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DETERMINATION OF FRICTION COEFFICIENTS FOR DIFFERENT VARIETIES OF SOME CEREAL CROPS

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ABSTRACT

A study was carried out to determine the coefficient of friction for some varieties of rice, corn, wheat and barely at five different levels of grain initial moisture content. A digital instrument was used for the experimental measurements using nine different friction surfaces of plywood, rubber, galvanized iron, normal iron, painted iron, stainless-steel, wire-net, perforated iron and plastic. The obtained results showed that, the coefficients of friction for the four studied crops were increased with increasing grain moisture contents and roughness of grain surface. The recorded friction coefficients were ranged from (0.3542 to 0.3765), (0.2415 to 0.6128), (0.2519 to 0.6988) and (0.2481 to 0.6927) for rice, corn, wheat and barely, respectively. Also, for all the tested crops rubber, perforated iron and wire net surfaces recorded the highest values of friction coefficients, normal, painted and galvanized iron surfaces recorded a moderate values, while plywood, plastic and stainless steel surfaces recorded the lowest values. The statistical analysis revealed a highly significant linear positive relationship between the grain moisture contents and the coefficient of frictions for all the studies friction surfaces.

INTRODUCTION

The need for knowledge of coefficient of friction of agricultural materials on various surfaces has long been recognized by engineers concerned with rational design of grain bins, silos and other storage structures (Mohesenin, 1984). The angle of internal friction has been considered as one of the physical properties directly affecting design of flow and storage structures such as hoppers, silos, bunkers and bins because it determine whether the flow will be smooth or not, and whether the bursting forces in relation to vertical forces will be great or not *(Kajuna and Rugenga, 1998).*

The rules of friction coefficients of materials generally used to construct agricultural equipment are often conflicting because the variation in the physical properties of the agricultural crops that have effect on the friction coefficient. The major parameters which affect in internal friction were grain size, shape, moisture content and specific weight of the test sample *(Lawton, 1980).*

Gumbe and Maina, (1990) determined the static coefficient of friction of oats and shelled maize for three different surfaces of (plywood, mild steel and concrete) at moisture contents within a range of 10-20 % (w.b). The results showed that, the coefficient of friction increased with increasing moisture content of the grain tested except for maize on concrete for which changes in moisture content seemed not to have effect. The results also showed that concrete surface had the highest value of (μ) obtained. These values were varied from 0.216 for mild steel on the driest oat to 0.598 for concrete on the wettest maize. On the other hands, the coefficients of friction for maize were generally higher than for oats for all the materials tested.

Irvine et al. (1992) determined the dynamic friction coefficient of wheat flax seed, lentils, and faba beans against plywood and galvanized steel surfaces perpendicular and parallel to the motion of seeds. The tests were conducted at 3 lateral pressures of (10, 30 and 50 kPa). The results showed that, coefficient of friction of all used types against all tested surfaces increased with increasing moisture content but with different degrees. The coefficient of friction between most seed types and tested surfaces also increased with increasing lateral pressure and it was lower for vertical surfaces in comparison with horizontal surfaces.

Zhang and Kushwaha (1991) evaluated the friction coefficient of grain on aluminum and galvanized steel as a function of atmospheric temperature and relative humidity (RH) on various metal surfaces. The results showed that, friction coefficient of grain increased with increasing RH for low grain moisture content at low ambient temperature. However, for grain with a high moisture content (19.6 % for wheat, 16.4 % for rap and 21 % for lentil), the coefficient of friction decreased as the RH increased to 70 % and 85 % at high ambient temperature. In general temperature emerged as an important parameter influencing the coefficient of friction especially when combined with high RH.

Helmy, (1991) determined the static coefficient of friction of some Egyptian varieties of corn, barley, wheat and rice using two different apparatus (digital and manual), four levels of grain moisture content (11, 12,13 and 14 %), five different friction surfaces (glass, galvanized metal, plywood, plastic and stainless steel) and four different masses of sample (75, 100, 125 and 150 gm). The results showed that increasing of grain moisture contents tended to increase the static coefficient of friction significantly. The highest value of static friction coefficient for both apparatus were obtained by using plywood surface in all cases, while the lowest values of static friction coefficient were obtained by using stainless steel surface. Also, the sample mass had no significant effect on the static friction coefficient and the highest values of static friction coefficient were achieved with rice grain followed by wheat, barley and shelled corn respectively.

Owies, (1995) determined the static coefficient of friction for some Egyptian varieties of rice, wheat, and corn at grain storage moisture content using a digital measuring device and a six surfaces of metal, fiber, glass, galvanized metal, stainless steel and plywood. The results cleared that for all tested crops, static coefficients of friction were varied according to the variety, and also to the measuring surface. The wood surface gave higher friction coefficient for some varieties comparing with the other surfaces, followed in descending order by galvanized, metal, fiber, stainless steel and the lowest friction coefficient was glass sheet.

Chakraverty (1987) found that, coefficient of friction between granular materials is equal to the tangent of the angle of internal friction for the material. The coefficient depends on grain shape, surface characteristics, and grain moisture content. He added that, the coefficient of sliding friction of heaped grain increases with increasing humidity. The relative velocity of the particles over the working surface of the grading equipment has practically no effect on the coefficient of friction.

The main objective of the present work is to determine the coefficient of friction for different varieties of some Egyptian cereal crop. The measurements were conducted under different levels of grain moisture content and different types of friction surfaces which generally used for the designing and manufacturing of harvesting and processing equipment.

MATERIALS AND METHODS

Measuring equipment

A digital measuring device was designed and fabricated at the laboratory of Rice Mechanization Center (R.M.C), Meet El-Dyba, Kafr El-Sheikh Governorate. The measuring device consists of an iron frame covered with a plastic sheet of 2 mm thickness and it has two adjustable leveling screws on the base of the frame for adjusting the horizontal level of the device using a water balance fixed on the top of the frame. A movable blade operated by a 0.1 hp two-direction electric motor was used for moving the test plate up and down. A calibration switch with electronic sensor and balance was installed to calibrate the device. A digital screen was installed on the front side of the measuring device used to display the angle of repose. Figure (1) shows the structure feature of the digital equipment which used for measuring the friction coefficient. Table (1) presents specifications of the equipment.

Calibration and test procedure

The calibration of the measuring equipment depended upon the adjustment of the electronic balance and the weight sensor to stop the lifting motor when 50% of the tested sample falls into the sample receiver. For measuring process, a grain sample of 200 gm placed over the surface of the lifting tray and leveled horizontally to cover all the tray surface. At operating switch on, the tray with grain sample titled up around its side pivot and when 50% of the grain sample fall into the samples receiver, the balance sensor give a signal to the lifting motor to stop and the angle of friction displayed on the digital screen. The coefficient of friction for the tested sample could be calculated using the following equation:

$C.F = \tan \alpha$

Where:

C.F = Coefficient of friction

α = Friction angle

The friction angle of the grain samples was taken as an average of three replicates for each surface. The tested surfaces used for experimental work were plywood, rubber, galvanized iron, normal iron, painted iron, stainless steel, wire net, perforated iron and plastic.

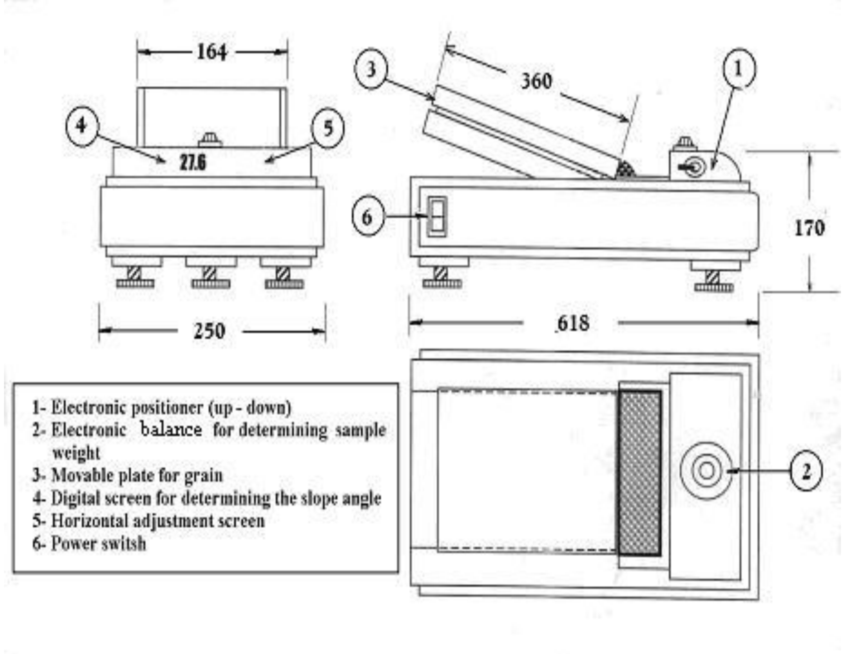

Figure (1): Elevation, plan and side view of the digital equipment used for measuring the friction coefficient

Table (1): Specifications of the digital friction coefficients measuring equipment

Items	Specifications
Type of power	Digital
Source of power	Electronic motor 0.1 h.p (AC 220v).
Structure materials	Iron frame covered with 2mm thick plastic sheets.
Weight	3.5 kg
Sensing unit	Electronic sensor
Range of measuring angle	From 0 to 60º
Instrument accuracy	0.01º

Preparation of grain samples

Four different cereal crops represent the major important food crops in Egypt were selected for the experimental work. These crops included wheat, rice, barely and maze. For each crop, different varieties were also selected based on the planted area and the total production of each variety. In order to grantee the purity of the varieties, the varieties of each crop were obtained from the research stations of Agricultural Research Center (A.R.C) during crop growing seasons of year 1999 and 2000 respectively.

After rejecting the damaged seeds, stones, and other foreign materials, the grain of each variety was stored in a burlap sacks inside a ventilated storage room. Before each experiment, the stored grain was taken out of the storage sacks and the moisture content of each variety was adjusted to five different levels using a mechanical grain mixture.

Adjustment of different levels of grain moisture content

Before using the mechanical grain mixture the initial grain moisture content was measured using an air oven adjusted at 130ºC for 16 h according to AOAC (1990), and then the required amount of water for each level of grain moisture content was calculated and added to the grain mixture which operated for 24 hours for each level of moisture content. Table (2) and Figure (2) present the structure feature and specification of the mechanical mixture used for adjusting the required levels of grain moisture content.

Table (2): Specification of the mechanical mixture used for the experimental work

Items	Specifications
Unit dimensions	98 x 49 x40 cm
Source of power	1 hp electric motor 3 phase model VEM
Power transmission	Pulleys and V belts
Speed control of motor	Electric inverter 1.5 hp
Capacity	10kg of grains

Time control	Electric timer of 24 h with automatic separation each 15 min.

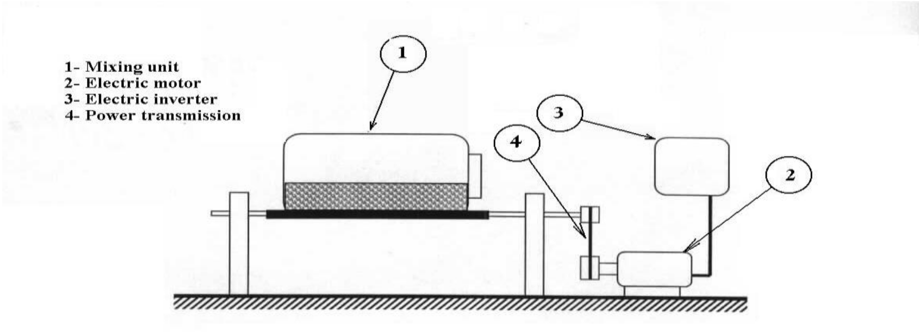

Figure (2): Mechanical mixture used for adjusting the levels of grain moisture content

RESULTS AND DISCUSSION

Coefficients of friction at different friction surfaces for the investigated crops (rice, wheat, barely and corn) were measured and plotted in relation to different levels of grain moisture contents. The obtained results showed that, for all the studied crops the coefficients of friction were varied with roughness of grain surface, grain moisture content and type of friction surfaces. For all the studied varieties, coefficients of friction were increased with increasing grain moisture content and roughness of both grain and test surface.

The friction coefficients for different rice varieties and different friction surfaces were plotted against the grain moisture contents (Figures 3 and 4). The obtained results revealed that, the friction coefficients of rice varieties were ranged from (0.3542 to 0.8765). Rubber, perforated iron and wire net sheets recorded the highest values of friction coefficients (0.5389 to 0.8765) plywood, normal iron and painted iron recorded a moderate values of (0.4807 to 0.7376) while, galvanized iron, plastic and stainless steel recorded the lowest values of (0.3542 to 0.5361). The obtained data showed that, for all tested surfaces, variety Giza 181 gave the highest values of friction coefficient followed by varieties Giza 178, Giza 177, Jasmin, Sakha 102 and Sakha 101 .

Figure (5) indicates the effect of different levels of grain moisture content on friction coefficients for different corn varieties and different friction surfaces. The results showed that, the coefficients of friction for maze crop were varied from (0.2415 to 0.6128). Rubber, perforated iron and normal iron recorded the highest values of friction coefficients (0.3263 to 0.6138), painted iron, galvanized iron and wire net sheets recorded moderate values of (0.2925 to 0.5006), while plastic, stainless and plywood sheets recorded the lowest values of (0.2415 to 0.4956). The results also revealed that, for similar grain moisture content and friction surface, variety Triple hybrid 310 gave the highest values of friction coefficient followed by varieties Triple hybrid 321, Single hybrid 10 and Balady.

Figure (6) represents the change in friction coefficients as related to grain moisture content for different wheat varieties at different friction surfaces. The results show that, friction coefficients of wheat were varied from (0.2519 to 0.6988). Rubber, wire net and perforated iron sheets recorded the highest values of friction coefficients (0.3820 to 0.6988), normal, painted and galvanized iron sheets recorded moderate values of (0.3192 to 0.6123), while plywood, plastic and stainless steel sheets recorded the lowest values of (0.2519 to 0.5877). The results also showed that, at similar grain moisture content and friction surface, variety Sids 1 gave the highest values of friction coefficients followed by varieties Giza 168, Gimiza 9 and Sakha 93.

Figure (7) presents the changes in friction coefficients for different varieties of barely as related to grain moisture content and different types of friction surfaces. The obtained data indicated that, the friction coefficients for the studied varieties of barely were varied from (0.2481 to 0.6927). On the other hands, rubber, wire net and perforated iron sheets recorded the highest values of friction coefficients of (0.4204 to 0.6927), normal, painted and galvanized iron sheets recorded a moderate values of (0.3186 to 0.5458) while, plywood, plastic and stainless steel sheets recorded the lowest values of (0.2481 to 0.5237). The results also showed that, variety Giza 126 gave the highest values of friction coefficients followed by Giza 125, Giza 124 and Giza 123.

As mentioned above, the obtained data revealed that, the coefficients of friction were increased with increasing grain moisture content. This may be attributed to the increase of contact surface area between grain to grain and grains to friction surface. Also, the observed variation in coefficients of friction between varieties of each crop may be due to the variance in grain surface roughness and also the variance in roughness of the tested surfaces.

To relate the change in grain moisture content with the coefficients of friction for different varieties of the studied crops and different tested friction surfaces a simple regression analysis was applied for each crop. The results of analysis showed linear positive relationships between the change in grain moisture content and the coefficient of friction for all the friction surfaces.

The obtained regression equations were in the form of y = a + bx. Table (3) to (7) present the obtained regression parameters for different varieties of rice, corn, wheat and barely respectively.

Table (3): Regression parameters for short grain varieties of rice crop.

Variety	Range of grain M.C. %, (w.b)	Type of friction surfaces	Regression parameters		
			a	b	R^2
Giza 177	12.58 to 24.90	Ply wood	0.5154	0.0069	0.9853
		Rupper	0.6100	0.0094	0.9956
		Galvanized iron	0.3719	0.0047	0.9790
		Normal iron	0.4897	0.0098	0.9890
		Painted iron	0.4971	0.0066	0.9473
		Stainless steel	0.3446	0.0055	0.9369
		Wire net	0.4933	0.0104	0.9819
		Perforated iron	0.5695	0.0109	0.9950
		Plastic	0.3378	0.0076	0.9318
Giza 178	12.57 to 26.22	Ply wood	0.5432	0.0049	0.9806
		Rupper	0.6510	0.0082	0.9877
		Galvanized iron	0.3711	0.0051	0.9729
		Normal iron	0.6036	0.0044	0.9773
		Painted iron	0.4026	0.0098	0.9855
		Stainless steel	0.2556	0.0087	0.9805
		Wire net	0.5457	0.0062	0.9813
		Perforated iron	0.6548	0.0070	0.9437
		Plastic	0.4116	0.0041	0.9826
Sakha 101	13.18 – 24.95	Ply wood	0.3690	0.0106	0.9804
		Rupper	0.5971	0.0084	0.9417
		Galvanized iron	0.2962	0.0085	0.9552
		Normal iron	0.5253	0.0058	0.9850
		Painted iron	0.3747	0.0092	0.9100
		Stainless steel	0.3007	0.0073	0.9403
		Wire net	0.4407	0.0086	0.9702
		Perforated iron	0.5447	0.0104	0.9780
		plastic	0.2829	0.0096	0.9907
Sakha 102	12.17 to 25.09	Ply wood	0.4404	0.0067	0.9952
		Rupper	0.6503	0.0062	0.9885
		Galvanized iron	0.3390	0.0063	0.9977
		Normal iron	0.4814	0.0071	0.9970
		Painted iron	0.4462	0.0060	0.9769
		Stainless steel	0.2760	0.0071	0.9930
		Wire net	0.4574	0.0065	0.9919
		Perforated iron	0.4888	0.0119	0.9815
		plastic	0.2661	0.0085	0.9749

Table (4): Regression parameters for long grain varieties of rice crop.

Variety	Range of grain M.C. %, (w.b)	Type of friction surfaces	Regression parameters		
			a	b	R^2
Giza 181	12.39 to 25.82	Ply wood	0.5104	0.0043	0.9740
		Rupper	0.6774	0.0076	0.9958
		Galvanized iron	0.3307	0.0081	0.9912
		Normal iron	0.5555	0.0056	0.9947
		Painted iron	0.4493	0.0065	0.9751
		Stainless steel	0.2144	0.0108	0.9880
		Wire net	0.5076	0.0069	0.9480
		Perforated iron	0.6472	0.0080	0.9937
		Plastic	0.3054	0.0088	0.9791
Jasmine	12.90 to 25.11	Ply wood	0.5029	0.0047	0.9967
		Rupper	0.6828	0.0057	0.9704
		Galvanized iron	0.2822	0.0106	0.9992
		Normal iron	0.5663	0.0041	0.9587
		Painted iron	0.4664	0.0056	0.9714
		Stainless steel	0.2241	0.0115	0.9925
		Wire net	0.5384	0.0071	0.9648
		Perforated iron	0.6678	0.0060	0.9866
		plastic	0.2634	0.0106	0.9917

Table (5): Regression parameters for different varieties of corn crop.

Variety	Range of grain M.C. %, (w.b)	Type of friction surfaces	Regression parameters		
			a	b	R^2
Triple hybrid 310	9.92 to 26.24	Ply wood	0.1296	0.0136	0.9900
		Rupper	0.3308	0.0107	0.9992
		Galvanized iron	0.1818	0.0120	0.9730
		Normal iron	0.3088	0.0085	0.9872
		Painted iron	0.2795	0.0078	0.9745
		Stainless steel	0.1223	0.0118	0.9925

		Wire net	0.2910	0.0080	0.9780
		Perforated iron	0.3290	0.0081	0.9777
		plastic	0.1258	0.0131	0.9758
Triple hybrid 321	**11.5 to 26.08**	**Ply wood**	0.1987	0.0069	0.9752
		Rupper	0.2676	0.0093	0.9899
		Galvanized iron	0.1987	0.0073	0.9620
		Normal iron	0.2280	0.0082	0.9880
		Painted iron	0.2432	0.0060	0.9569
		Stainless steel	0.2158	0.0045	0.9295
		Wire net	0.2389	0.0069	0.9976
		Perforated iron	0.2569	0.0084	0.9984
		plastic	0.1988	0.0064	0.9600
Singl44e hybrid 10	**10.87 to 24.94**	**Ply wood**	0.1990	0.0077	0.9940
		Rupper	0.3224	0.0105	0.9620
		Galvanized iron	0.2315	0.0076	0.9822
		Normal iron	0.2937	0.0078	0.9603
		Painted iron	0.2732	0.0060	0.9805
		Stainless steel	0.1759	0.0081	0.9779
		Wire net	0.2699	0.0091	0.9798
		Perforated iron	0.3348	0.0080	0.9612
		plastic	0.1924	0.0077	0.9501
Balady	**10.40 to 26.65**	**Ply wood**	0.1954	0.0069	0.9977
		Rupper	0.2694	0.0115	0.9945
		Galvanized iron	0.1971	0.0084	0.9635
		Normal iron	0.2242	0.0100	0.9780
		Painted iron	0.2040	0.0095	0.9907
		Stainless steel	0.1524	0.0096	0.9831
		Wire net	0.2043	0.0101	0.9943
		Perforated iron	0.2462	0.0105	0.9943
		plastic	0.1748	0.0093	0.9734

Table (6): Regression parameters for different varieties of wheat crop.

Variety	**Range of grain M.C. %,(w.b)**	**Type of friction surfaces**	**Regression parameters**		
			a	**b**	**R^2**
Giza 168	**10.85 to 25.56**	**Ply wood**	0.2313	0.0119	0.9628
		Rupper	0.3031	0.0146	0.9992
		Galvanized iron	0.2405	0.0120	0.9863
		Normal iron	0.2529	0.0136	0.9790
		Painted iron	0.2313	0.0132	0.9809
		Stainless steel	0.0964	0.0159	0.9694
		Wire net	0.3125	0.0134	0.9936
		Perforated iron	0.3093	0.0125	0.9796
		plastic	0.1844	0.0129	0.9987
Sakha 93	**10.87 to 25.77**	**Ply wood**	0.1574	0.0129	0.9963
		Rupper	0.2604	0.0140	0.9721
		Galvanized iron	0.1528	0.0146	0.9795
		Normal iron	0.1873	0.0145	0.9841
		Painted iron	0.1514	0.0123	0.9778
		Stainless steel	0.0933	0.0147	0.9991
		Wire net	0.2639	0.0128	0.9727
		Perforated iron	0.2390	0.0127	0.9284
		plastic	0.1211	0.0142	0.9873
Sids 1	**11.17 to 25.70**	**Ply wood**	0.1782	0.0145	0.9934
		Rupper	0.2385	0.0173	0.9781
		Galvanized iron	0.1049	0.0181	0.9899
		Normal iron	0.1969	0.0153	0.9846
		Painted iron	0.1895	0.0155	0.9826
		Stainless steel	0.0574	0.0190	0.9878
		Wire net	0.1998	0.0174	0.9642
		Perforated iron	0.1896	0.0187	0.9890
		plastic	0.0417	0.0208	0.9857
Gimiza 9	**10.60 to 25.40**	**Ply wood**	0.1868	0.0132	0.9821
		Rupper	0.3001	0.0153	0.9931
		Galvanized iron	0.1707	0.0146	0.9713
		Normal iron	0.2459	0.0143	0.9909
		Painted iron	0.2135	0.0154	0.9823

		Stainless steel	0.0876	0.0165	0.9885
		Wire net	0.3082	0.0134	0.9953
		Perforated iron	0.2833	0.0132	0.9900
		plastic	0.1576	0.0135	0.9829

Table (7): Regression parameters for different varieties of barley crop.

Variety	**Range of grain M.C.** %, **(w.b.)**	**Type of friction surfaces**	**Regression parameters**		
			a	**b**	R^2
Giza 123	11.81 to 24.68	**Ply wood**	0.2791	0.0060	0.9038
		Rupper	0.3906	0.0075	0.9837
		Galvanized iron	0.2101	0.0089	0.9953
		Normal iron	0.3085	0.0066	0.9750
		Painted iron	0.2989	0.0061	0.9224
		Stainless steel	0.1178	0.0114	0.9825
		Wire net	0.2731	0.0118	0.9876
		Perforated iron	0.3519	0.0089	0.9868
		plastic	0.1451	0.0108	0.9902
Giza 124	11.51 to 24.67	**Ply wood**	0.2709	0.0074	0.9913
		Rupper	0.3434	0.0105	0.9895
		Galvanized iron	0.2339	0.0086	0.9965
		Normal iron	0.3354	0.0055	0.9915
		Painted iron	0.2906	0.0072	0.9878
		Stainless steel	0.0968	0.0131	0.9910
		Wire net	0.3697	0.0066	0.9755
		Perforated iron	0.3409	0.0096	0.9522
		plastic	0.0987	0.0137	0.9861
Giza 125	11.95 to 23.87	**Ply wood**	0.2374	0.0102	0.9725
		Rupper	0.3629	0.0116	0.9979
		Galvanized iron	0.1820	0.0123	0.9926
		Normal iron	0.2625	0.0113	0.9868
		Painted iron	0.2384	0.0116	0.9926
		Stainless steel	0.0515	0.0161	0.9976
		Wire net	0.3520	0.0090	0.9909
		Perforated iron	0.3283	0.0123	0.9932
		plastic	0.0726	0.0153	0.9981
Giza 126	11.22 to 24.41	**Ply wood**	0.2082	0.0124	0.9725
		Rupper	0.3425	0.0138	0.9899
		Galvanized iron	0.1767	0.0133	0.9523
		Normal iron	0.2530	0.0115	0.9860
		Painted iron	0.2416	0.0110	0.9964
		Stainless steel	0.0684	0.0160	0.9836
		Wire net	0.3046	0.0124	0.9667
		Perforated iron	0.3285	0.0119	0.9956
		plastic	0.0693	0.0161	0.9800

Fig3

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CONCLUSIONS

1- For all the studied crops, the coefficients of friction were varied with the roughness of grain surface, grain moisture content and type of friction surface.
2- The recorded friction coefficients were ranged from (0.3542 to 0.9765), (0.2415 to 0.6128), (0.2519 to 0.6988) and (0.2481 to 0.6927) for rice, corn, wheat and barely, respectively.
3- The friction surfaces of rubber, perforated iron and wire-net iron gave the highest values of friction coefficients while, normal, painted and galvanized iron recorded a moderate values and plywood, plastic and stainless steel recorded the lowest values.
4- A mathematical relationships were developed to relate the grain moisture contents with the friction coefficients for all the studied crops and all the friction surfaces.

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تعيين معامل الاحتكاك للأصناف المختلفة لبعض محاصيل الحبوب

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أجريت تلك الدراسة لتعيين معامل الاحتكاك لبعض أصناف محاصيل الحبوب الرئيسية والتى شملت الأرز، الذرة، القمح، الشعير وذلك عند خمس مستويات مختلفة من المحتوى الرطوبى لكل صنف .وقد تم استخدام جهاز رقمى لقياس زوايا الاحتكاك لتلك المحاصيل تم تصميمه وتصنيعه بمركز ميكنة الأرز بميت الديبة -كفر الشيخ، حيث أجريت التجارب العملية باستخدام تسعة أسطح احتكاك مختلفة شملت معظم الخامات التى يتم استخدامها فى تصنيع آلات الحصاد والتداول والتصنيع لمحاصيل الحبوب وهى :الصاج العادى، الصاج المجلفن، الصاج المطلى، الصاج المثقب، الستانليس ستيل، البلاستيك، الخشب، الشبك السلك، المطاط. أظهرت النتائج زيادة معامل الاحتكاك بزيادة المحتوى الرطوبى للحبوب وكذا درجة خشونة سطح الحبوب. وتراوحت قيم معامل الاحتكاك بين (0.3542 – 0.8765) ، (0.2415 – 6128.0) ، (0.2519 – 0.6988) ، (0.2481 – 0.6927) لمحاصيل الأرز، الذرة، القمح، الشعير على التوالى.

أظهرت النتائج أيضا أن أسطح المطاط، الصاج المثقب، شبك السلك قد أعطت أعلى قيم لمعامل الاحتكاك وذلك لجميع المحاصيل التى تم دراستها تلى ذلك أسطح الصاج العادى، الصاج المطلى، الصاج المجلفن بينما أعطت أسطح الخشب، البلاستيك، الستانليس ستيل اقل قيم لمعامل الاحتكاك.

أظهرت نتائج التحليل الإحصائي وجود علاقة خطية طردية بين التغير فى المحتوى الرطوبى للحبوب ومعامل الاحتكاك حيث تم الحصول على مجموعة من المعادلات تصف تلك العلاقة للأصناف المختلفة لكل محصول من المحاصيل التى تم دراستها.