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COMPARISON OF EXTERNAL FRICTION COEFFICIENTS FOR SINGLE SEEDS IN THE STABILISED SYSTEM

Renata Urbańska-Gizińska*, Stanisław Konopka

Department of Mills and Methodology of Research, University of Warmia and Mazury in Olsztyn

Contact details: ul. Oczapowskiego 11, 10-719 Olsztyn, e-mail: renata-gizinska@wp.pl

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ABSTRACT

The paper presents comparison of average static values of external friction coefficients of single caryopses of wheat of Naridana cultivar with caryopses in the-so called stabilised system at their various orientation towards the motion direction on a steel base. The research was carried out on the research position with an optielectronical system of lift angle of the plane arm. It was found out that average values of static friction coefficients of single wheat caryopses and caryopses in the stabilised system depend on the manner of their arrangement during measurements. For single caryopses, a significantly lower value of this parameter was reported in case of caryopses contact with a base with a back side up and their arrangement with longitudinal axis perpendicular towards the movement direction, whereas for caryopses in the stabilised system - at their arrangement with the back side on a steel plate and with a longitudinal axis in parallel to the motion direction. Moreover, it was determined that average values of static friction coefficients for single caryopses are considerably higher than for caryopses in the stabilised system at their identical arrangement during measurements.

Introduction

Friction is a set of phenomena, which occur in the area of contact of two bodies sliding against each other as a result of which resistance to motion take place. With regard to solid bodies (loose materials) two basic friction types can be distinguished: external (particle-working surface) and internal between neighbouring particles (Hebda and Wachal, 1980; http://pl.wikipedia.org/wiki/Tarcie).

In production and processing of agricultural produce external friction is of special significance. It mainly relates to technological operations related to soil cultivation, cutting off plant mass, threshing, transport, storing and processing (Gach et al., 1991; Molenda et al., 1995; Horabik, 2001).

This phenomenon also decides on the course of separation of seed mixtures. In practice, the value of external friction is expressed with the use of the so-called coefficient of friction: static (at the beginning of motion) and kinetic, which is determined during a relative motion of the considered objects. The most frequently, a plane of a variable inclination angle of an arm is used for measurement of this property and gluing seeds to a thin tape in order to ensure a sliding motion (the so-called stabilised system) is an additional treatment. Unfortunately, data available in literature, concerning coefficients of external friction indicate a high discrepancy of their values even for the same materials. The main reasons for this fact include: diversity of methods and measurement devices, variability of properties of particular mixture components and uniformity of conditions of measurements. Thus, works concerning research in coefficients of friction had a permanent nature and numerous researchers recommend determination of value of this property on current basis (Grochowicz, 1994; Horabik and Molenda, 2002; Konopka, 2000; Kram, 2006; Laskowski and Skonecki, 1999; McLean, 1989; Thompson et al., 1988; Zhang and Kushwaha, 1991).

Additionally, a question arises whether the measurement of friction coefficient in the stabilised system objectively reflects this property for single seeds. It should be emphasised that in real conditions of implementation of the separation process (cleaning, fractioning, sorting) seeds are connected and initiation of motion may take place through sliding or wheeling (Konopka, 2006).

The objective of the paper

The objective of the paper was to compare average static values of external friction coefficients of single wheat caryopses with caryopses in the so-called stabilised system at their various orientation towards the motion direction on a specific surface.

Methodology of research

Caryopses of winter wheat of Naridana cultivar purchased in Olsztyńska Hodowla Ziemniaka i Nasiennictwo OLZNAS-CN Sp. z o. o. were used for the research. The purchased batch of seeds of 1 kg mass was sieved with the use of a sifter with a flat sieve with rectangular meshes of side dimensions of 3.1 x 10.0 mm. The objective of this operation was removal of small seeds which characterize with significantly diverse (wrinkled) texture of external surface towards the correctly shaped seeds and the part of contamination. The sieved material was treated as a proper fraction of caryopses for preparation of samples.

Then, with an over-drying method (pursuant to PN-EN ISO 712:2012 P), moisture of selected seeds was determined. It was 11.3%. Caryopses for further stages of research were stored in exsiccator. It was assumed that moisture did not change significantly and has no significant impact on the measurements results.

From a separated fraction 90 single caryopses and caryopses for preparation of samples in the stabilised system were selected. Samples for research in the stabilised system were carried out in two variants. Caryopses were glued to a 1.5 cm thick piece (one-side adhesive) tape to avoid their contact with the use of tweezers. Seeds were identically oriented with a lengthwise axis and equally glued (for a given sample) – with a back side or the side with a fissure. 90 such samples were carried out for each variant.

Experiments including determination of external friction angles of single wheat caryopses and in the stabilised system at the moment of the beginning of motion were carried out on the research position (fig. 1) constructed acc. to the patented idea (no P.397572 as of 17th December 2011) and which is owned by Department of Mills and Methodology of Research, University of Warmia and Mazury in Olsztyn.

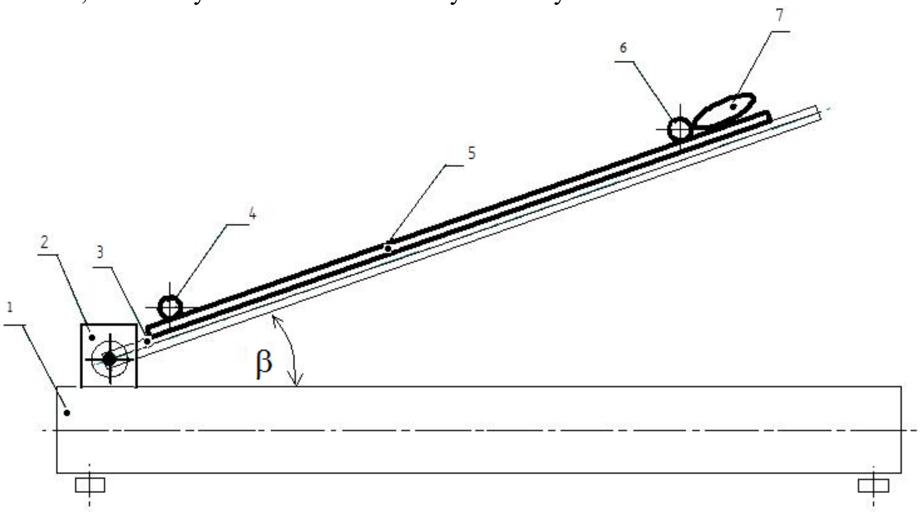

Figure 1. Schematic representation for external measurement of angle of friction of seeds: 1 – base, 2 – system for lifting the plane arm, 3 – the plane arm, 4 – lower optielectronical system, 5 – replaceable base (steel plate), 6 – upper optielectronical system, 7 – wheat caryopses (stabilised system of caryopses)

It is a measuring device with a lifted plane arm which enables determination of external friction angles for loose materials on bases made of various materials. After appropriate calculations of the recorder data, external friction coefficients may be determined.

In the research as a base a construction steel plate ST3 was used. Roughness of the working surface was determined with HOMMEL TESTER T1000 according to PN-EN ISO 4287:1999/A1:2010 P.

Experiments were commenced from arranging a sample (a single caryopses or a stabilised system). Samples were arranged manually with the use of tweezers on the horizontally located plane arm (3) along with a mounted based (5) just before a light ray of optielectronical system (6). Upon starting the mechanism of lifting (2), the plane arm (3) was lifted from the beginning of the single movement of caryopses or the stabilised system (7). In the moment of cutting the light ray of the system (6) the motion of an arm was stopped and the lifting angle of the plane arm was recorded. These data were transferred to the PC computer coupled with the measurement device and calculated according to a formula (1) into values of coefficients (μ) of external friction angles (Grochowicz, 1994):

$$\mu = tg\ \beta \quad (-) \tag{1}$$

where the symbol:

β – determined the lift angle of the plane arm in comparison to the level (^{o}).

Then, the plane arm was dropped and the following measurement (for a new sample) - was repeated.

Measurements were carried out for single caryopses and caryopses in the stabilized system in 4 variants:

– arranged on a steel plate with the furrow side up and a longitudinal axis perpendicular towards the motion direction (BD-H),
– arranged on a steel plate with the furrow side up and a longitudinal axis in parallel towards the motion direction (BD-V),
– arranged on a steel plate with the back side up and a longitudinal axis towards the motion direction (GD-H),
– arranged on a steel plate with the back side up and a longitudinal axis towards the motion direction (GD-V),

Results of measurements were developed statistically with the use of the following procedures (Greń, 1984; Rabiej, 2012):

– checking out, whether the assumed number of a sample for a given measurement variant is sufficient,
– checking out assumptions indispensable for carrying out analysis of variance, i.e. compatibility of distribution of external friction angles with a regular distribution for a given measurement variant (test χ^2) and equality of variance for comparable variants (Lavene's test),
– carrying out comparative analysis of average values of static coefficient of external friction for particular measurement values in order to separate significant differences in this property. in case of determining significant differences, Duncan's "post-hoc" test was applied which enabled extinguishing of the-so called uniform groups.

For calculation, a package of statistical software „*Statistica*" v. 10 was used and testing hypotheses were carried out at the significance level of α=0.05.

Research results and their analysis

The calculations, which were carried out proved that the accepted number of samples for a given measurement variant was sufficient. The determined minimum number of trials did not exceed 90 measurements.

Moreover, it was determined that distribution of the measured static friction angles for particular measurement variants are in accordance with the regular distribution. An exemplary graphical illustration of a test for variant (BD-H) was presented in figure 2.

Results of Levene's tests also proved that there were no bases to reject hypotheses on uniformity of variation for the compared measurement variants.

Detailed results of statistical calculations for single caryopses were presented in table 1.

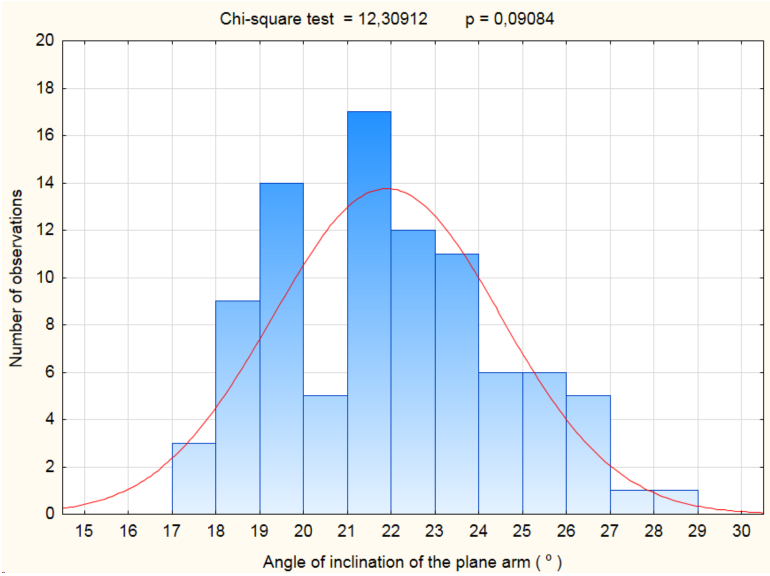

Figure 2. A histogram of the distribution of the value of external static friction angles for single wheat caryopses oriented during the measurement perpendicularly towards the motion direction and touching each other with the furrow side with and a steel plate

Table 1
The list of statistical parameters which characterize coefficients of static external friction of single wheat caryopses and results of analyses of variation for various measurement variants

Measurement variant	Minimum sample size	Average value of friction coefficient μ (-)*	Standard deviation (-)	Value of statistics of F-Snedecor's	Value of probability
BD-H	62	0.40^{a}	0.053	71.88	0.000
BD-V	78	0.41^{a}	0.063		
GD-H	50	0,31^{b}	0.042		
GD-V	61	0.39^{a}	0.051		

* - average values determined with the same letters do not differ statistically significantly (uniform groups)

The lowest average value of static friction coefficient for single caryopses on the steel base was reported for their arrangement with a back side up and with a longitudinal axis perpendicular to the motion direction. This value differed statistically significantly from the remaining (separated uniform group). The most probably it follows from the initiation of the seed motion by wheeling (turnover of the lifted caryopses on the contact side of a furrow with a base. For the remaining measurement variants statistically significant differences between average values of coefficients of static friction were not determined.

Results of statistical calculations for the stabilized system of caryopses were presented in table 2.

Table 2
The list of statistical parameters which characterize coefficients of static friction of the stabilised system of wheat caryopses and results of analyses of variation for various measurement variants

Measurement variant	Minimum sample size	Average value of friction coefficient μ (-)*	Standard deviation (-)	Value of statistics of F-Snedecor's	Value of probability
BD-H	49	0.29[a]	0.035	24.09	0.000
BD-V	50	0.28[a]	0.035		
GD-H	54	0.28[a]	0.043		
GD-V	51	0.5[b]	0.037		

* - average values determined with the same letters do not differ statistically significantly (uniform groups)

The lowest average value of static friction coefficient for caryopses in the stabilised system was reported for their arrangement with a back side up on a steel plate and with a longitudinal axis in parallel to the motion direction. This value differed statistically significantly from the remaining (separated uniform group). Probably, it follows from a relatively smaller contact surface of seeds with a surface (point contact) and more "favourable" conditions for motion initiation through sliding in case of measurement variants. For the remaining measurement variants statistically significant differences between average values of coefficients of static friction were not determined.

Additional comparison of average values of static friction coefficients between single caryopses and the stabilized system for a given measurement variant proved in all cases the occurrence of statistically significant differences. Considerably higher values of coefficients were reported for single wheat caryopses.

Conclusion

Based on the research results and their analysis one may state that average values of static friction coefficients of single wheat caryopses in the stabilized system on the steel base depend on the manner of arrangement during measurements. For single caryopses lower value of this parameter in case of caryopses contact with a back side and arranging them with a longitudinal axis perpendicular towards the motion direction. Identical relation for caryopses in the stabilized system was reported for their arrangement with a back side up on a steel plate and with a longitudinal axis in parallel to the motion direction.

Moreover, it was determined that average values of static friction coefficients for the tested wheat are considerably higher than for single caryopses (from 0.31 to 0.41) in the stabilised system at their identical arrangement during measurements. This fact requires further research because it is difficult to precisely define its reason.

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Renata Urbańska-Gizińska, Stanisław Konopka

PORÓWNANIE WSPÓŁCZYNNIKÓW TARCIA ZEWNĘTRZNEGO DLA POJEDYNCZYCH NASION I W UKŁADZIE STABILIZOWANYM

Streszczenie. W pracy przedstawiono porównanie średnich wartości statycznych współczynników tarcia zewnętrznego pojedynczych ziarniaków pszenicy odm. Naridana z ziarniakami w tzw. układzie stabilizowanym, przy różnej ich orientacji w stosunku do kierunku ruchu po podłożu ze stali. Badania przeprowadzono na stanowisku z optoelektronicznym układem pomiaru kąta uniesienia ramienia równi. Stwierdzono, że średnie wartości współczynników tarcia statycznego pojedynczych ziarniaków pszenicy i ziarniaków w układzie stabilizowanym zależą od ich sposobu ułożenia w trakcie pomiarów. Dla pojedynczych ziarniaków istotnie niższą wartość tego parametru odnotowano w przypadku styku ziarniaków z podłożem stroną grzbietową i ułożeniu ich podłużną osią prostopadle w stosunku do kierunku ruchu, zaś dla ziarniaków w układzie stabilizowanym - przy ułożeniu ich stroną grzbietową na stalowej płytce i podłużną osią równolegle do kierunku ruchu. Stwierdzono również, że średnie wartości współczynników tarcia statycznego dla pojedynczych ziarniaków są znacznie wyższe niż dla ziarniaków w układzie stabilizowanym, przy identycznym ich ułożeniu podczas pomiarów.

Słowa kluczowe: współczynnik tarcia statycznego, nasiona pszenicy, podłoże ze stali