Bulgarian Journal of Agricultural Science, 30 (No 1) 2024, 96–100

Physical and mechanical characteristics of grain and seeds

Bozhidar Kolev and Miroslav Mihaylov*

University of Ruse "Angel Kanchev", 7017 Ruse, Bulgaria
**Corresponding author:* mmihaylov@uni-ruse.bg

Abstract

Kolev, B. & Mihaylov, M. (2024). Physical and mechanical characteristics of grain and seeds. *Bulg. J. Agric. Sci., 30*(1), 96–100

When designing and manufacturing machines and installations for processing, transporting and storing grain and seeds, it is necessary to know some of their basic physical and mechanical characteristics. They are also necessary for the correct selection of the operating modes of the facilities in the grain warehouses.

In this paper, an engineering and technical classification of the mass-grown cereals, legumes and oilseed crops in Bulgaria is presented. For the most used varieties and hybrids, density of grains (seeds), hectoliter mass, angle of natural slope, and angle of friction on smooth materials are determined.

Keywords: grain; seeds; shape; dimensions; roughness; density; hectoliter mass; angle of natural slope; friction

Introduction

In the post-harvest period, a number of operations, such as transportation, cleaning, sorting, calibration, handling, packaging, as well as processes such as drying and storage of grain and seeds are carried out. During these activities, goals are pursued to minimize losses from scattering and spoilage, improve grain and seed quality, and reduce processing and storage costs per unit mass of production.

In order to achieve the above results, it is mandatory to know some basic physical and mechanical characteristics of the grain and seeds, such as shape, dimensions, roughness, density, hectolitre mass, angle of the natural slope (internal friction), coefficient of friction on different materials (external friction) and others. These characteristics must also be known when designing the machines and equipment for processing, drying, storage and inter-machine transport (Altuntas & Demirtola, 2007; Jouki & Khazaei, 2012; Riyahi et al., 2011; Sologubik et al., 2013).

While the shape, size, and roughness of the grain (seeds) depend only on the species and variety (hybrid), according to the studies of Davies & El-Okene (2009), Izli et al. (2009), Kalkan & Kara (2011), Kara et al. (2012), Sharobeem (2007), Tarighi et al. (2011) and other researchers, the other characteristics are also determined by the content of moisture and impurities, the type of surface on which the grain (seeds) is rubbed, and the normal pressure on the grain layer.

Material and Methods

A large number of cereals, legumes and oilseed crops are grown in Bulgaria. Wheat, barley, corn, rice, sorghum, peas, soybeans, rapeseed and sunflower crops are more important and occupy a larger part of cultivated areas.

The target of the study is grain and seeds of these crops and the object of the study are some of their physical and mechanical characteristics.

The research was conducted with some of the most widely used varieties and hybrids in our country: wheat, variety Milena; barley, variety Stunt 3 and sunflower, hybrid Dalena (from Dobrudja Agricultural Institute – General Toshevo); corn, hybrid Knezha 435 and soybean, variety Izidor (from the Institute of maize – Knezha); rice variety Luna (from R&F); sorghum, hybrid Lupus (from KWC); peas, variety

Skinado; canola hybrid Ambassador (from LG).

The studied grain and seeds from the above crops have a storage humidity and impurity content permissible according to the standard (EN ISO 24333: 2010). All tests were carried out in laboratory conditions at an ambient temperature of 27÷32°C, relative humidity 38÷45%.

From an engineering and technical point of view, grain and seeds are divided according to:

– shape – round, oblong and irregularly shaped;

– size – small, medium and large;

– roughness – smooth and grooved.

According to the shape, all those with similar dimensions along the three coordinate axes – width, thickness and length – are included in the round grains group. Oblong grains include grains and seeds with one size significantly larger than the other two. The rest are irregularly shaped.

The density ρ of the grains or seeds was calculated in g/cm³. It was determined by separating a certain number at random according to the size (500, 1000 or 2000), measuring the mass *M* with an accuracy of 0.001 g and pouring them into a graduated measuring cylinder of volume 500 cm³, half filled with water. The difference in the volume V_0 of the water before and V_1 in cm³ after the pouring of the seeds was recorded. The density is determined by the expression:

$$\rho = \frac{M}{V_1 - V_0}, \text{ g/cm}^3 \quad (1)$$

Hectolitre mass was calculated in kg/hl using the libra or feed meter method (Figure 1) (ISO 7971-1:2009). The mass *M* of grain with a volume of 1 litre from the feed meter is weighted with an accuracy of 0.001 kg and the hectolitre mass *HM* is obtained by the expression:

$$HM = 100 \times M, \text{ kg/hl} \quad (2)$$

Fig. 1. Determination of the hectoliter mass with a feed meter

The angle of natural slope α (or internal friction) is locked between the formation and the diameter of the base of the cone formed by the pouring of grain or seeds on a flat horizontal surface. It is measured in degrees using the device in Figure 2 (Kolev, 2005). From a height of 1 m, a volume of 10±1 l of the grain or seeds was poured onto a flat horizontal base 2, forming a mound 1, and with the help of a protractor 3 with a long arm 4, the slope angle was read with an accuracy of ±1 deg.

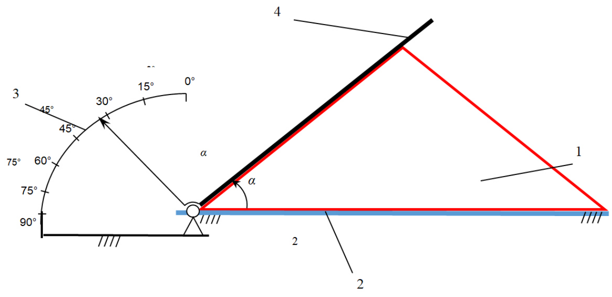

Fig. 2. Determining the angle of the natural slope α: *1* – mound of grain or seeds; *2* – base; *3* – protractor; *4* – shoulder

When reading the angle of the natural slope, the long arm of the protractor is placed so that it touches the cone shape formed by the bulk material. It is not allowed to relax the shoulder so that it exerts pressure with its weight.

The internal friction between the particles in the embankment directly affects the possibility and speed of their leakage through technological or accidentally appearing openings in channels, chutes, troughs, silos, bunkers, baskets of transport vehicles, etc.

During processing and storage, the grain or seeds are in contact with smooth metal or plastic surfaces. It is important to know the coefficient of friction of the grain or seeds on these materials. The coefficient of friction *f* represents the tangent of the angle of friction φ or $f = tg\,\varphi$. To determine the friction angle ϕ between a stationary plane of smooth metal sheet or plastic and an elementary layer[1] of grain or seeds, a stand A (Figure 3) was used, consisting of a frame 1 rotating around a horizontal axis 2, a protractor scale 3 and a pointer 4. A sheet 6 of a relevant material is attached to the frame.

Changing the angle of inclination of the frame, the beginning of the sliding of the elementary layer 5 of grain (seeds) on the sheet 6 was observed and the friction angle φ was read on the scale 3 of the protractor with an accuracy of ±1 deg. It should be noted here that two friction angles are distinguished – static φ_s and dynamic φ_d. The static angle φ_s was measured

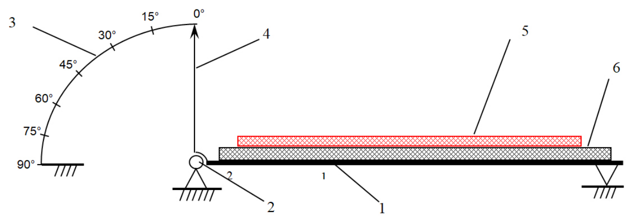

Fig. 3. Stand A for determining the friction angle ϕ:
***1* – frame; *2* – axis; *3* – scale; *4* – indicator;**
***5* – elementary layer of grain or seeds;**
***6* – sheet of researched material**

at the moment of sliding of layer 5 on sheet 6. When reducing the inclination of frame 1, the angle on scale 3 was measured at the moment of stopping the flow of layer 5 on sheet 6. This is the value of the dynamic friction angle φ_d . The static angle is always greater than the dynamic one – $\varphi_s > \varphi_d$.

In order to compare and possibly confirm the results of the tests with stand A for determining the friction angle ϕ on different materials, tests were also carried out on stand B (Figure 4).

The stand B consists of a stationary horizontal Table 1, on which a replaceable plate 2 with dimensions of 500×300×5 mm is fixed, glued with grains or seeds 5. On top is a plate 4 with dimensions of 200×200×5 mm covered with the one we are interested in material 3 (metal or plastic).

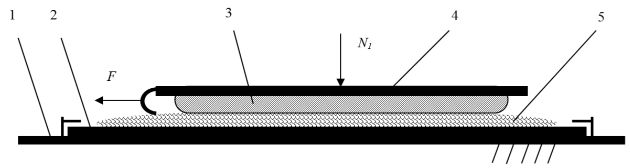

Figure 4. Scheme for researching the angle of friction with load stand B:
***1* – broad board; *2* – lower plate;**
***3* – researched material; *4* – upper plate;**
***5* – elementary layer of grains or seeds**

The loading was carried out with a normal force N_1 with a step of 5 N up to 50 N, and the friction force F, at which the plate 4 starts to slide on the elementary layer 5, was read with a dynamometer with a range of 100 N and an accuracy of 1 N. The tests were carried out with triple repetition.

The friction angle ϕ is determined by the load diagram $F = f(N_1)$, and the friction coefficient is $f = tg\ \varphi$. The dependence is linear and its character is shown in Figure 5. The angle of friction ϕ coincides with the angle of inclination of the line and is obtained from expression (3):

$$\varphi = arctg\frac{F}{N_1}. \qquad (3)$$

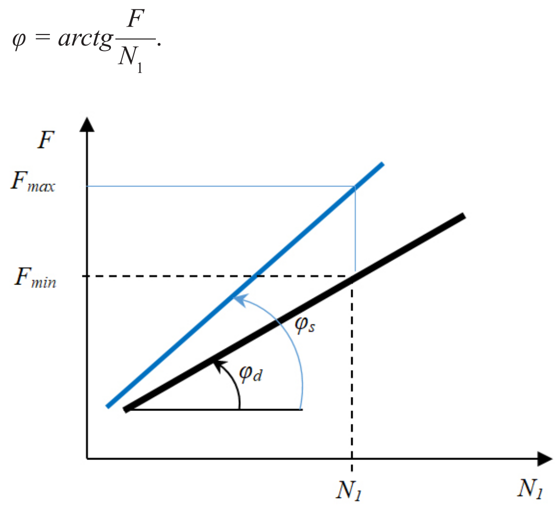

Fig. 5. Diagram for determining the friction angle ϕ

Two friction angles can be considered in this case as well – static φ_s and dynamic φ_d. The first angle is calculated from the value of the force F at the moment of sliding, and the second – from the value of the force F at the moment of stopping of the sliding.

For each of the studies, n (number of) trials were performed, guaranteeing with probability γ the set relative error Δ of the estimate of the arithmetic mean value of the random variables ρ, α, φ_s and φ_d (Mitkov, 2011; Triola & Franklin, 1994).

Results and Discussion

To solve the engineering and technical tasks, grain and seeds are classified into groups according to characteristic external signs. For the grain and seeds of the widely distributed and cultivated crops in Bulgaria, the results are shown in Table 1.

The above results point to a characteristic behavior of grain and seed in their movement to and through machines and processing plants, as well as in their storage. All seeds and grain with a round shape are much more mobile, and the larger ones provide larger air spaces in the bulk, which facilitates active ventilation. In small grains and seeds, for those with irregular shape and in oblong ones, active ventilation is difficult due to the increased resistance to air flow. The internal friction in the mound of round and smooth grain and seeds is smaller compared to others.

The average values of the results for the density of grains and seeds and the hectoliter mass are presented in Table 2.

It is known that the greater the density of grains (seeds),

Table 1. Classification of grain and seeds according to external characteristics

Type of culture	By form	By size	By roughness
Wheat	Oblong	Average	Grooved
Barley	Oblong	Average	Grooved
Corn	Irregularly shaped	Large	Grooved
Rice	Oblong	Average	Grooved
Sorghum	Rounded	Small	Smooth
Peas	Rounded	Large	Smooth
Soy	Rounded	Large	Smooth
Rapeseed	Rounded	Small	Smooth
Sunflower	Oblong	Average	Smooth

Table 2.Density and hectoliter mass of grain and seeds

	Density, g/cm^3		Hectoliter mass, kg/hl	
Type of culture	min	max	min	max
Wheat	1.32	1.35	78.9	80.2
Barley	1.26	1.28	68.8	68.9
Corn	1.25	1.29	72.7	73.1
Rice	1.44	1.46	82.7	83.0
Sorghum	1.22	1.26	71.8	72.0
Peas	1.33	1.37	82.8	83.1
Soy	1.23	1.25	72.1	72.4
Rapeseed	1.10	1.12	66.9	67.2
Sunflower	1.01	1.03	37.9	38.1

the heavier they are and the more nutrients they contain. The hectoliter mass is a basic characteristic of cereals, which directly affects the purchase price, as the grain with a larger hectoliter mass than the basic one is valued higher, i.e. the price receives a bonification compared to the stock price. Otherwise, the price is discounted.

The variation range of the natural slope angle α by the measured minimum and maximum values of the natural slope angle test results is shown in Table 3. This angle is related to arching (clogging) when grain and seeds flow out of hoppers, silos, gravity pipes. The smallest values of angle α were observed for seeds with a round, close to spherical shape, large and with a smooth surface.

Table 3. Angle of natural slope α of grain and seeds

Type of culture	α_{min}, deg	α_{max}, deg
Wheat	27	29
Barley	26	27
Corn	25	26
Rice	24	26
Sorghum	26	27
Peas	23	24
Soy	25	26
Rapeseed	24	26
Sunflower	26	27

The slope of the walls of the prismatic or conical bottoms of bunkers and silos, as well as the slope of gravity pipes must be greater than the maximum angle α_{max}.

The results of the study of the friction angle φ of a grain (seeds) on a smooth metal and plastic surface using stand A are presented in Table 4.

During the examination of the friction angle ϕ by stand B for the minimum and maximum values of F at different loads N_1, the corresponding values of the friction angles φ_s

Table 4. Angle of friction ϕ of grain and seeds on different materials by stand A

Type of culture	On metal		On plastic	
	φ_s, deg	φ_d, deg	φ_s, deg	φ_d, deg
Wheat	17	15	18	16
Barley	18	16	18	16
Corn	16	14	17	15
Rice	17	16	18	16
Sorghum	14	13	15	13
Peas	15	14	16	14
Soy	16	14	17	15
Rapeseed	14	13	14	13
Sunflower	19	17	20	18

Table 5. Friction angle ϕ of grain and seeds on different materials by stand B

Type of culture	On metal		On plastic	
	φ_s, deg	φ_d, deg	φ_s, deg	φ_d, deg
Wheat	16	15	17	16
Barley	18	16	18	17
Corn	17	16	18	17
Rice	16	15	17	15
Sorghum	16	14	17	16
Peas	16	15	18	16
Soy	17	14	18	16
Rapeseed	14	13	15	14
Sunflower	19	18	21	19

and φ_d of the elementary layer of grain (seeds) on metal and on plastic were calculated. The average values of the results are given in Table 5.

The deviations of the values of the friction angles φ_s and φ_d measured by the two stands are within the tolerance field, i.e. are negligibly small. The larger the grain and seeds are, the closer to the round shape and the smoother, the smaller the friction angles.

Conclusion

The classification of grain and seeds of the main crops according to characteristic external signs allows the quick and adequate determination of the operating modes of machines and installations in processing and storage bases. Knowledge of the methodology, as well as the values of density and hectoliter mass, allow the correct determination of bonifications or refractions in relation to the exchange prices of grain and seeds. Significant values of the dynamic and static grain and seed friction angles were confirmed when comparing the measured (by stand A) and calculated values (by stand B). The same can be used in the design and manufacture of machines and equipment for processing, transporting and storing grain and seeds. It is recommended that the slope of the walls of the prismatic or conical bottoms of bunkers and silos, as well as the slope of the gravity pipes, be designed and made with an angle to the horizon >30 deg.

References

Altuntas, E. & Demirtola, H. (2007). Effect of moisture content on physical properties of some grain legume seeds. *New Zealand Journal of Crop and Horticultural Science*, *35*, 423–433.

Davies, R. M. & El-Okene, A. M. (2009). Moisture-dependent physical properties of soybeans. *International Agrophysics*, *23*, 299–303.

EN ISO 24333:2010. Cereals and cereal products.

ISO 7971-1:2009. Cereals — Determination of Bulk Density, Called Mass Per Hectoliter.

Izli, N., Unal, H. & Sincik, M. (2009). Physical and mechanical properties of rapeseed at different moisture content. *International Agrophysics*, *23*, 137–145.

Jouki, M. & Khazaaei, N. (2012). Some physical properties of rice seed (*Oriza sativa*). *Research Journal of Applied Sciences, Engineering and Technology*, *4*(13), 1846–1849.

Kalkan, F. & Kara, M. (2011). Handling, frictional and technological properties of wheat as affected by moisture content and cultivar. *Powder Technology*, *213*, 116–122.

Kara, M., Bastaban, S., Ozturk, I., Kalkan, F. & Yildiz, C. (2012). Moisture-dependent frictional and aerodynamic properties of safflower seeds. *International Agrophysics*, *26*, 203–205.

Kolev, B. (2005). Study of the Threshing Process of Small-Seed Dry Fruit Vegetable Crops. Doctoral dissertation, Ruse University, Ruse (Bg).

Mitkov, A. (2011). Theory of Experiment. Ruse, Academic Publishing House of Ruse University, Ruse (Bg), 228.

Mitkov, A. & Minkov, D. (1993). Statistical Methods for the Study and Optimization of Agricultural Machinery. Part 2, Zemizdat, Sofia (Bg), 368.

Riyahi, R., Rafiee, S., Dalvand, M. J. & Keyhani, A. (2011). Some physical characteristics of pomegranate, seeds and arios. *Journal of Agricultural Technology*, *7*(6), 1523–1537.

Sharobeem, Y. F. (2007). Apparent dynamic friction coefficients for grain crops. *Misr. Journal of Agricultural Engineering*, *24*(3), 557–574.

Sologubik, C. A., Campanone, L. A., Pagano, A. M. & Gely, M. C. (2013). Effect of moisture content on some physical properties of barley. *Industrial Crops and Products*, *43*, 762–767.

Tarighi, J., Mahmondi, A. & Rad, M. K. (2011). Moisture-dependent engineering properties of sunflower (var. Armaviriski). *Australian Journal of Agricultural Engineering*, *2*(2), 40–44.

Triola, M. F. & Franklin, L. A. (1994). Business Statistics. *Addison-Wesley Publishing Company,* 823.

Received: **March, 12, 2023**; *Approved*: **June, 14, 2023;** *Published:* **February, 2024**