# The Analysis of The Process of Barley Grain Separation from Undesirable Particles

*Jiří ZEGZULKA[1,2,3], Lucie JEZERSKA[1], Vladimíra HETCLOVA[2], Rostislav PROKES[3], Vaclav RUTTKAY[3]*

[1] VSB-Technical University of Ostrava, ENET Centre, Bulk Solids Centre, 17. listopadu 15, 708 33 Ostrava, Czech Republic
[2] VSB-Technical University of Ostrava, Faculty of Mining and Geology, Department of Environmental Engineering, 17. listopadu 15, 708 33 Ostrava, Czech Republic
[3] VSB-Technical University of Ostrava, Faculty of Mechanical Engineering, Institute of Transportation, 17. listopadu 15, 708 33 Ostrava, Czech Republic

http://doi.org/10.29227/IM-2019-01-33
Submission date: *11-07-2018* | Review date: *02-04-2019*

## Abstract

*The article focuses on the intensification of raw barley grains initial purification and separation processes before the subsequent processing in the area of brewing. Above all, it deals with the physical and mechanical concepts of the purification and separation of qualitatively satisfactory grains from undesirable impurities, e.g. coarse impurities, as the prevention from the potential damage of milling and scrapping facilities. Four different cultivated barley species were tested within the study. Physical and mechanical parameters were determined in all samples, for instance powder density, angle of internal friction and external friction angle with steel contact material, particle size distribution and morphology. The first results of measuring revealed the difference in the quality of initial entering component of barley grains before the purification process compared to the output quality of grains after machine purification and separation processes in the facilities determined for the subsequent grain storage. As a result of the non-effective process of separation, the final quality of the product, i.e. the beer, may be affected by the qualitative parameters of partial processes involved in treating barley grains.*

*Keywords: barley, angle of internal friction; separation; qualitative parameters*

**Introduction**

Especially grown types of malt barley grains are used in the food industry, especially in brewing, where they are one of the most important ingredients used in beer production. The effort to objectively and comprehensively illustrate the malting quality of varieties of barley has led to the creation of different assessment systems and procedures. At present, the malting quality of barley varieties is evaluated according to the "malting quality indicator", which was based on the requirements of the processing industry. The key indicators of quality malting barley are especially germination and germination energy. A very important feature is nitrogen content - protein and starch content. Important quality criteria are further mechanical features such as the proportion of grains of 2.5 mm above the screen, at a base value of 80% at baseline and 20% in the size of 2.8 mm. Malting barley should not contain any waste - dry and undeveloped grains which pass through a sieve size 2.2 mm [1,2]. When barley is picked up by growers, the malt house performs a basic analysis that determines the quality for classification, but also whether barley may be specially treated. Pre-treatment, cleaning and storage in silos are then carried out. The pretreatment leads to the removal of dust, light parts and metal parts. The cleaning takes place in two stages, first in the first conical cylinder, the coarse impurities are separated from a mixture of material that passes through the conical cylinder. In the second stage, barley is separated from fine particles of impurities, barley grains, and round grains of weeds, which overflow through the trimer - cylinder, the jacket of which is provided on the inner side with pocket-shaped pits with a diameter of 6.5 mm. The attachments are then transferred by means of the auger to the collecting point where they are conveyed to the sacking socket. Separated barley is lifted above the cylinder axis at the end of the cleaning and drops to the collecting point by sliding, at this stage the last product separation from the finest air extraction particles takes place. Grading of barley grains by size has technological significance to achieve uniform soaking, germination and obtaining perfectly homogeneous malt [3]. It is clear that his detailed analysis will help to understand the basic principles and to find critical places with the possibility of innovation.

**Experiments and Methods**

***Material***

In our case, malted barley was chosen as the material evaluated, and 4 varieties of specially brewed brewer's barley grown in the Czech Republic – Moravia region were selected. These barley samples were taken from silos. These are the species called Malz, Sebastian, Francin and KWS Irina, where the basic quality parameters - humidity in the range of 13–13.2%, overflow of the overfill fraction 2.5 mm in the range 91.6–95.5% were determined upon receipt. %, 2.2 mm sub-saturation fraction from 4.5–7.3 wt. %, germination in total 99%.

***Powder density***

A sample of barley of specified weight was poured into the measuring cylinder and the apparent volume value was

Tab. 1. Parameters of powder density, angle of repose, flow characteristics based on the Hausner ratio (HR) and the Carrs index (CI)
Tab. 1. Gęstość proszku, kąt tarcia wewnętrznego, charakterystyki przepływu w oparciu o współczynnik Hausnera (HR) i indeks Carrsa (CI)

| Barley's sample | Powder density [kg.m$^{-3}$] | Angle of repose α [°] | CI [%] | HR [-] | Flow |
|---|---|---|---|---|---|
| **Malz before** | 656.3 | 25.6 | 3.4 | 1.03 | excellent |
| **Malz after** | 676.6 | 17.6 | 5.8 | 1.06 | excellent |
| **Sebastian before** | 627.1 | 21.8 | 9.6 | 1.11 | excellent |
| **Sebastian after** | 669.4 | 15.6 | 8.7 | 1.10 | excellent |
| **Francin before** | 669.4 | 19.2 | 9.6 | 1.10 | excellent |
| **Francin after** | 707.7 | 18.6 | 9.1 | 1.10 | excellent |
| **KWS IRINA before** | 638.5 | 18.2 | 10.0 | 1.10 | excellent |
| **KWS IRINA after** | 659.1 | 16.4 | 8.7 | 1.10 | excellent |

Tab. 2. Parameters of the external and internal friction angles
Tab. 2. Parametry zewnętrznego i wewnętrznego kąta tarcia

| Barley's sample | Angle of internal friction [°] | Angle of external friction [°] | Classification of flowability |
|---|---|---|---|
| **Malz before** | 29.1 | 11.1 | Free flowing |
| **Malz after** | 30.5 | 8.2 | Free flowing |
| **Sebastian before** | 31.3 | 10.9 | Free flowing |
| **Sebastian after** | 31.7 | 8.8 | Free flowing |
| **Francin before** | 29.9 | 9.6 | Free flowing |
| **Francin after** | 30.7 | 8.5 | Free flowing |
| **KWS IRINA before** | 29.9 | 9.7 | Free flowing |
| **KWS IRINA after** | 30.4 | 9.3 | Free flowing |

Tab. 3. Parameters of particle size distribution, particles'sphericity (SPHT3), width/length ratio (b/l3)
Tab. 3. Parametry rozkładu wielkości cząstek, sferyczność cząstek (SPHT3), stosunek szerokości do długości (b/l3)

| Barley's sample | Malz before | Malz after | Sebastian before | Sebastian after | Francin before | Francin after | KWS IRINA before | KWS IRINA after |
|---|---|---|---|---|---|---|---|---|
| **$D_{10}$ [mm]** | 3.05 | 3.04 | 3.04 | 3.02 | 2.92 | 3.00 | 3.00 | 3.03 |
| **$D_{50}$ [mm]** | 3.70 | 3.67 | 3.62 | 3.59 | 3.54 | 3.56 | 3.69 | 3.67 |
| **$D_{90}$ [mm]** | 4.22 | 4.17 | 4.08 | 4.05 | 4.05 | 4.06 | 4.29 | 4.21 |
| **$SPHT_3$** | 0.69 | 0.71 | 0.71 | 0.73 | 0.73 | 0.74 | 0.71 | 0.72 |
| **$b/l_3$** | 0.49 | 0.50 | 0.51 | 0.52 | 0.52 | 0.53 | 0.50 | 0.51 |

subtracted. Powder density was determined by weight and apparent volume [4, 5]. The barley sample was evenly dispensed from the hollow cylinder to a conical-shaped horizontal surface. The powder angle was determined as the largest angle, which forms the horizontal surface and the surface line of the cone formed by the embedded barley sample. The powder angle was determined as a tagengs angle equal to the height of the cone and the radius of the cone.

### *Angle of internal friction and wall friction*

The principle of measuring the shear properties of powder materials consists of loading the volume of the powder mass where the masses by normal load of the preset size and the subsequent displacement of the powder layer in a direction perpendicular to the normal load. The shear stress will result from the friction between the particles, which is detected. Specifically, the force required to overcome shear forces occurring between the particles due to the action of normal force is measured. These forces are further recalculated to the stress [6,7]. Measurement of angles of internal and wall friction was performed on Schulze Ring Shear Tester RST-01 (Wolfenbuttel, Germany), where the principle of measuring these parameters is the use of rotational motion [8].

### *Granulometry and particle shape*

To measure the size and shape of grains of free-flowing powder materials an Camsizer optoelectronic device consisting of a planar light source, feeder, measured material, two CCD cameras for bulk images, a cleaning unit, and a PC with an evaluation program were used. Powder material particles overlap the end edge of the vibrating trough, rotation occurs during fall. Rotating particles pass through the instrument through the measuring space - images are generated using one or two CCD cameras and then analyzed. The granulometric analysis of the test material is generated automatically from the frames obtained.

## Results and Discussion

### *Mechanical and physical parameters*

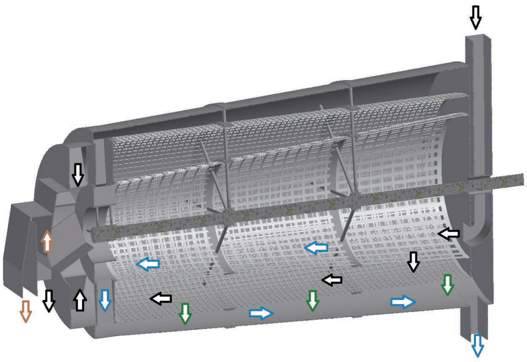

Fig. 1. Proposal for the innovation of the separation process
Rys. 1. Propozycja innowacji procesu separacji

The flow properties were first determined for unpurified raw state samples and for samples after cleaning. The resulting values of powder densities, the angle of repose, CI (Carrs index) and HR (Hausner ratio) [9] for test samples are shown in Tab. 1.

The results show that the values for unpurified samples are different in all measurements, but the mass flow rate as a whole is identical when compared to the Hausner ratio (HR) and Carr's index (CI). It can be stated that the purity of the test materials does not significantly affect their flow properties. The flow pattern was defined as excellent for all cases. The specified parameters of the wall and internal friction angles are summarized in Tab. 2. From the results of the measured values, it is clear that the values of the internal friction angles are slightly smaller than the values for the samples of the cleaned. It is likely that the unpurified material contains fine dust or other fine impurities that contribute to reducing friction. The external friction angle is higher for uncleaned samples than for the cleaned ones. From the flowability point of view, the same conclusion as in density measurements was reached, ie. the degree of purity of the accepted barley in the tested cases does not significantly affect their flowability.

In terms of particle size measurement, it is possible to see the difference in b/l3 - width/length ratio. This ratio is greater for cleaned grains than for uncleaned (Tab. 3). It is further apparent substantial difference in the parameters of sphericity $SPHT_3$ when this parameter is also always greater at the purified grains than in untreated grains.

***Separation process***

On the basis of the determined characteristics, it was found that the critical process of separation is not the mechanical cleaning process itself, but the removal of impurities from the technological line. Consequently, the conical shape of the discharge drum has been proposed in which the rough material is displaced along with fine impurities as shown in Fig. 1.

The mixture of material enters the upper part of the cleaner shown in Fig. 1 with a black arrow, this arrow further showing the direction of travel of the resulting barley product. In the first stage, the mixture is separated from coarse impurities by a conical roller, and the remaining material blends into the second cleaning step, perforated by the drum, where barley is separated from fine impurities. Fine impurities fall through the drum, as shown by the green arrow, and mix with coarse particles in the last drum, and the mixture is taken out for recycling. The barley, free of coarse and fine impurities, is lifted above the cylinder axis at the end of the cleaning and drops into the collection point by slipping. At this stage, a brown arrow shows the last separation of the product from the finest particles by air extraction in Fig. 1.

**Conclusion**

The objective of this work was to analyze the process of separation of barley grains from undesirable particles, such as admixtures of clay, stones, metal particles, grass, but also damaged and small grains. Evaluation was conducted in four different areas, where four kinds of barley grain samples were compared, which were taken in primary unpurified form with samples that underwent a purification and separation process. Despite the fact that there are different types of brewery barley varieties, a certain phase appeared in our measurements, as evidenced by the recorded values. From the established characteristics it was found that the critical point of separation is not the mechanical cleaning process itself, but the removal of impurities from the technological line. Consequently, the conical shape of the draining drum has been designed, in which the rough material is displaced along with fine dirt.

**Acknowledgements**

This paper was conducted within the framework of the project LO1404:Sustainable development of ENET Centre and by student grand competition SP2018/47: Calibrating and experimental devices for research and validation of simulation models.

**Literatura – References**

1. CHLÁDEK, L. Beer industry, Production and processing of beer, Volume 207, October 2007, p. 45 – 52.
2. KOSAŘ, K., PROCHÁZKA, S. Technology and production of malt and beer, Volume 398, May 2000, p.30 – 68.
3. RHODES, M. Introductin to particle technology, Analysis to particle sice, Volume 450, Marc 2008, p. 36 – 5.
4. SCHULZE, D. Powders and bulk solids, Behaviore, characterization, storage and flow, Volume 511, September 2008, p. 210 – 246.
5. MELLMANN, J., HOFFMANN, T., FÜRLL, CH. Mass flow during unloading of agricultural bulk materials from silos depending on particle form, flow properties and geometry of the discharge opening, Powder Technology, Volume 253, Issue 1, February 2014, p. 46-52.
6. ZEGZULKA, J. The angle of internal friction as a measure of work loss in granular material flow, Powder Technology, Volume 233, January 2013, p. 347-353.
7. SCIESZKA, S. F., ADAMECKI, D. The importance of wall friction between particulate solids and elastomeric belt, Powder Technology, Volume 245, Issue 1, September 2013, p. 199-207.
8. ZEGZULKA, J., GELNAR, D., JEZERSKA, L., RAMOREZ-GOMEZ, A., NECAS, J., ROZBROJ, J. Internal Friction Angle of Metal Powders, Metals, Volume 255, 2018, p.1-12.
9. CARR, R.L., JR. Evaluating flow properties of solids. Chemical Engineering, Volume 72, 1965, p. 163-168.

## *Analiza procesu oddzielania ziarna jęczmienia od zanieczyszczeń*

*Artykuł koncentruje się na intensyfikacji wstępnych procesów oczyszczania i separacji surowych ziaren jęczmienia przed dalszym przetwarzaniem w procesie warzenia piwa. Przede wszystkim zajmuje się fizycznymi i mechanicznymi koncepcjami oczyszczania i oddzielania jakościowo zadowalających ziaren od niepożądanych zanieczyszczeń, np. gruboziarniste zanieczyszczenia, zapobiegające potencjalnym uszkodzeniom urządzeń do mielenia oddzielania zanieczyszczeń. W ramach badań przetestowano cztery różne gatunki jęczmienia. We wszystkich próbkach określono parametry fizyczne i mechaniczne, na przykład gęstość proszku, kąt tarcia wewnętrznego i kąt tarcia zewnętrznego ze stalowym materiałem kontaktowym, rozkład wielkości cząstek i ich morfologię. Pierwsze wyniki pomiarów ujawniły różnicę w jakości ziaren jęczmienia przed procesem oczyszczania w porównaniu z jakością wyjściową ziaren po oczyszczeniu. W wyniku nieefektywnego procesu separacji na jakość końcową produktu (piwo) mogą wpływać parametry jakościowe kolejnych procesów związanych z obróbką ziaren jęczmienia.*

*Słowa kluczowe: jęczmień, kąt tarcia wewnętrznego, separacja, parametry jakościowe*