Lubrication impact on the value of friction coefficient of coffee beans sliding ever the steel surfaces of various roughness

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Abstract. The article analyzes the influence of steel surfaces processing quality on the value of sliding friction coefficient of Robusta and Arabica coffee beans at dry and lubricated fricbica. The research obtained coffee dry and lubrication functions and parameters of sliding friction coefficients distributions and mathematical models for determining the index which depends on the roughness of steel surfaces.

Key words: coffee beans, steel surfaces, roughness, dry friction, sliding friction coefficient, lubrication.

INTRODUCTION

Advanced technologies of procession, transportation and storage of agricultural production as well as planning of new production operations and designing of new machines and tools are impossible without studies of physical and mechanical properties of agricultural materials serving the functions of structural and technological parameters of machines and equipment.

The research of friction coefficient is especially important [28]. In fact the working surfaces of machines are made mainly of steel or cast-iron of different grades with the use of various technological methods, and that is why their surfaces are characterized by the different processing quality. Inaccuracies in friction coefficient determination result in the increasing of energy and material consumption of equipment, and also result in machines breakage.

A lot of articles are devoted to the method of physical properties investigation of agricultural materials [6, 9, 14, 25, 26]. It is established [3, 12, 16, 19] that relative humidity of seeds and beans has a significant impact on their physical and mechanical properties. Varieties in differences are also essential.

Researches pay a particular attention to the study of friction coefficients of different agricultural materials [10; 11; 15; 16; 19] and to the development of the special means of index measuring [2; 27]. As to coefficients of static friction and sliding it is known that the values of these indexes depend on the sizes of seeds or beans, and value on the relative humidity, and on the friction surfaces material [4; 10; 11; 15; 16; 19]. However, the conducted researches concerned the values of friction coefficients of seeds of different crops in pairs with various materials (steel, aluminum, concrete, glass, etc.) not taking into account the roughness of friction surfaces. At the same time the first researches of friction coefficient concerning the seed of oil-bearing flax [13] showed the necessity to take into account this important index of surfaces processing quality.

As to the coffee beans, the size of seeds [21, 22], coefficients of external and internal friction [20, 23, 24], aerodynamic [1] and thermal properties [7, 17] are determined. At the same time, the published results contain mainly average values and also values range of physical and mechanical properties for different varieties of coffee beans without specifying the nature of the distribution of these random values.

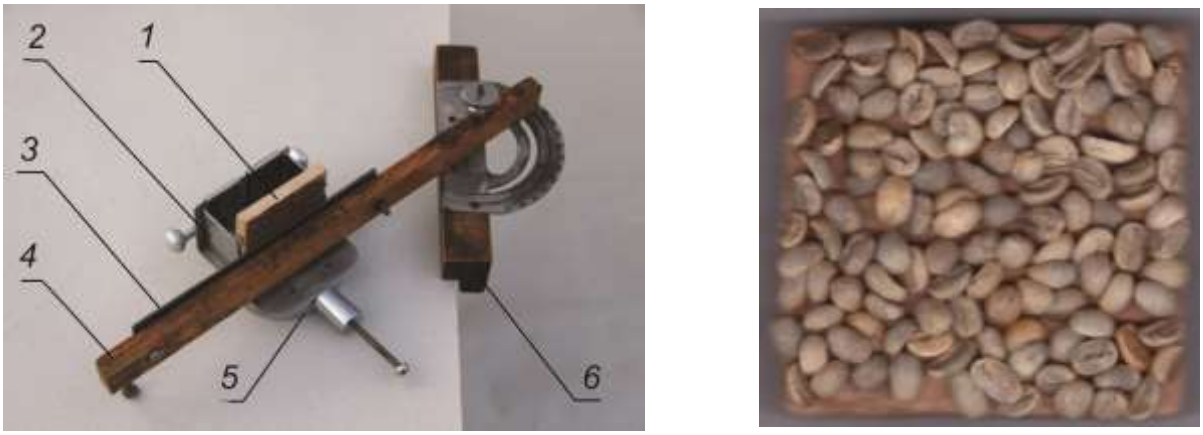
Thus, there is a need for clarification of values of sliding friction coefficients of coffee beans taking into accounts not only their relative humidity and varietal differences, but also surface roughness of sliding and lubrication.

OBJECTIVE OF RESEARCHES

The objective of researches was to determine the sliding friction coefficient of coffee beans of different varieties on the steel surfaces of different roughness under conditions of dry friction and under the presence of lubrication.

METHODOLOGY OF RESEARCHES

The research used Arabica and Robusta coffee beans. The value of relative humidity was obtained with the help of drying preliminary moistened coffee beans in the heat chamber at 100 ^{o}C by changing the drying period.



a *b*

Fig. 1. Device for determination of sliding friction coefficient (*a*) and bar with coffee beans (*b*):
1 – bar of the research material, 2 – carriage 3 – sliding surface, 4 – ruler,
5 – automatic recorder 6 – guide block

Determination of the angle φ and sliding friction coefficient f was conducted using well-known structures (Fig 1) [26, 27]. As sliding surfaces the flat surface of steel parts, processed to a roughness Ra = 12,5 mcm, R_a = 6,3 mcm, R_a = 2,5 mcm, Ra = 1,25 mcm are used. Different roughness values that were determined according to the models of roughness are obtained due to changing the surface processing mode (milling and grinding).

The results of experimental researches were obtained up using the methods of mathematical statistics [5, 18] calculated the mathematical expectation M[f], average quadratic deviation σ[*f*] and variation coefficient *υ*[*f*] of values of sliding friction f, matched the distribution law, application of which was checked using Pearson and Kolmohorov-Smirnov statistic fitting test.

The significance of the difference of obtained results of the sliding friction coefficient and geometrical parameters for the different varieties of coffee beans were checked using the Wilcoxon signed-rank test [5, 18].

The method of regression analysis [8] for obtaining the dependencies of values of mathematical expectation of sliding friction coefficient M[*f*] of different varieties of coffee beans on steel surface roughness Ra in the presence of lubrication was used. Checking of obtained regression dependencies was conducted using the F-test.

RESULTS OF RESEARCHES

According to the results of determination of sliding friction coefficient *f* the distribution of this random variable for Arabica and Robusta coffee beans for different values of steel surface roughness Ra under conditions of lubrication are obtained. (Fig 2).

The distribution parameters of obtained values of sliding friction coefficient of coffee beans of these two varieties on steel surfaces of different roughness under condition of lubrication, namely the mathematical expectation M[*f*], average quadratic deviation [*f*] and variation coefficient [*f*] are defined.

Checking of received results according to the Wilcoxon signed-rank test showed that the difference of values of sliding friction coefficient under condition of dry friction and f_c and under condition of lubrication $f_м$ on steel surfaces of different roughness (1 – *Ra* = 1,25 mcm, 2 – *Ra* = 6,3 mcm, 3 – *Ra* = 12,5 mcm, 4 – *Ra* = 2,5 mcm.) is statistically significant for both varieties of Arabica coffee beans (Fig. 3) and for Robusta coffee beans (Fig 4).

With the help of regression analysis [8] dependencies of mathematical expectation of sliding friction coefficient M[*f*] of Arabica and Robusta coffee beans under condition of lubrication of steel surfaces roughness Ra are obtained:

$$M[f] = c_0 + c_1 \cdot Ra + c_2 Ra^2, \qquad (1)$$

where: c_0, c_1 і c_2 – regression coefficient; *Ra* – surface roughness, mcm.

Checking of the regression model (1) according to the F-test [5, 8, 18] did not give reasons for its rejection.

As we can see (Fig 5), at the same relative humidity φ = 23-26 % for coffee beans of both varieties in case of steel surfaces roughness decreasing starting with Ra = 12,5 mcm (turning) and to Ra = 1,25 mcm (grinding) the values M [*f*] are reducing nonlinear.

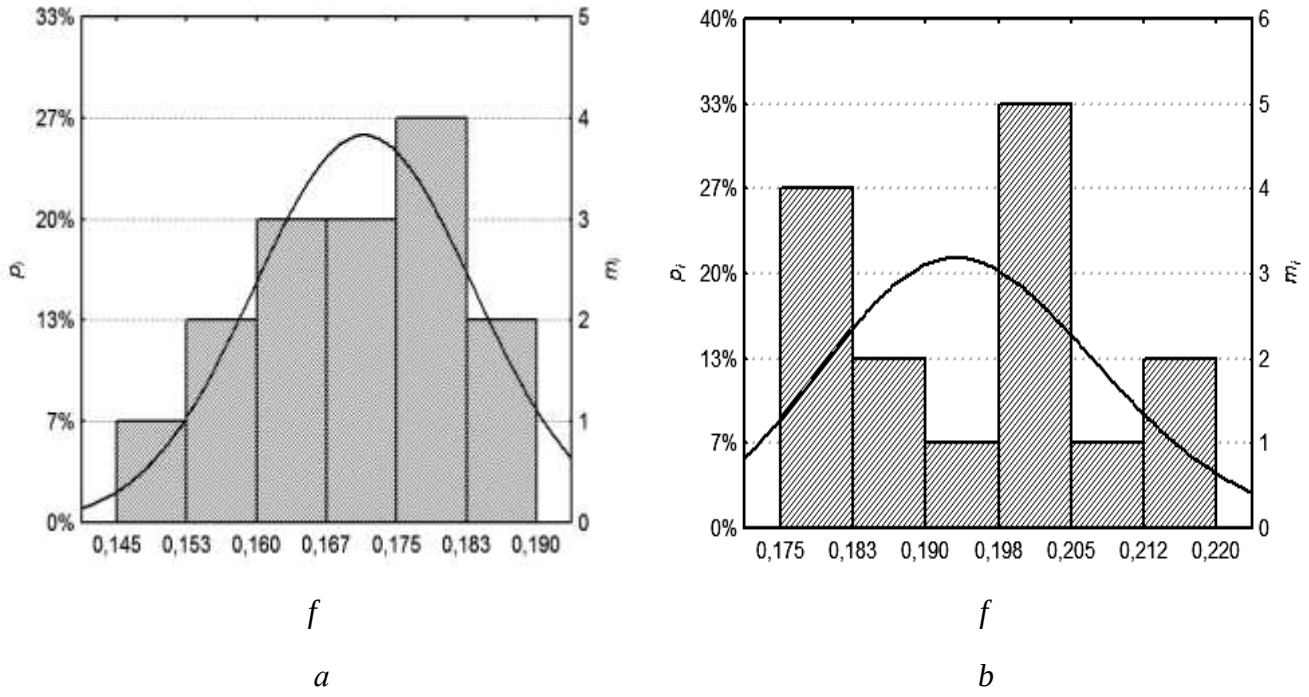


Fig. 2. The results of determination of distribution of values of the sliding friction coefficient of Arabica (*a*) and Robusta (*b*) coffee beans of relative humidity φ = 23-26 % on steel surface roughness Ra = 6,3 mcm under condition of lubrication

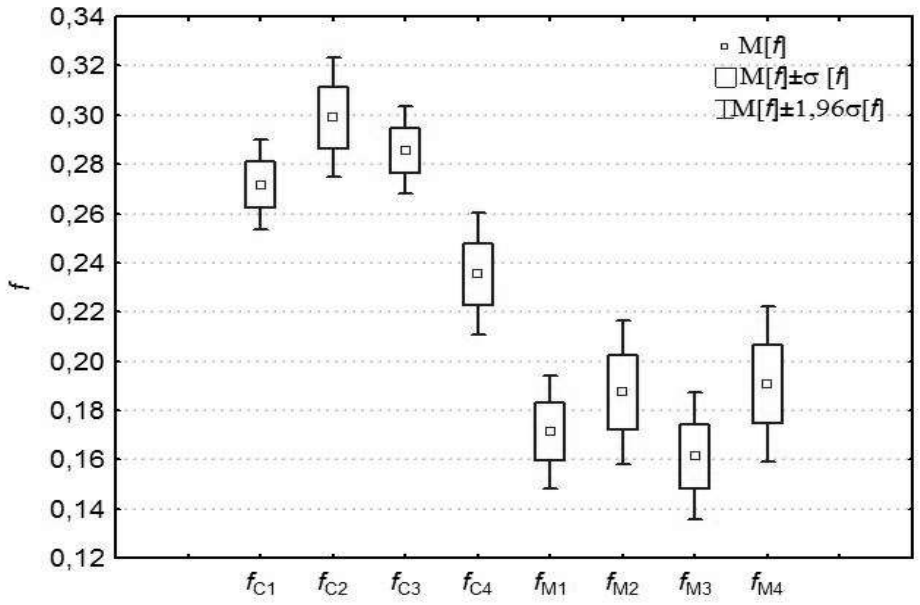


Fig. 3. The results of checking of sampling values of sliding friction coefficient of Arabica coffee beans under condition of lubrication (f_{M1}, f_{M2}, f_{M3}, f_{M4}) and dry friction (f_{C1}, f_{C2}, f_{C3}, f_{C4})on steel surfaces of different roughness according to the Wilcoxon signed-rank test:1 – *Ra* = 1,25 mcm 2 – *Ra* = 6,3 mcm, 3 – *Ra* = 12,5 mcm, 4 – *Ra* = 2,5 mcm

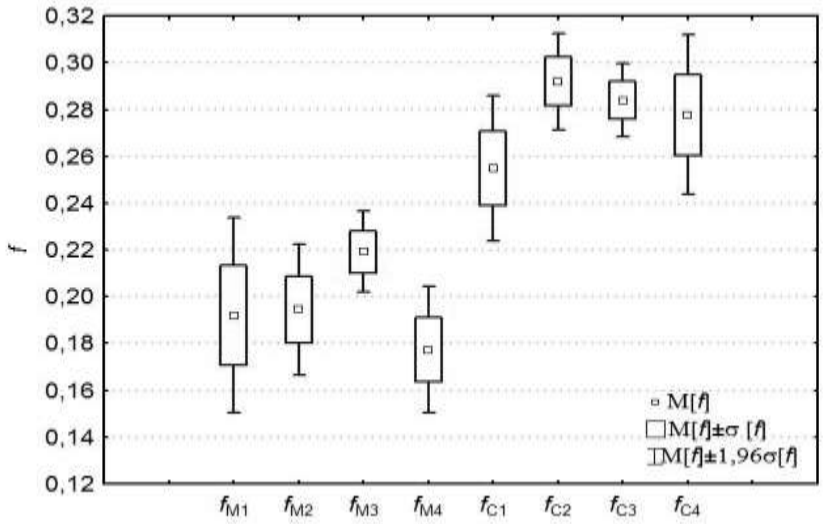
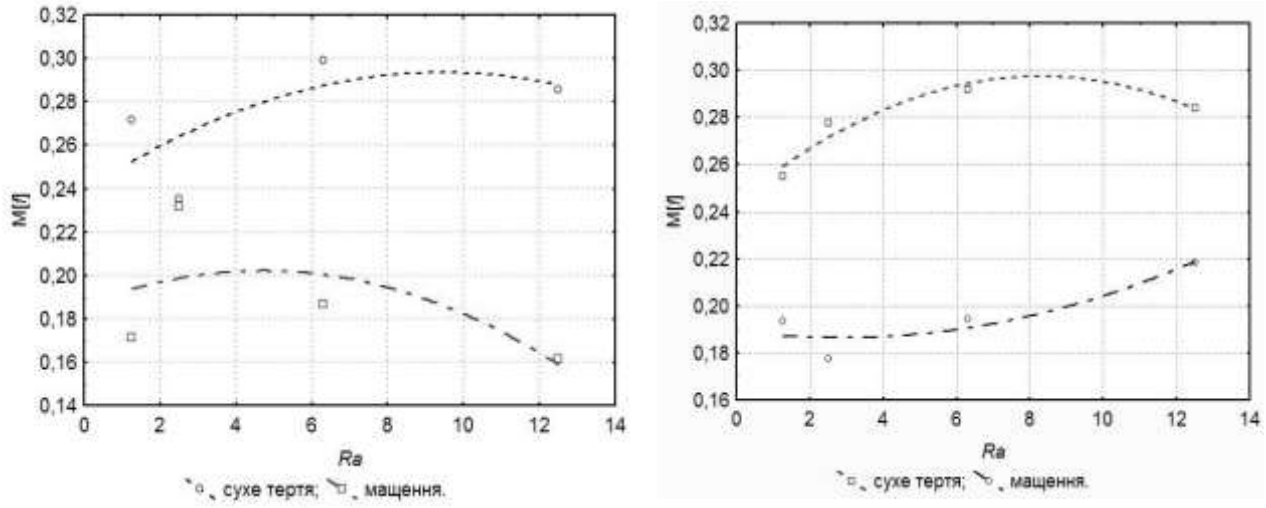


Fig. 4. The results of checking of sampling values of sliding friction coefficient of Robusta coffee beans under condition of lubrication (f_{M1}, f_{M2}, f_{M3}, f_{M4}) and dry friction (f_{C1}, f_{C2}, f_{C3}, f_{C4})on steel surfaces of different roughness according to the Wilcoxon signed-rank test:1 – *Ra* = 1,25 mcm 2 – *Ra* = 6,3 mcm, 3 – *Ra* = 12,5 mcm, 4 – *Ra* = 2,5 mcm



a *b*

Fig. 5. Dependencies of mathematical expectation of sliding friction coefficient M [*f*] of coffee beans on steel surface roughness Ra: *a* – Arabica variety *b* – Robusta variety

CONCLUSIONS

1. The value of sliding friction coefficient of coffee beans on steel surfaces should be considered as random variables distributed according to normal or logarithmic normal laws, the parameters of which significantly depend on the roughness of the processed steel surfaces and the factor of lubrication that should be considered during the project calculations of machines and equipment.

2. Under dry friction the increase of relative humidity of coffee beans influences the values change of sliding friction coefficient more significantly than the increasing of steel surface roughness.

3. The sliding friction coefficient of Arabica coffee beans is much more sensitive to changes of frictional surfaces roughness than for Robusta coffee beans, because of the differences of geometrical parameters of different varieties of beans.

4. Lubrication significantly reduces the value of sliding friction coefficient of coffee beans on steel surfaces with different processing quality.

5. Since the differences of obtained sampling values of sliding friction coefficient for coffee beans of different varieties on steel surfaces with the same processing quality were statistically significant, this index should be given in the reference data taking into account the sorts differences.

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