricult. Techn. Ols., Aedif. Mech., 25: 81–87.

Rawa T., Semczyszyn M. 1988. *Analysis of methods of qualifying of grain compositions distribution in winnowing problems*. Acta Acad. Agricult. Techn. Ols., Aedif. Mech., 18: 41–53.

Semczyszyn M., Fornal Ł. 1990. *Analysis of work effectiveness of winnowing devices used in the process lines of buckwheat grain winnowing*. II. *Results of examination of work quality of winnowing devices*. Acta Acad. Agricult. Techn. Olst., Aedif. Mech., 21: 111–121.

Szulc Z., Koczara W. 2005. *Improving energy efficient of drive system with medium voltage induction motor by using frequency converter*. Zeszyty Problemowe – Maszyny Elektryczne, 73: 49–53.

Wierzbicki K., Pietkiewicz T., Choszcz D., Mańkowski S. 1991. *Effectiveness of the wheat grain cleaning process with complex movement of sieve basket*. Acta Acad. Agricult. Techn. Ols., Aedif. Mech., 22: 179–189.