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COEFFICIENT OF EXPLOSION OF GRAPE OIL REPAS IN RESPECT OF VARIETY, CONTENT OF HUMIDITY AND SURFACE

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Abstract: *Knowing the coefficient of friction of bio material is important in determining the angle of the grain elevator elevator when designing combines, as well as the angles of gravity tables and pipes in seed finishing. The basic characteristic of biological materials, or seeds of agricultural crops, is that they differ in their physical and morphological characteristics. Therefore, the friction depends on: the types of plants, variety, shape, dimensions and seed content, the humidity of the seed, the intensity of the normal force on the substrate and the roughness of the substrate. The paper presents the results of the study of the influence of individual factors (varieties, water content of the grain and the type of substrate) and their interactions on the grain friction coefficient. The domestic varieties that are grown in Serbia are selected for testing the fruiting grain fruity: Banaćanka, Jasna and Slavica. The experimental measurement of the static coefficient of grain slip friction was done using the level of the mechanical device Tribometr. Plastic, plywood, galvanized, steel, aluminum and stainless steel sheet are made for the experiment purposes. Research was carried out with different water content in grains: 6%, 11%, 16% and 24%. The variety Banaćanka had a lower friction coefficient compared to Jasna and Slavica varieties on all substrates and with all the water content of the grain. It was found that with the increase of water content in the grain, a significant increase in the friction coefficient of the grains of the tested varieties on all substrates was achieved. The highest friction coefficient for all water content of the grains of the tested varieties was on the base of the plywood board, and the smallest on the base of stainless steel sheet.*

Keywords: *oilseed rape, variety, static coefficient of friction, substrate, water content in grains.*

1. INTRODUCTION

Oilseed rape is among the four most important oil plants in the world next to soya, palm and sunflower. Oilseed rape is grown for grains containing 40-48% oil and 18-25% protein. Rape oil is used in people's eating, for the production of biodiesel, in the soap industry, for lubricating parts in machinery assemblies, etc. After grain pressing and oil extraction, oil rich cakes with proteins used in domestic animal feeding are obtained [1], [2], [3].

The development and design of agricultural mechanization and seed treatment equipment required the need to know the friction properties of bio-materials. Knowing the static coefficient of friction is important when determining the angle at which elevators and gravity tubes can be positioned for the smooth transport of grain, as well as the angles of gravity tables in seed finishing.

The basic characteristic of biological materials, or seeds of agricultural crops, is that they differ in their physical and morphological characteristics. During harvest, and even after harvest in the process of finishing, the seed moves on a surface, resulting in friction. The value of the friction coefficient depends on: the types of plants, variety, shape, dimensions and material of the individual seeds, the humidity of the seed, the intensity of the normal force on the substrate and the roughness of the substrate [4], [6], [7], [8] [9], [10], [11], [12], [13].

The static coefficient of friction of solid materials depends on the roughness of the friction surfaces and their microreef expressed by the number, shape, depth, width and surface of the holes, as well as the number and height of the ridge. Experiments have shown that the static friction coefficient decreases with decreasing roughness, ie the mean surface roughness (Ra) [14], [15]. Based on the studied friction parameters [15], they modeled the relief surface in order to reduce friction.

In addition to the roughness of the friction of solid materials, the nature of the surface of the body that touches is influenced, which depends on the composition of the material and the way of processing the base substrates. Surfaces with the same roughness values have different friction coefficients depending on the surface treatment of the substrate surface [14] [15], [16].

Research on the surface roughness of fruiting surfaces significantly influences the static friction coefficient of wheat grains of Jensen [11]. The smallest coefficient of wheat grain static friction was on the tar surface of roughness Ra = 0.93 μm, and the highest on Ra = 5.86 μm and ranged from 0.29 to 0.45.

Many researchers examined the static coefficient of friction of agricultural crops on various substrates, citing only the material from which the substrate was made, but not the values of the unevenness and the method of processing. Therefore, for some authors, the values of the coefficient of seed friction differ in the same types of plants and varieties on the same substrates. The authors also established a positive relationship between the friction coefficient and the content of water in the grains [4], [6], [7], [8], [12], [13], [17].

The only way to determine the precise static friction coefficient coefficient between the substrate of the two materials is in the labs using experiments using different methods [13], [14], [18], [19]. However, on the basis of the results of the previous measurement, the authors [13] developed mathematical models for determining the coefficient of friction in silos in the scaling and processing of wheat seeds. According to the above-mentioned authors, the developed models are sufficiently reliable to directly determine the coefficient of friction of wheat grain under conditions of storage and processing without the need for actual measurement.

The aim of the research is to determine the static coefficient of grain friction of three varieties of rapeseed on various substrates and water content of grains, and to determine their significance by means of statistical analysis of the trophactorial experiment. The obtained friction coefficient results can be used in the construction of transport and separation bodies on combines and equipment for storage and processing of seeds.

2. MATERIAL AND METHOD OF WORKŽ

To measure the coefficient of static friction, a pure grain of three varieties of rapeseed Banaćanka, Jasna and Slavica was used. All three varieties were created at the Institute of Field and Vegetable Crops in Novi Sad. The grain is cleaned on the Dakota selector from the presence of foreign matter (particles of soil, dust, stones, weed seeds, parts of plants, damaged grains). Determination of the static coefficient of friction of the rape seed was carried out with a humidity content of 6%, 11%, 16% and 21%.

The initial content of grain water was determined using a standard drying method in a drying oven at a temperature of 105°C. After drying, the samples with the grain were placed in a desiccator to cool for 15-20 minutes. The samples were after cooling, measured on a scale and calculated by the initial water content in the grain. By adding and mixing a certain amount of distilled water with grain, a higher content of water in grains of 11%, 16% and 21% was achieved. The amount of water added to the grain was calculated according to the following formula [4], [6], [7], [13].

$$w_2 = w_1 x \left[\frac{M_2 - M_1}{100 - M_2} \right] \quad (1)$$

Where: w_2 is the weight of the distilled water (kg), w_1 weight of the initial sample (kg), M_1 initial water content in the grain (%), and M_2 the desired water content in the grain (%).

Marked grain samples were placed in plastic bags and stored in a refrigerator for at least 7 days at a temperature of 5°C. During storage, the moisture was evenly distributed to all the grains in the sample, so that a uniform sample was obtained with the same moisture content. Before the start of the measurement, the samples were taken out of the fridge and left for two hours at room temperature. By re-measuring the grain mass after storage in the refrigerator, the true grain moisture for all varieties was determined (Table1). After that, the determination of the coefficient of static friction of the grain of rapeseed was started.

The values of the static friction coefficient coefficient were experimentally determined using a hair level on a mechanical device Tribometer T1 constructed at the Faculty of Mechanical Engineering in Kragujevac [14], [18], [19]. For the needs of the experiment, substrates made of different materials were made: galvanized sheet, steel sheet, stainless steel, aluminum sheet, plastic and plywood. Prior to each measurement of grain samples, the substrates were purified by distilled water and wiped with a dry cotton cloth to clean all impurities from them [11], [19]. To determine the friction coefficient coefficient of the same grain mass, the plastic hollow is placed in the hollow, which is placed on the flat Tribometer flat and slightly raised from the substrate.

Figure 1. Friction coefficient measuring device Tribometar 1

The analysis of the obtained data of the coefficient of the rapeseed rapeseed friction fracture was analyzed by the method of variance analysis (ANOVA) of the trophactorial experiment. Testing the significance of the difference between the mean values of the investigated properties (factors) was determined using the LSD test, for a level of significance of 5% and 1%.

3. RESULTS AND DISCUSSION

The content of grain water is a physical property on the basis of which the beginning of the harvest is determined, and after harvest the parameters in the process of drying and storing grains in order to preserve its quality. From the content of the grain moisture content and the operating mode of the combustion chamber of the combine depends on the quality of the performance of the grain, or the degree of grain damage during the harvest. Based on the known initial grain moisture content of the harvested grain in the field, the parameters and length of the grain drying process are determined. During storage of grain in warehouses, monitoring of the humidity and grain conditions, certain technological procedures are undertaken in order to preserve its quality.

During the study of the static coefficient of friction, the desired content of water in the genus Banaćanka, Jasna and Slavica varieties was approximate to the measured values. The indicated values of water content in the grain were achieved in the laboratory by the indicated method (Table 1.)

Table 1. Predicted and measured mean values of water content in rape seed

Predicted values of water content in grains *w* (%)		6	11	16	21
Realized mean value content of water in the grain *w* (%)	Banaćanka	6,04	11,44	16,03	21,17
	Jasna	5,82	11,15	15,91	20,90
	Slavica	5,98	10,73	15,97	20,46
The mean value of water content in the grain *w* (%)		5,74	11,11	15,97	20,84

The friction coefficient varied considerably under the influence of all three factors (Table 2), as well as the interaction of their interaction between the substrate / variety and the substrate / water content of the grains.

The smallest grain friction coefficient was measured in the Banaćanka variety (0,288), and it significantly differed from the Jasna variation (0,322), and Slavica (0,321), on all substrates and with all the water content of the grain.

The smallest grain friction coefficient was measured in the Banaćanka variety (0,288), and it significantly differed from the Jasna variation (0,322), and Slavica (0,321), on all substrates and with all the water content of the grain. The results of the survey [7] for the varieties Samurai, Jet Neuf and Capitol are also confirmed by the differences between the varieties of oilseed rape, irrespective of the types of water and the content of water in the grain, the coefficient of friction. The most significant coefficient of friction was the Capitol variety and the smallest variety of Samurai on all substrates at all grain moisture levels. Also, authors [6] found for the Orient least the smallest, and for the SLM variety, the greatest coefficient of static friction, regardless of the substrate and the content of the water in the grain.

Table 2. Friction coefficient depending on the type of substrate, variety and water content in the grain

Substrate type (A)	**n**	$\overline{X} \pm S\overline{x}$
Galvanized sheet	48	0,302±0,004[c]
Steel sheet	48	0,308±0,006[bc]
Prohrom sheet	48	0,271±0,005[d]
Aluminum sheet	48	0,313±0,006[b]
Plastics	48	0,331±0,007[a]
Plywood	48	0,337±0,007[a]
Sorta (B)		
Banaćanka	96	0,288±0,004[b]
Jasna	96	0,322±0,004[a]
Slavica	96	0,321±0,005[a]
Vlažnost (C)		
6%	72	0,264±0,003[d]
11%	72	0,298±0,003[c]
16%	72	0,325±0,004[b]
21%	72	0,354±0,005[a]
Anova	***df***	
A	5	**
B	2	**
C	3	**
A ***x B***	10	**
A ***x C***	15	**
B ***x C***	6	Ns
A ***x B x C***	30	**

Mean values per columns marked with the same letters do not differ (P> 0.05) based on the LSD test.

* F-test significant at P <0.05; ** F-test significant at P <0.01; ns -F-test is not significant (P> 0.05).

Regardless of the variety and type of substrate, the static coefficient of friction increased significantly with the increase in water content in the grain.

In all substrates, irrespective of the variety, with the lowest content of grain water (6%), the smallest friction coefficient of 0.264 was significantly increased from 0.298 (11%) to 0.325 (16%), in order to achieve the highest value of 0.354 at the highest water content in a 21% grain (Table 2).

Therefore, the increase in the grain moisture content significantly influenced the increase in the coefficient of grain friction coefficients on all substrates. As the moisture content increases, the grains become sticky, and because of this, the cohesive forces between the grain and the contact surface increase, leading to an increase in the friction coefficient. Research on other authors [4], [6], [7], [20] confirms that the grain friction coefficient increases with the increase in the content of water in the beans. According to the results [6], the static coefficient of friction on different substrates increases non-linearly with increasing water content in the grain.

Table 3. Friction coefficient depending on the type of substrate and variety.

Substrate type	N	Friction coefficient $\overline{X} \pm S\overline{x}$		
		Sort		
		Banaćanka	Jasna	Slavica
Galvanized sheet	16	$0{,}293\pm 0{,}007^{hi}$	$0{,}312\pm 0{,}009^{efg}$	$0{,}301\pm 0{,}007^{gh}$
Steel sheet	16	$0{,}276\pm 0{,}009^{j}$	$0{,}329\pm 0{,}008^{cd}$	$0{,}319\pm 0{,}011^{def}$
Stainless steel sheet	16	$0{,}247\pm 0{,}009^{k}$	$0{,}285\pm 0{,}008^{ij}$	$0{,}283\pm 0{,}006^{ij}$
Aluminum sheet	16	$0{,}294\pm 0{,}009^{hi}$	$0{,}324\pm 0{,}008^{d}$	$0{,}322\pm 0{,}010^{de}$
Plastics	16	$0{,}308\pm 0{,}012^{fg}$	$0{,}337\pm 0{,}009^{bc}$	$0{,}347\pm 0{,}013^{ab}$
Plywood	16	$0{,}312\pm 0{,}010^{efg}$	$0{,}346\pm 0{,}011^{ab}$	$0{,}354\pm 0{,}014^{a}$

Note: The mean values per columns marked with the same letters do not differ (P> 0.05) based on the LSD test.

On average for all varieties and water content in the grain, the highest coefficient of friction was on the surface of plywood plate 0.337 and plastic 0.331. On rough and uneven surfaces, the substrate from the plywood plate and the plastic grain tend to slide, so the greatest friction coefficients are measured on them. There was no difference in the coefficient of friction between the substrate of aluminum 0.313 and the steel sheet 0.308 as well as the galvanized 0.302 and steel sheet (Table 2.) However, there is a deviation in the Banančanka variety between the coefficient of friction on the substrates of aluminum and steel sheet (interaction of the substrate / sort). In all varieties, there was also a difference in the coefficient of friction between galvanized and steel sheet (interaction of the substrate / variety) (Table 3). It was expected that the surface surfaces of the galvanized and steel sheet substrates, similar roughness, however, the results of the substrate/variety interactions did not confirm this. This can be explained by the fact that the surface of the steel sheet substrate is greater than the roughness of the galvanized sheet surface.

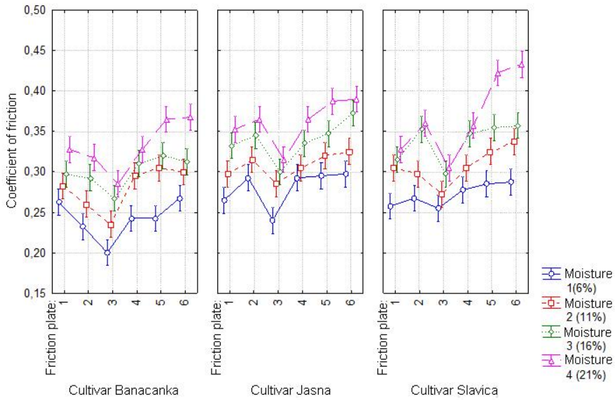
Table 4. Friction coefficient depending on the type of substrate and water content in the grain

Substrate type	n	Friction coefficient, $\overline{X} \pm S\overline{x}$			
		The content of water in the grain			
		2014 year			
		6%	11%	16%	21%
Galvanized sheet	12	$0{,}262\pm 0{,}004^{j}$	$0{,}295\pm 0{,}004^{gh}$	$0{,}315\pm 0{,}005^{f}$	$0{,}336\pm 0{,}005^{cde}$
Steel sheet	12	$0{,}264\pm 0{,}008^{j}$	$0{,}291\pm 0{,}010^{gh}$	$0{,}330\pm 0{,}009^{de}$	$0{,}347\pm 0{,}008^{bc}$
Stainless steel sheet	12	$0{,}232\pm 0{,}008^{k}$	$0{,}264\pm 0{,}007^{ij}$	0,288± 0,006h	$0{,}302\pm 0{,}005^{g}$
Aluminum sheet	12	$0{,}271\pm 0{,}007^{j}$	$0{,}302\pm 0{,}005^{g}$	$0{,}331\pm 0{,}006^{de}$	$0{,}350\pm 0{,}009^{b}$
Plastics	12	$0{,}274\pm 0{,}008^{ij}$	$0{,}312\pm 0{,}005^{f}$	$0{,}341\pm 0{,}006^{bcd}$	$0{,}392\pm 0{,}008^{a}$
Plywood	12	$0{,}284\pm 0{,}006^{hi}$	$0{,}321\pm 0{,}007^{ef}$	$0{,}347\pm 0{,}009^{bc}$	$0{,}397\pm 0{,}009^{a}$

Note: The mean values per columns marked with the same letters do not differ (P> 0.05) based on the LSD test.

The coefficient of friction on the plastic substrate did not differ from the coefficient of friction on the substrate of aluminum, steel sheet with the content of water in grains of 6% and 16%, as well as on the galvanized sheet with a water content of 6% grain content (substrate/water content) (Table 4). Most likely, when measuring the value of the friction coefficient, the water and oils content of the grain was transferred to the pores on the surface of the substrate on the plastic. Such a moist fret surface of the substrate has become smooth or rough roughness of the other substrates, except the substrate of stainless steel sheet. Up to the same conclusions came [13] in determining the friction coefficient of wheat grain.

The smallest friction coefficients of the grains of the tested varieties and all the water content of the grains were on the basis of stainless steel sheet (0,271). The smooth and flat-polished surface of stainless steel sheet allows the grain to slide smoothly over it without any resistance.



Types of substrate: 1. Galvanized sheet, 2. Steel sheet, 3. Stainless steel sheet, 4. Aluminum sheet, 5. Plastic, 6. Plywood plate

Figure 2. Friction coefficient depending on the type of substrate, variety and water content in the grain

Figure 2 shows the results of measuring the values of the static coefficient of slip friction depending on the variety, the type of substrate, the content of water in the grain and their interaction.

The order of the friction coefficient shown in this paper coincides with research [4] [7] for sheet metal, steel, aluminum and stainless steel sheets. The results of these investigations are also in agreement with the results [20] for friction coefficients on plastic, galvanized and stainless steel sheet. [21] have found that the smallest coefficient of friction of grain of rapeseed on the steel sheet (0.273) is approximately the value obtained in these studies. The research results [22] for coefficient of friction on galvanized substrates (0.318), aluminum (0.305) and stainless steel sheet (0.288) are similar to the values published in this paper.

The results of these studies for friction coefficients differ from the results [6], only in that the coefficient of friction on the surface of galvanized sheet is greater than the coefficient on the plastic substrate. This difference in friction coefficient values is most likely a consequence of the fact that the roughness of the surface of the plastic substrate in these researches was not the same as in the studies of the mentioned authors.

4. CONCLUSION

Friction coefficient is a physical feature that plays an important role in the construction of means of transport, seeds processing and storage design.

It was found that with the increase of water content in the grain, a significant increase in the friction coefficient of the grains of the tested varieties on all substrates was achieved.

The coefficient of friction of the Banaćanka variety is lower in relation to the varieties Jasna and Slavica on all substrates and with all the water content of the grain.

It was found that with the increase of water content in the grain, a significant increase in the friction coefficient of the grains of the tested varieties on all substrates was achieved.

The highest coefficient of friction for all water content of the grains of the tested varieties was on the base of plywood and plastic, and the smallest on the base of stainless steel sheet. However, the coefficient of friction on the plastic substrate did not differ from the coefficient of friction on the substrate of aluminum, steel and galvanized sheet metal in the content of water in a grain of 6% (substrate water/water content).

There is no difference in the coefficient of friction of the tested varieties for all grain moisture content on the base of aluminum and steel sheet, except for the Banaćanka variety. Also, there was no difference between the friction coefficient of grains of investigated varieties between the substrate of galvanized and steel sheet in all grain water content (substrate / variety interactions).

Based on the results of the research, mathematical models and computer simulations can be made for the direct prediction of the static friction coefficient, for the investigated substrates and the water content of the rapeseed grains, as they did [13] for grain wheat and [8] for soybean grain.

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