Scientific quarterly journal e-ISNN 2449-5999

Agricultural Engineering

2015: 2(154):65-73

Homepage: http://ir.ptir.org

DOI: http://dx.medra.org/10.14654/ir.2015.154.122

PURIFICATION AND SORTING OF DRY CORNFLOWER PETALS MIXTURE IN A HORIZONTAL AIR STREAM

Marian Panasiewicz, Paweł Sobczak, Jacek Mazur*, Kazimierz Zawiślak, Rafał Nadulski, Zbigniew Kobus

Department of Engineerings and Food Machines, University of Life Sciences in Lublin

*Contact details: ul. Doświadczalna 44, 20-236 Lublin; e-mail: jacek.mazur@up.lublin.pl

ARTICLE INFO

Article history:
Received: October 2014
Received in the revised form: November 2014
Accepted: December 2014

Keywords:
cornflower petals
pneumatic separation
contamination

ABSTRACT

The paper aims at determination of parameters, approximate to optimal, of pneumatic separation of the mixture of wild cornflower dried petals obtained by mechanical harvesting. Moreover, the investigated raw material contamination was assessed through comparison and identification of various groups of contaminants and undesired components of the mixture in the basic raw material. Separation was carried out in a horizontal air stream with the use of the designed pneumatic separator. The most efficient and effective was the process of petals separation at the air stream velocity which was 4 m·s^{-1}. The amount of the obtained clean petals from the mixture in case of a fraction with bigger dimensions was 48.3%. With the increase of the air stream velocity the coefficient η increases but along with this, the amount of a valuable fraction, which is taken by the stream, grows. At the growth of air stream velocity from V_s=4 m·s^{-1} to V_s=6 m·s^{-1} (within the same size fractions), the highest increase of the coefficient η was in case of the fraction of 400÷500 µm and was 48.3%.

Introduction

Cornflower (*Centaurea cyanus* L.) is a popular weed but at the same time it is herb which grows in grains, on baulks and fallows. It occurs in Europe and Asia as an annual plant or a biennial plant. Its petals are used as a half-product of herbs cultivation and as a medication (Kozłowska, 2002; Kuźnicka and Dziak, 1987; Tomczak, 2007). Herbal raw materials obtained from agricultural farms, herbs plantations or collected ground cover, are, as a rule, highly contaminated with various undesired materials. Dried petals of wild cornflower are in particular difficult for separation and purification, especially when they were previously harvested mechanically (mowing, threshing). Both cornflower petals and other herbs cultivated in the garden as well as wildly growing have various physical properties. Their different parts i.e. flowers, leaves, fruit, seeds, rhizomes and roots are used as a medication or as spices (Kozłowska, 2002; Ożarowska and Jaroniewski, 1989; Panasiewicz et al., 2012; Wierzbicka and Jadwisieńczak, 2003).

Separation of particular components of the mixture in the air stream may take place at any angle of deviation of the stream within 0 to 90º to the level. Thus, at the separation two basic but different processes, namely cleaning in a horizontal and vertical air stream may be applied (Grochowicz, 1994; Tylek, 2003). Furthermore, in each case both suction as well as pumping of air stream are used. Figure 1 presents various structural solutions of cleaning devices, where as a basic separating factor a horizontal air stream was used.

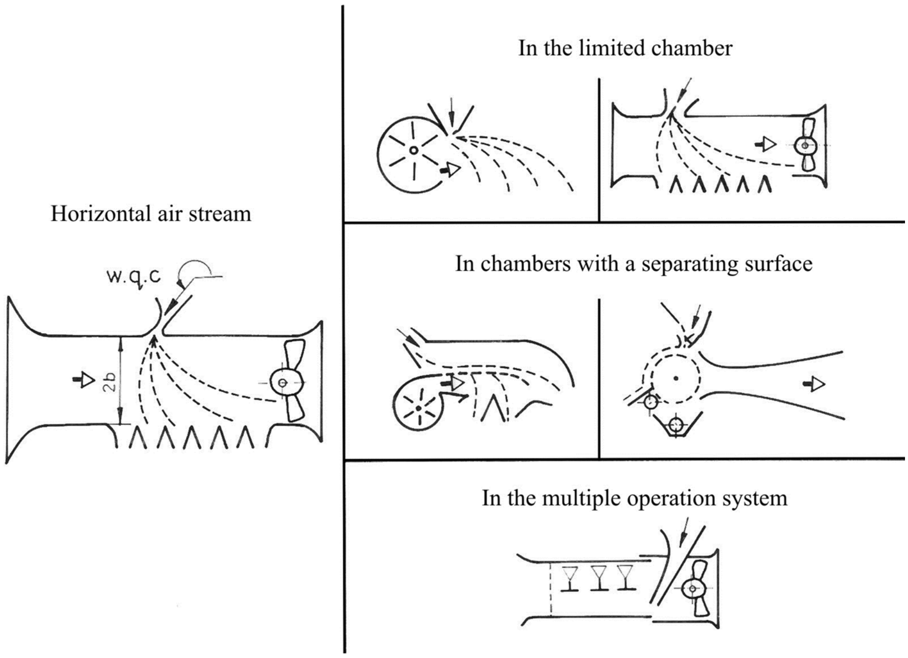

Figure 1. Schemes of pneumatic systems with a horizontal air stream (Grochowicz, 1994): b – width of the pneumatic channel, w – speed of supplying grain mixture, q – amount of the supplied mixture (loading of a channel), c – size which characterizes input contamination of the mixture

The separation process of grain mixtures in this type of systems consists in various vertical tilts of the route of particles which freely fall in the air stream in relation to their aerodynamic properties and the initial speed. Thus, one may state that the separation process is based on the principle of "stretching" the grain mixture in any distance, which enables its precise separation into fractions according to the distance of fall of particles from the place of their inlet to the stream. Both in the horizontal stream as well as in the diagonal one, the separation process takes place at speeds where the vertical component is always lower than the critical speed of seeds (Dmitrewski et al., 1981; Horabik, 2001; Tomczak, 2007).

The principle of separation of grain biological mixtures in the air stream is used both in a special pneumatic separator but also in more or less complex threshing machines and purifying machines (Gierz and Kęska 2011; Grochowicz, 1994; Lorestani et al., 2012; Panasiewicz et al., 2012; Tylek and Walczyk, 2002). Extensive use of this separation method is justified by a simple structure and operation of devices constructed for this purpose.

The objective and the scope of research

The paper aims at determination of approximate to optimal parameters of pneumatic separation of the mixture of dried petals of wild cornflower obtained by mechanical harvesting. The scope of the research covered assessment of the contamination degree of the investigated raw material through comparison and identification of various groups of contaminations and components of undesired mixtures in the basic raw material.

Methods, test stand and test conditions

In order to precisely separate contamination samples, which contain valuable material were tested on the designed pneumatic separator with a horizontal air stream (Fig.2).
The structure of the separator enables multiple iteration of the pneumatic separation process in laboratory conditions. Furthermore, the following were used in the research:

- high scope of variability referred to the direction of air stream flow,
- high scope of variability of air stream intensity (luminar and turbulent flows),
- obtaining great amount of size fractions,
- the use of a precise dispenser for loose materials (a screw type) which ensures regularity of supply of the separated mixture to the working zone.

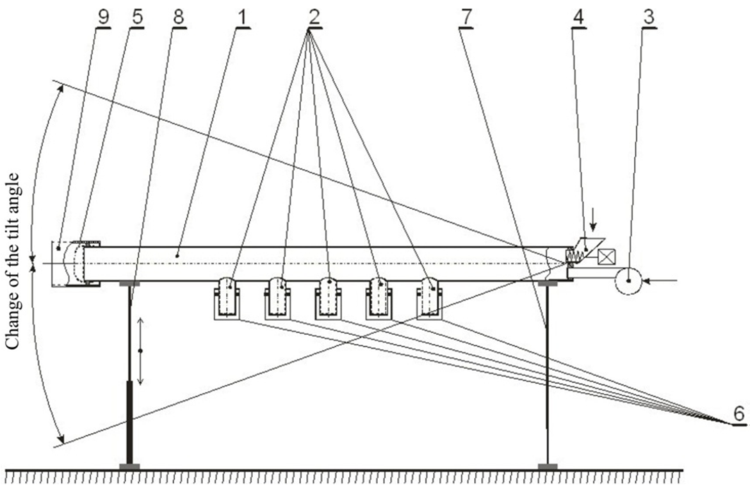

Figure 2. Separator – a stand for measurement of aerodynamic plant materials: pipe channel of pneumatic separator, 2 – outlets of particular fractions, 3 – fan with expenditure regulator, 4 – precise dispenser of raw material for separation, 5 – dust filter (cloth filter), 6 – receiving dispenser of separated fractions, 7 – back base of separation channel, 8 – front base of separation channel (regulated- telescopic), 9 – outlet of purified gas

The structure of device enables precise change of the air stream flow angle from the horizontal to the diagonal one (maximum angle of 30^o). Samples of the mixture of cornflower petals and fractions to be separated of the mass of 40 g each were batched to the container of the dispensing device. Then, a fan which produces air stream with complex velocity within 2÷6.5 $m \cdot s^{-1}$ was activated; next the valve of the container with the mixture was opened. Air stream carried away mixture fractions from the lightest to the highest which caused their dropping to particular containers of a separating pipe. To pneumatic separation samples including the highest amount of valuable fraction (petals) were qualified - dimensions of sieve meshes were from 100 µm to 500 µm and above this dimension. Fraction with dimensions below 100 µm, (mainly contaminations) which does not contain petals was rejected.

Based on the obtained results coefficient of separation effectiveness was computed and it η was:

$$\eta = \frac{b}{b_o} \cdot 100\% \qquad (1)$$

where:

b – the amount of contaminations in the separated fraction in the air stream, (kg)

b_o – the amount of contaminations in the batch material, (kg)

Measurement of the air stream speed was carried out with the use of anemometer PROVA AVM-03 (precision of measurement ±0.1 $m \cdot s^{-1}$). Research was carried out in five iterations.

Research results and their analysis

Determination of conditions and parameters of the cleaning and pneumatic sorting process, close to optimal, of dried cornflower petals was preceded by determination of the size distribution of the tested mixture (Table 1). The composition of particular fractions, majority of which contained various contaminations and unuseful waste, basic material was selected, which constituted the most valuable part of the processed material, i.e. petals. Using variability within the scope of dimensions, shape and mass of particles of particular fractions, conditions of the process, which ensured the most efficient and precise effect of separation, were determined. In case of separation and purification of cornflower petals, particles contained in all fractions had similar values of all three aerodynamic parameters, i.e. critical velocity V_k, aerodynamic resistance coefficient k and volatility coefficient k_o (Table 1). Small differences between those parameters practically disable effective separation of the most precious fractions of petals (sort I and II).

Table 1
Aerodynamic characteristics of the selected fractions of cornflower mixtures

Fractions of mixture (dimensions of square meshes of a sieve)	Critical velocity V_k ($m \cdot s^{-1}$)	Coefficient of Aerodynamic resistance k	Coefficient of Volatility k_o
Diameter above φ-500 µm; other contaminations	17.50	0.229	0.0320
Diameter within the scope φ-400÷500 µm; thick contaminations (cornflower seeds)	6.08	0.149	0.2654
Diameter within the scope of φ-315÷400 µm; petals (sort I)	5.32	0.139	0.3466
Diameter within the scope of φ-200÷315 µm; petals (sort II.	4.56	0.124	0.4718
Diameter within the scope φ-100÷200 µm; husks contaminations (cornflower seeds)	4.02	0.116	0.6070
Diameter within the scope φ-50÷100 µm; very light contaminations (cornflower seeds)	3.22	0.099	0.9469
Diameter below 50 µm; dust contaminations	3.16	0.095	0.9801

Except for the aerodynamic characteristics, knowledge of the sort and composition of contamination in the mixture is a significant factor (table 2).

Table 2
Size distribution of the cornflower mixture on Retsch AS 200 sieve shaker

Fractions of mixture (dimensions of square meshes of a sieve)	Sample mass (g)	Participation (%)
Higher than 500	0.72	1.76
400÷500	0.22	0.58
315÷400	1.16	2.90
200÷315	21.44	53.75
100÷200	11.17	28.00
50÷100	3.37	8.45
Lower than 50	1.82	4.56
Total	40	100%

When assessing a percentage participation of particular size fractions it should be stated that the most numerous (53.75%) fraction are particles retained on a sieve with meshes of 200 μm. Less numerous fraction (28.00%) contained particles which remained on a sieve with meshes dimensions which was 100 μm. With reference to the technological value of the investigated mixture, total over 80% participation of those two fractions constitutes a valuable material, consisting of non-crumbled cornflower petals and seeds useful in the processing. In fractions bigger than the mentioned ones, except for small number of petals, also undesired parts of flowers were found, whereas in smaller fractions fine contaminations.

Based on the tests which were carried out, values of the coefficient were computed η, which allowed assessment of the efficiency of the pneumatic separation process of dry cornflower petals in relation to the size distribution and aerodynamic properties and the air stream velocity in the working zone of a separator. Figure 3 presents values of the coefficient η for various fractions of the separated mixture.

$$\eta=12{,}845\cdot V_u+0{,}3443\cdot\phi-1{,}588\cdot V_u^2+0{,}0016\cdot V_u\cdot\phi-0{,}0005\cdot\phi^2-34{,}654$$

$$R^2=0{,}92$$

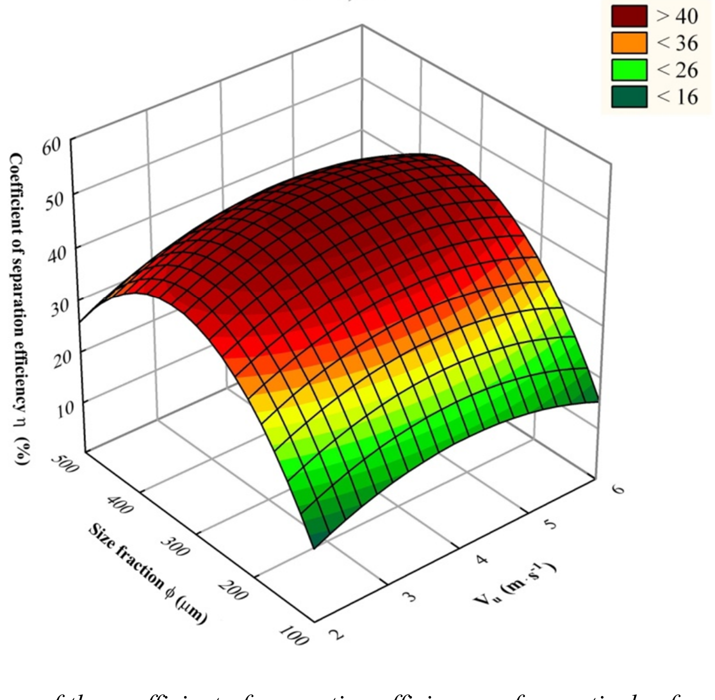

Figure 3. Values of the coefficient of separation efficiency η for particular fractions of the mixture and various speeds of the air stream V_s

The analysis of the obtained values of the coefficient of separation efficiency η indicates relatively varied correlation, which determines relations between the impact of particular parameters on the efficiency of the pneumatic separation process. Change of one of parameters (even to a small extent) leads to a considerable disturbance and deterioration of the separation process of a cover, which impedes determination of optimal conditions for pneumatic separation.

Thus, as a result of pneumatic separation of the cornflower mixture, the highest values of the coefficient η were obtained at the separation of petals in the air stream with the velocity of 4 $m \cdot s^{-1}$. Effectiveness of separation for the fraction of mixture of 400÷500 μm, was the highest and was 48.3%. The lowest values of the coefficient η for all size fractions were reported at the speed of the air stream which was 2 $m \cdot s^{-1}$. At the highest level of air stream velocity (V_s=6 $m \cdot s^{-1}$) efficient separation of petals was obtained (η=42.9) but at the same time more intense air stream carried away also various contaminations and deteriorated thus a general quality of separated petals. Figure 4 presents exemplary fractions of the mixture separated in the horizontal air stream.

Figure 4. Example of selected fractions of the mixture subject to pneumatic separation

According to the analysis of the obtained research results, the undertaken attempt of effective (100%) separation of contaminations from the tested mixture proved to be difficult. A considerable number and amount of particular contaminations was characterized with very approximate (in comparison to features of the basic species) physical properties. It caused that it was hard to remove them in the horizontal air stream. Thus, a conclusion was made that this type of a mixture requires a special technological approach and the use of frequent specific and unconventional set of other cleaning and separating machines. It is also necessary to use multiple iterations of cleaning operations, which elongates the total duration of the process and its energy consumption.

Conclusions

1. Pneumatic separation of the mixture of contaminated cornflower petals in the horizontal air stream on account of the considerable amount of varied and difficult to separate contaminations proved to be low efficient.
2. The most efficient and effective was the process of petals separation at the air stream velocity which was 4 $m \cdot s^{-1}$. The amount of the obtained clean petals from the mixture in case of a fraction with bigger dimensions was 48.3%.
3. With the increase of the air stream velocity the coefficient η increases but along with this, the amount of valuable fraction, which is taken by the stream, grows. At the growth of air stream velocity from V_s=4 $m \cdot s^{-1}$ to V_s=6 $m \cdot s^{-1}$ (within the same size fractions), the highest increase of the coefficient η was in case of the fraction of 400÷500 μm and was 48.3%.
4. Separation in the horizontal air stream may not be one effective method of cornflower petals separation. This method may be related to other manners of cleaning and separation with the use of specialistic cleaning machines e.g. sieving pneumatic and vibrating devices.

References

Dmitrewski, J.; Gach, S.; Roszkowski, H.; Waszkiewicz, C. (1981). *Elementy teorii i obliczania maszyn czyszczących oraz urządzeń suszarniczych.* Wydawnictwo SGGW, Warszawa, ISBN 8300016902.

Gierz, Ł.; Kęska, W. (2011). Badania laboratoryjne nad rozdziałem strumienia nasion w głowicy siewnika pneumatycznego. *Inżynieria Rolnicza, 8*(133), 117-125.

Grochowicz, J. (1994). *Maszyny do czyszczenia i sortowania nasion.* Wydawnictwo AR, Lublin, ISBN 83-901612-9-X.

Horabik, J. (2001). Charakterystyka właściwości fizycznych roślinnych materiałów sypkich istotnych w procesach składowania. *Acta Agrophisica, 54*, 121.

Kozłowska, J. (2002). Rośliny bogate w barwniki oraz ich znaczenie i zastosowanie. Cz. I. *Wiadomości zielarskie, 5*, 9-12.

Kuźnicka, B.; Dziak, M. (1987). *Zioła i ich zastosowanie. Historia i współczesność.* Warszawa. Państwowy Zakład Wydawnictw Lekarskich. ISBN 83-200074-7-X.

Lorestani, A. N.; Rabani, H.; Khazaei, Y. (2012). Design and construction of an automatic coefficient of friction measuring device. *Agricultural Engineering International. CIGR Journal, vol. 14 no.1*, 120-124.

Ożarowska, A.; Jaroniewski, W. (1989). *Rośliny lecznicze i ich praktyczne zastosowanie*. Instytut Wydawniczy Związków Zawodowych. Warszawa. ISBN 8320204720.

Panasiewicz, M.; Sobczak, P.; Mazur, J.; Zawiślak, K.; Andrejko, D. (2012). The technique and analysis of the process of separation and clearing grain materials. *Journal of Food Engineering, 109*, 603-608.

Tomczak, B. (2007). Chaber bławatek – biologia, występowanie i zwalczanie. *Ochrona Roślin, 5,* 27-29.

Tylek, P. (2003). Kształt jako cecha rozdzielcza nasion. *Inżynieria Rolnicza, 11*(53), 213-222.

Tylek, P.; Walczyk, J. (2002). Separator pneumatyczny do nasion drzew leśnych. *Przegląd Techniki Rolniczej i Leśnej, 10*, 16-25.

Wierzbicki K.; Jadwisieńczak K. (2003). Próba określenia współzależności pomiędzy wybranymi cechami rozdzielczymi nasion fasoli (*Phaseolus Vulgaris* L.). *Problemy Inżynierii Rolniczej, 4*(42), 43-50.

CZYSZCZENIE I SORTOWANIE MIESZANINY SUCHYCH PŁATKÓW CHABRU BŁAWATKA W POZIOMYM STRUMIENIA POWIETRZA

Streszczenie. Praca dotyczy określenia zbliżonych do optymalnych parametrów pneumoseparacji mieszaniny suszonych płatków dzikiego bławatka, pozyskanych poprzez mechaniczny zbiór. Ponadto dokonano oceny stopnia zanieczyszczenia badanego surowca, poprzez zestawienia i identyfikację różnych grup zanieczyszczeń i komponentów mieszaniny niepożądanych w surowcu podstawowym. Separację prowadzono w poziomym strumieniu powietrza z wykorzystaniem zaprojektowanego separatora pneumatycznego. Najbardziej skutecznie i efektywnie proces wydzielania płatków przebiegał przy prędkości strumienia powietrza wynoszącej 4 $m \cdot s^{-1}$. Ilość pozyskanych, czystych płatków z mieszaniny w przypadku frakcji o większych wymiarach sięgała 48,3%. W miarę wzrostu prędkości strumienia powietrza wzrasta współczynnik η, ale wraz z tym powiększa się ilość frakcji wartościowej, którą porywa strumień. Przy wzroście prędkości strumienia powietrza z V_s=4 $m \cdot s^{-1}$ do V_s=6 $m \cdot s^{-1}$ (w obrębie tych samych frakcji wymiarowych), najwyższy przyrost współczynnika η miał miejsce w przypadku frakcji 400÷500 µm i wyniósł 48,3%.

Słowa kluczowe: płatki chabru, pneumoseparacja, zanieczyszczenia