DETERMINATION OF DYNAMIC COEFFICIENT OF FRICTION FOR SOME MATERIALS FOR FEED PELLET UNDER DIFFERENT VALUES OF PRESSURE AND TEMPERATURE

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ABSTRACT

Knowledge of frictional characteristics of materials is required for equipment design. The force of friction must be overcome before these materials flow. The objective of this study is to determine the dynamic coefficient of friction "μd" for yellow corn grits, wheat bran, soybean meal, cotton seed meal and mixtures of some of these materials used for manufacturing pellet for cattle animals, under different values of pressure and temperature. A dynamic coefficient of friction device was developed for estimating this coefficient under pressure ranging from 9 kPa up to 109 kPa and temperature ranging from 30 to 150 ^{o}C. The value of "μd" was determined at ten levels of pressure "P": 9, 18, 27, 42, 53, 65, 75, 88, 97 and 109 kPa, and six levels of the temperature "T": 30, 50, 75, 100, 125 and 150 ^{o}C.

The determined values of "μd" ranged from 0.113 to 0.397 for Yellow corn grits, from 0.122 to 0.505 for wheat bran, from 0.105 to 0.410 for *cotton seed meal, from 0.105 to 0.347 for soybean meal and from 0.391 to 0.105 for mixtures of these materials.*

The empirical results obtained from the carried out experiment were used to introduce a group of graphical charts, using "Excel program" to predict the value of "μd" for the different tested material as a function of both pressure and temperature. These empirical results were also used to derive six mathematical equations to predict the value of "μd" as a function of both pressure and temperature. Also, one general mathematical equation was derived to predict the value of "μd" as a function of raw material contents (protein, ash and moisture content), material pressure and temperature.

Keywords: *Dynamic coefficient of friction, Pressure, Temperature, Yellow corn grits, Wheat bran, Soybean meal, Cotton seed meal.*

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INTRODUCTION

Friction is defined as a set of phenomena existing in the contact region of two bodies moving with respect to each other. The problem of the correct description of this phenomenon is very important both from the point of view of engineering practice and the design of new machines and installations as well as the optimisation of many technological processes.

Coefficients of friction are influenced by numerous factors. Knowledge about the role of many of these factors is still incomplete, and additional experimental work is needed to determine the limits of uncertainty and to explicate the behavior of material in various conditions.

Overcoming the static force of friction is necessary to start motion. Once the motion is started, the force needed for overcoming the frictional forces to maintain motion is reduced. The friction forces existing between the surfaces of relative motion are called forces of dynamic friction (***Halling, 1975***).

Fairfield (2003) stated that the pelleting – the most intensive capital- and energy-consuming feed manufacturing operation – is a key driver in feed mill profitability. While pelleting of feed can provide many significant benefits, the pelleting operation is cost-effective. Two important factors in achieving success are: 1) proper pellet system equipment operations; and 2) measuring pelleting operation efficiency.

Miguel and Guillermo (2002) reported that for densification of biomass, it is important to know the parameters that influence the extrusion process which are moisture content, compaction pressure, temperature and size of particles, these are the required parameters of raw materials.

Mohsenin (1970) investigated the reasons of variation in the coefficient of friction values of biological materials. The experimental results showed that sliding surface, moisture content, velocity, normal pressure, temperature, humidity and operating technique affected friction values. Therefore, specific conditions should be considered while determining the coefficient of friction values of agricultural products.

Many researchers have attempted to measure the mechanical friction coefficient in a laboratory setting. ***Shukla et al. (2005) and Rosentrater et al. (2005)*** mentioned that the coefficient of friction is the most important rheological property. During extrusion processing, (under high compacting pressure), the bio based feed materials turn into pseudo plastic melt and the moisture contents of ingredient mix, and the cooking temperature significantly affects the coefficient of friction and thus the extrudate properties.

Molenda et al. (2002) investigated the coefficients of friction of wheat, for grain–on–grain, and on galvanized corrugated steel sheet using a modified direct shear apparatus. They conducted the tests under a normal pressure of 20.7 kPa using soft red winter wheat at a moisture content of 11.2% (w.b.) and an uncompressed bulk density of 740 kg/m^3. Test results of grain–on–grain coefficients of friction were in a range from 0.47 to 0.007, while for grain on steel sheet were from 0.56 to 0.004 depending on the galvanized corrugated steel.

Faruk Taser et al. (2005) found that the measured values of coefficient of dynamic friction against hard-wood sheet, galvanized steel, mild steel, chipboard and rubber surfaces were 0.29, 0.30, 0.33, 0.33, and 0.41 respectively for Hungarian vetch seed

Rusinek and Molenda (2007) studied the coefficient of friction of rapeseed according to Eurocode (kinetic) in direct shear test and (static) in model silo. Samples of rapeseed in a range of moisture content from 6 to 15% (w.b.) were used and the tests were performed for galvanized steel, stainless steel and concrete. Coefficient of friction for both steel types approached stable value for all levels of moisture content. in a range from 0.11 to 0.18. For concrete, it was found in a range from 0.25 to 0.43. The coefficient of static friction found in model silo decreased with an increase in vertical pressure from 0.3 to 0.2 for first loading, while in subsequent loading cycles, it decreased from 0.2 to 0.1.

Grift et al. (2006) determined the dynamic mechanical friction coefficient of individual urea fertiliser particles in real time. A method based on theoretical analysis was proposed. The analysis showed that the friction coefficients can be measured using a single radial velocity measurement per particle. The friction coefficients found for urea fertilizer showed a near-Gaussian distribution with a mean of 0.36.

Ghadge et al (2008) found that the static coefficient of friction varied for Chick Pea on three different surfaces from 0.30 on galvanized steel sheet, 0.43 on Plywood to 0.45 on glass

Ahmadi et al. (2008) found that the static coefficient of friction varied for apricot fruits on four different surfaces from 0.62 on galvanized steel sheet, 0.51 on wood, 0.55 on fiberglass sheet to 0.49 on glass

The objective of this study was concentrated on the determination of the dynamic coefficient of friction for six feed materials used for manufacturing pellet for the cattle animals (yellow corn grits, wheat bran, soybean meal, cotton seed meal and two mixtures from these materials) sliding on steel 50 under different values of compacting pressure and temperature.

MATERIALS AND METHODS

This research work was conducted in Agric. Eng. Dept. Faculty of Agriculture - Cairo University during the year 2008. The method followed was developed and guided to some extent from the method described by (***Mohsenin 1970***). A device was developed and used for the determination of the dynamic frication coefficient for six materials

The friction device was developed and fabricated, **Fig. (1)**. This device mainly consists of: two open sides cylinder threaded from its outer side to adjust it, up and down, by a nut resting on a carriage surface. The carriage has a horizontal plate surface 275×120×20 mm and fixed to three roll bearing wheels, one in the front and 2 in the back to support the carriage. Under this design, the cylinder down open side could be adjusted to be very close to a third part which is a metallic surface made of steel 50.(200 cm wide and 350 cm), but without touching it. This steel 50 surface was mounted on a horizontal steel base of 50 mm height, to allow fixing the heating element and thermostat very close the down face of steel 50 surface to control its temperature as required.

The two open sides cylinder is partially filled with the tested sample of the feed materials. The feed material is compressed by a cylindrical rod (a piston), 40 mm in diameter and 70 mm in depth. A 600 Watt heater was

fixed very close to the down face of the sliding surface and was provided by a thermostat to adjust temperature of the required temperature.
The upper surface of the piston is fixed to a steel cage in which load weights are put to resemble the compacting pressing forces existing on the feed material inside any extruder producing the feed material pellet.
The carriage is connected through a pivoting point to a 250 N load measuring transducer. The transducers cell is attached to a digital force gauge (Japanese made) to measure the needed pulling force to move the carriage to oppose the dynamic friction force between the sample and steel surface to maintain the motion. Fig (1) shows this designed device. This locally designed and fabricated device was used to measure the dynamic friction force between feed material and the friction surface (steel 50).

All metallic surfaces were cleaned by compressed air before each test to remove any contamination from any previous tests. Sliding steel surface was horizontally adjusted by applying a bubble level fixed on the base to insure eliminating the effect of any force resulting from slopes, and hence, the result when sample is pulled, the pulling force will represent only the frictional force.

Treatments:

1. Types of food material

Six types of feed materials used for feeding cattle were tested: *Yellow corn grits, wheat bran, Soybean meal, Cotton seed meal , mixture (1)* (50 % *corn, 25* % *wheat bran, 5* % *Soybean meal*, 20 % *Cotton seed meal*) and *mixture (2)* (40 % *corn, 35* % *wheat bran, 10* % *Soybean meal,* 15 % *Cotton seed meal*).
The chemical components of the tested feed materials were determined according to ***NRC (2001)***. The chemical components are shown in table (1). It is clear that the percentage of protein, fat content, total carbohydrates, crude fiber, ash and moisture content for the tested materials ranged between (8.40 to 38.01 %), (3.33 to 4.13 %), (32.68 to 72.36 %), (2.28 to 10.68 %), (1.14 to 5.48 %) and (10.21 to 12.50 %), respectively.

Table (1): Chemical components of the tested materials.

Feed materials	*Pr*, %	*F*, %	*Car*, %	Fib, %	*Ash*, %	*MC*, %
Yellow corn	8.40	3.33	72.36	2.28	1.14	12.50
Wheat bran	13.44	3.45	57.30	8.84	5.39	11.58
Cotton seed meal	36.81	4.13	32.68	10.68	5.48	10.21
Soybean meal	38.01	3.99	36.06	5.23	5.32	11.39
Mixture (1)	16.82	3.55	58.85	5.75	3.28	11.76
Mixture (2)	17.39	3.56	57.51	6.13	3.70	11.72

Pr = Protein content, ***F*** = Fat content, ***Car*** = Carbohydrates,
Fib = Crude fiber, ***Ash*** = Ash, ***MC*** = Moisture content

Particle Size Distribution:

A 100 g sample of each grind material was placed in a stack of sieves arranged downward from the largest to the smallest opening. The sieve series selection was based on seven sizes of particles in the sample. Sieve analysis was repeated three times for each ground samples. The particle size was determined according to ANSI/ASAE standard S319.3JUL97 (**ASAE, 2002*)***.

The mass percentages distribution of the particle size of *Yellow corn grits, wheat bran, Soybean meal, Cotton seed meal* are shown in table (2).

Table (2): Size distribution of feed material.

Feed materials	Percentage of Particle size, (%) Particle size (mm)						
	2 - 3	**2 - 1**	**1 - 0.5**	**0.5 - 0.25**	**0.25-0.125**	**0.125 - 0.053**	**< 0.053**
Yellow corn	54.21	24.02	10.79	6.11	3.39	1.19	0.28
Wheat bran	13.69	29.66	41.52	14.21	0.52	0.31	0.10
Cotton meal	58.13	23.21	11.48	4.95	1.87	0.36	-
Soybean meal	36.88	26.52	6.39	8.87	14.12	6.46	0.76

Moisture content "MC $_{d.b}$"

Moisture content was determined as dry base for materials (table 1).

2.Pressure "P"

The tested values of pressure were: *9, 18, 27, 42, 53, 65, 75, 88, 97 and 109 kPa*, which resulting from normal load imposed on the sample over the area of the cylinder.

3. Temperature "T"

Six levels of the temperature were tested: 50, 70, 90, 100, 125 and 150 ^{o}C. The temperature of the sliding surface was measured by a digital infrared thermometer.

The dynamic coefficient of friction was determined by applying equation (1):

$$\mu d = F_r / N_l \ldots\ldots\ldots\ldots (1)$$

Where:

μd = dynamic coefficient of friction;

F_r = Friction force, kg_f ;

N_l = Normal load pressing the food material to the surface of contact, kg_f

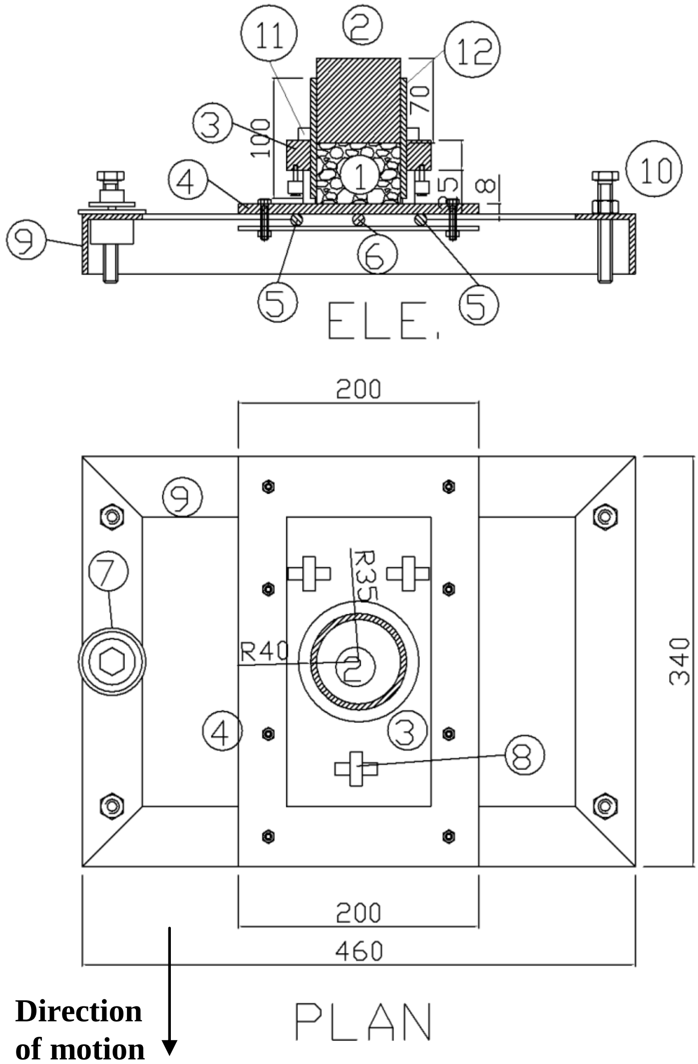
Three replicates were conducted for each of the tested treatments. The friction force was measured using digital force gauge (accuracy ± 10 gm).

Microsoft Excel and SPSS software programs regression method were applied for data analysis.

RESULTS AND DISCUSSION

1. **Effect of pressure "P" and Temperature "T" on the dynamic coefficient of friction "µd" between the tested materials and steel 50**

The values of the dynamic coefficient of friction "µd" for *Yellow corn grits*, *wheat bran*, *Soybean meal*, *Cotton seed meal* , *mixture (1)* and *mixture (2)* are shown in table (3-a) , table (3-b) and Fig. (2). These results show that μd decreased by increasing the pressure "P" and by increasing the temperature "T" for any tested material.



Dims. in mm

1-Sample　**2-** Piston　**3-** Carriage

4- Sliding surface　**5-** Heater　**6**- Temperature sensor

7- Thermostat　**8-** Rolling wheels　**9**- Base (Angle steel 50×50×5)

10- Adjustable screw　**11**- Adjustable nut　**12-** Cylinder

Fig. (1): The designed device for measuring the dynamic friction force.

The reason why wheat bran had the highest dynamic coefficient of friction at 30 ^{o}C, may be due to that its size particles > 0.5 and < 2.0 mm, (table 2), which could be more rough and stable under low pressing force had the highest percentage. Although both corn grits and the cotton seed meal had higher percentage of the rough particles 2 – 3 mm, but they were not stable, and large protein of its rough extrusions were easily broken, and became smoother. Under higher compressing force, all the materials particles became smoother and had low dynamic coefficient of friction.

Also, table (1) shows that the "fat" in all the tested materials had a percentage of almost 3 to 4 percent. Under higher temperature, the viscosity of the "fat" decreases and it acts as a lubricant agent. That is the reason why under higher values of temperature, the value of the dynamic coefficient of friction dramatically decreases, for all the tested materials and under any compressing force. Similar observations were offered by ***Thompson and Ross (1983)***, since they applied normal pressure in a range from 7 to 172 kPa. These authors observed in tests performed for wheat against steel a decrease in the coefficient of friction with an increase in normal pressure, A similar tendency was observed by ***Rusinek and Molenda (2007)*** when testing the coefficient of friction for rapeseed with steel in a pressure range from 20 to 60 kPa.

Another reason for decreasing in dynamic coefficient of friction, due to the increase in pressure may be due to that compressed material could form a smooth compacted surface layer sliding easier on the surface of contact.

The obtained results for the effect of pressure and temperature on dynamic coefficient of friction, Table (3-a) and (3-b), were used to have both a graphical set of charts and a set of mathematical equations to predict the value of the dynamic coefficient of friction for different tested feed material against "steel 50", as function of both pressure and temperature.

Table (3- a): The effect of pressure and temperature on the dynamic coefficient of friction.

	T, °C	Pressure, kPa									
		9	18	27	42	53	65	75	88	97	109
Corn	30	0.397	0.315	0.280	0.265	0.259	0.257	0.253	0.244	0.243	0.243
	50	0.379	0.268	0.249	0.209	0.189	0.177	0.178	0.173	0.169	0.169
	75	0.347	0.240	0.208	0.172	0.151	0.142	0.139	0.134	0.136	0.131
	100	0.315	0.240	0.193	0.165	0.144	0.137	0.131	0.124	0.125	0.120
	125	0.315	0.246	0.182	0.162	0.141	0.133	0.130	0.124	0.119	0.113
	150	0.303	0.233	0.178	0.158	0.135	0.128	0.120	0.114	0.113	0.113
Wheat bran	30	0.505	0.489	0.432	0.374	0.330	0.301	0.290	0.262	0.249	0.236
	50	0.385	0.290	0.260	0.192	0.178	0.159	0.154	0.157	0.154	0.153
	75	0.347	0.240	0.217	0.165	0.151	0.151	0.147	0.141	0.142	0.137
	100	0.328	0.240	0.215	0.165	0.146	0.142	0.139	0.137	0.139	0.129
	125	0.315	0.278	0.215	0.159	0.141	0.138	0.135	0.131	0.132	0.128
	150	0.303	0.249	0.193	0.158	0.135	0.134	0.131	0.124	0.125	0.122
Cotton seed meal	30	0.410	0.309	0.262	0.225	0.216	0.217	0.214	0.199	0.199	0.188
	50	0.315	0.246	0.217	0.174	0.157	0.146	0.139	0.131	0.132	0.129
	75	0.284	0.230	0.195	0.166	0.151	0.133	0.131	0.124	0.128	0.122
	100	0.259	0.215	0.193	0.159	0.144	0.124	0.124	0.118	0.119	0.116
	125	0.240	0.196	0.184	0.158	0.141	0.120	0.120	0.111	0.116	0.113
	150	0.208	0.170	0.152	0.144	0.135	0.115	0.116	0.110	0.113	0.105

Table (3-b): The effect of pressure and temperature on the dynamic coefficient of friction.

	T, °C	Pressure, kPa									
		9	18	27	42	53	65	75	88	97	109
Soy meal	30	0.347	0.268	0.249	0.231	0.225	0.217	0.209	0.209	0.205	0.191
	50	0.284	0.237	0.219	0.185	0.165	0.149	0.146	0.141	0.135	0.129
	75	0.265	0.205	0.193	0.166	0.151	0.142	0.133	0.124	0.128	0.122
	100	0.252	0.183	0.172	0.159	0.144	0.137	0.127	0.121	0.120	0.105
	125	0.221	0.170	0.163	0.158	0.151	0.136	0.127	0.118	0.113	0.105
	150	0.189	0.151	0.148	0.137	0.135	0.135	0.128	0.118	0.113	0.105
Mixture (1)	30	0.391	0.268	0.217	0.203	0.192	0.186	0.185	0.173	0.172	0.169
	50	0.315	0.237	0.206	0.168	0.157	0.142	0.139	0.131	0.132	0.129
	75	0.284	0.215	0.197	0.166	0.151	0.142	0.133	0.126	0.128	0.122
	100	0.252	0.205	0.195	0.159	0.144	0.133	0.124	0.121	0.116	0.105
	125	0.221	0.189	0.184	0.179	0.146	0.134	0.122	0.118	0.115	0.113
	150	0.189	0.183	0.178	0.158	0.145	0.135	0.120	0.118	0.113	0.105
Mixture (2)	30	0.284	0.221	0.195	0.185	0.179	0.167	0.162	0.160	0.160	0.169
	50	0.189	0.174	0.156	0.151	0.145	0.133	0.131	0.131	0.131	0.129
	75	0.177	0.151	0.148	0.144	0.141	0.128	0.127	0.124	0.120	0.122
	100	0.151	0.142	0.141	0.126	0.124	0.120	0.117	0.114	0.119	0.105
	125	0.139	0.132	0.130	0.117	0.114	0.111	0.112	0.112	0.113	0.105
	150	0.126	0.120	0.119	0.113	0.108	0.105	0.116	0.118	0.107	0.105

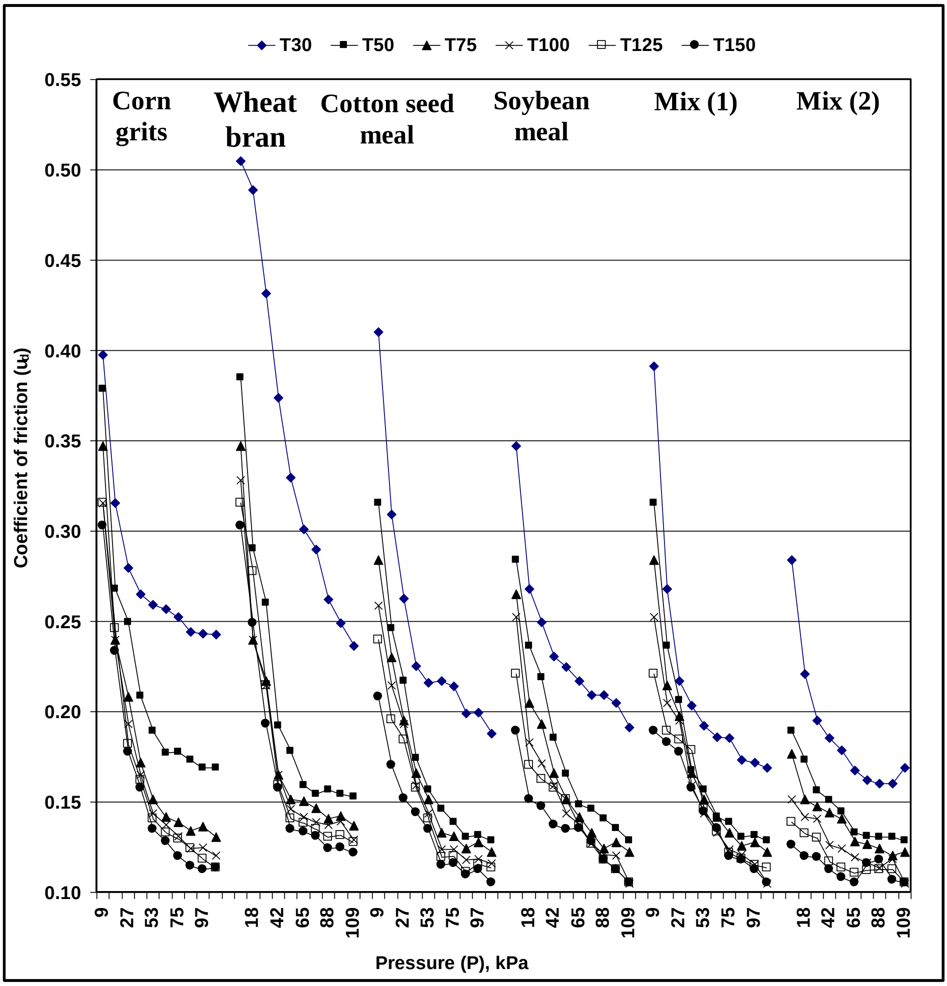


Fig. (2): Effect of pressure and temperature on the dynamic coefficient of friction between steel 50 and different feed materials.

Effect of pressure "P" and Temperature "T" on the dynamic coefficient of friction "µd" between yellow corn grits and steel 50:

For corn grits, a relation was derived between both temperature and pressure in one side the dynamic coefficient of friction "µd" on the other side, by transfering the data of Table (3) (for corn grits) into a spread sheet (Excel program) to draw a surface contour charts relating the values of the dynamic coefficient of friction "µd" by both the (pressure x-axis) and the (temperature y-axis), Fig. (3).

Fig. (3) shows the contour lines limiting each selected or needed range values of the dynamic coefficient of friction "µd". Fig. (3) could be applied to find out the value of "µd" corresponding to both the value of pressure and the value of temperature.

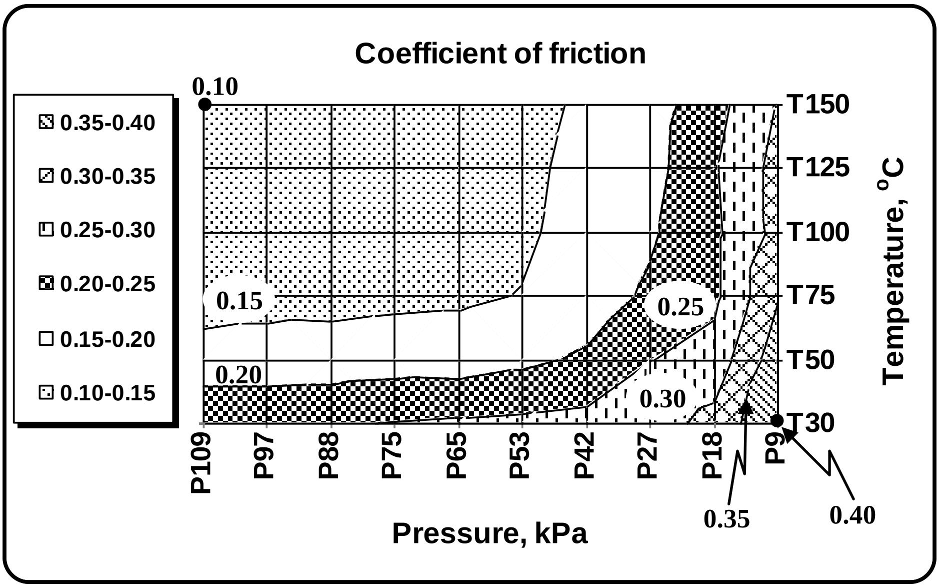


Fig. (3): Effect of pressure "P" and temperature "T" on the dynamic coefficient of friction "µd" between yellow corn grits and steel 50.

Effect of pressure "P" and Temperature "T" on the dynamic coefficient of friction "µd" between wheat bran and steel 50:

The same technique used for corn grits was applied for wheat bran using the same Excel program to find out the chart relating contour lines for each range of "µd" with both pressure and temperature, Fig. (4).

Also, applying the same above technique, contour charts could be drawn for the dynamic coefficient of friction between steel 50 and other feed material, Fig. (5) shows the chart for cotton seed meal, Fig. (6) shows the chart for soybean meal, Fig. (7) shows the chart for mixture (1) and Fig. (8) shows the chart for mixture (2).

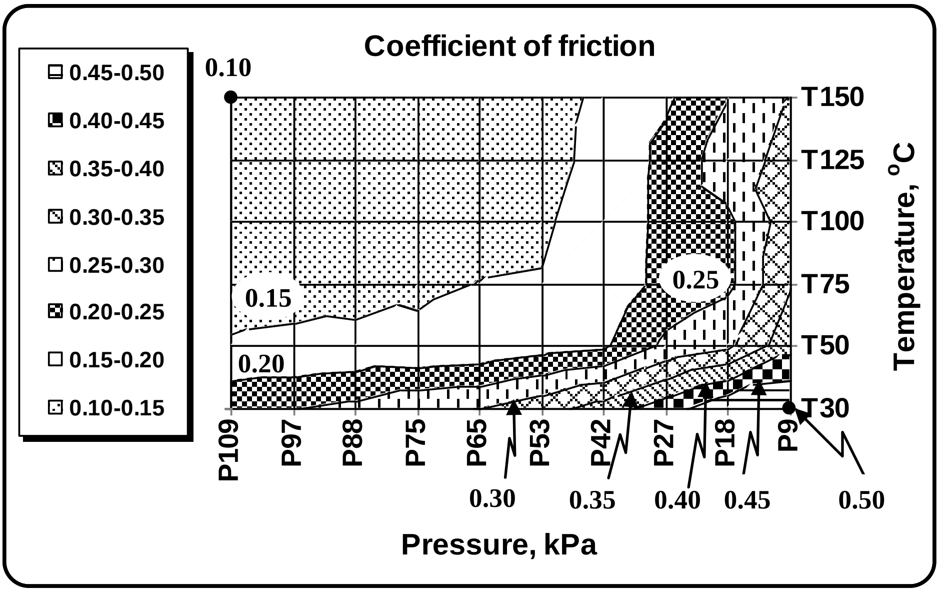


Fig. (4): Effect of pressure "P" and Temperature "T" on the dynamic coefficient of friction "µd" between wheat bran and steel 50.

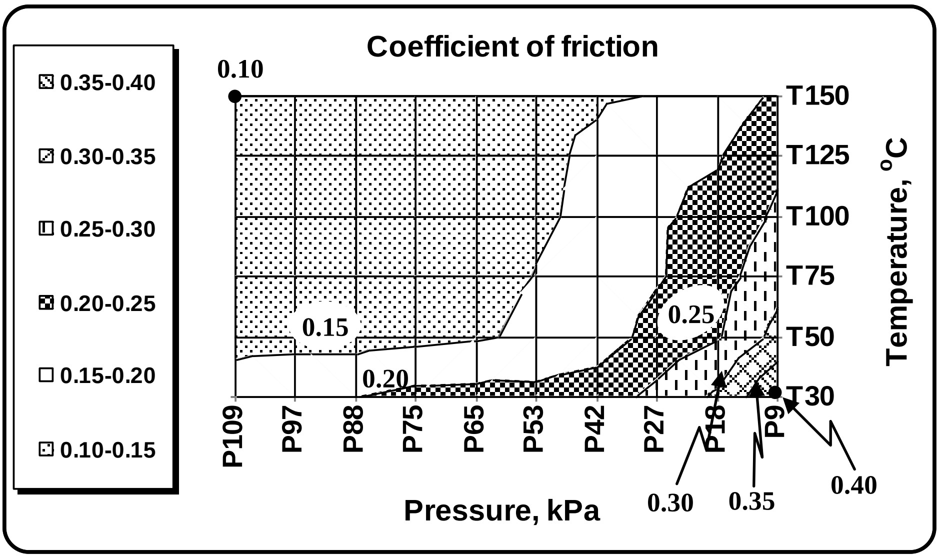


Fig. (5): Effect of pressure "P" and Temperature "T" on the dynamic coefficient of friction "µd" between cotton seed meal and steel 50.

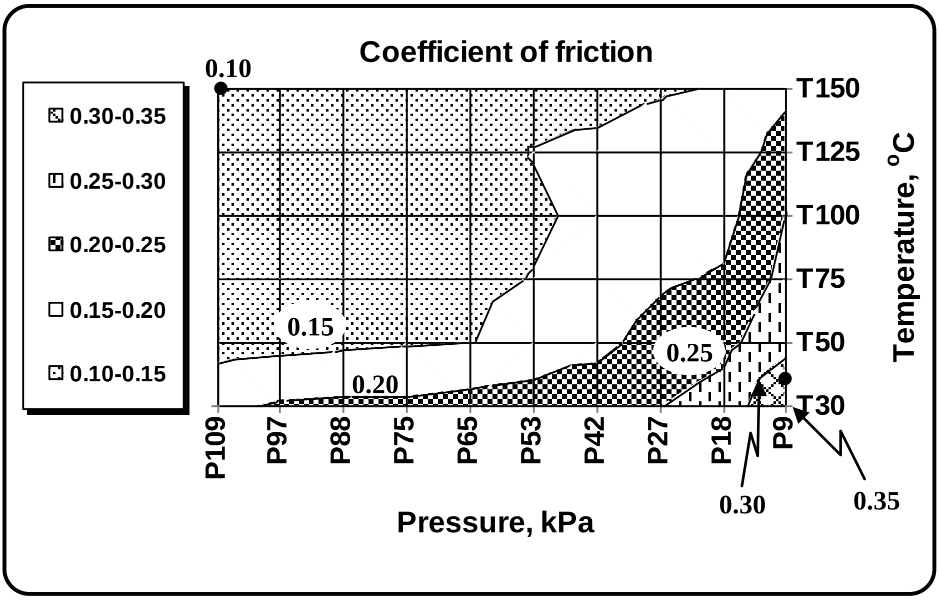


Fig. (6): Effect of pressure "P" and Temperature "T" on the dynamic coefficient of friction "µd" between soybean seed meal and steel 50.

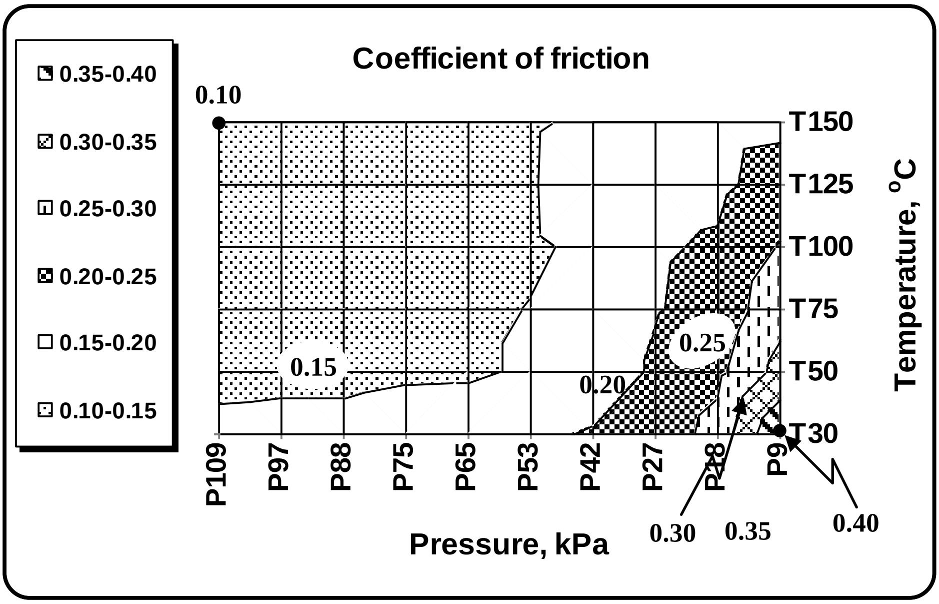


Fig. (7): Effect of pressure "P" and Temperature "T" on the dynamic coefficient of friction "µd" between mixture (1) and **steel 50.**

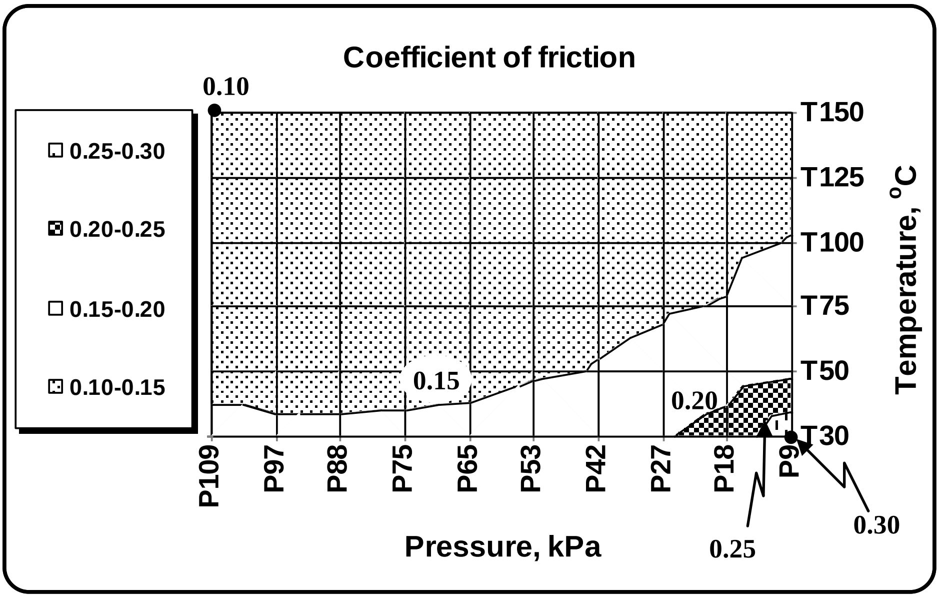


Fig. (8): Effect of pressure "P" and Temperature "T" on the dynamic coefficient of friction "µd" between mixture (2) and steel 50.

2. The mathematical expression of the effect of pressure "P" and Temperature "T" on dynamic coefficient of friction between the tested materials and steel 50

The above mentioned graphical technique for finding out the value of the dynamic coefficient of friction "µd", could be replaced by another mathematical technique applying multiple regression approach to find out the value of dynamic coefficient of friction "µd" as a function of both pressure and temperature.

2.1 Mathematical expression for the effects of "P" and *"T"* on the value of "µd" by applying the multiple regression approach.

Multiple regression approach was used to derive a regression equation (3), expressing the effects of the pressure "P" and temperature "T" on the dynamic coefficient of friction "µd"

$$\mu d = a \times P + b \times T + k \ \ldots\ldots\ldots\ldots\ldots \mathbf{(2)}$$

Where

μd = dynamic coefficient of friction

P = Pressure pressing the feed material to the surface of contact, kPa; ($9 \le P \le 109$)

T = Temperature , ^{o}C; ($30 \le T \le 150$)

a, b & k = Empirical constants

The values of the empirical constants (a, b and k) and the coefficient of determination of equation (3) are shown in table (4).

Table (4): The empirical constants and the coefficient of determination of equation 3 for the six tested materials.

Material	Empirical constant			R^2
	A	b	k	
Yellow corn	-1.542×10^{-3}	-8.554×10^{-4}	0.360	0.723
Wheat bran	-1.870×10^{-3}	-1.139×10^{-3}	0.420	0.670
Soybean meal	-1.074×10^{-3}	-7.000×10^{-4}	0.293	0.786
Cotton seed meal	-1.340×10^{-3}	-7.285×10^{-4}	0.315	0.754
Mixture (1)	-1.284×10^{-3}	-5.063×10^{-4}	0.288	0.754
Mixture (2)	-4.631×10^{-4}	-5.449×10^{-4}	0.214	0.729

2.2 Mathematical expression for the effects of *P*, *T* and the feed chemical components (protein, fat, carbohydrates, fiber, ash and moisture content) on the values of μd by applying the multiple regression approach.

The obtained data of table (1) for the chemical components of the tested materials were used as factors affecting the values of the dynamic coefficient of friction. So, multiple regression approach (by using SPSS software) was used to derive a regression equation (3), expressing the effects of the pressure "*P*", the temperature "*T*", protein, fat, carbohydrates, fiber, ash and moisture content on the value of the dynamic coefficient of friction "μd". The results of this analysis were reviewed to exclude the variables which had minor effects. The excluded variables are fat content, carbohydrates and fiber.

Equation (3) expresses this mathematical relation.

$$\mu d = a \times P + b \times T + c \times Pr + d \times Ash + e \times MC + k \ldots\ldots \textbf{(3)}$$

where

μd	= dynamic coefficient of friction
P	= Pressure pressing the feed material to the surface of contact, kPa; ($7 \le P \le 52$)
T	= Temperature , ^{o}C; ($30 \le T \le 150$)
Pr	= Protein content;% ; ($0.92 \le Pr \le 11.6$)
Ash	= Ash;% ; ($0.53 \le Ash \le 24.42$)
MC	= Moisture content; %; ($10.21 \le MC \le 12.5$)
a, b, c, d, e & k	= Empirical constants

$a = -1.262 \times 10^{-3}$, $b = -7.456 \times 10^{-4}$, $c = -1.183 \times 10^{-3}$,
$d = 6.478 \times 10^{-3}$, $e = 1.923 \times 10^{-3}$, $k = 0.292$, $\mathbf{R^2 = 0.601}$

Thus, equation (4) can be used to predict the dynamic coefficient of friction of any feed materials resembling those tested materials or any other materials , under different values of pressure and temperature with tested conditions.

CONCLUSION

From this investigation the following conclusions can be made:

1. The dynamic coefficient of friction "µd" of the tested materials decreased by increasing the pressure imposed on the tested materials.
2. The dynamic coefficient of friction decreased by increasing the temperature the tested materials.
3. A maximum value of *µd*, 0.505, was found for wheat bran at 9 kPa and 30 ^{o}C.
4. A minimum value of *µd*, 0.105, of *µd* was found for cotton seed meal soy meal and mixture at P 109 kPa and T from 100 to 150 ^{o}C,.
5. The effect of pressure and temperature on *µd* was highly significant.
6. Graphical charts were introduced, applying Excel program to predict the values of *µd* for different tested materials.
7. Mathematical equations applying the multiple regression technique were derived for each material (six materials) for expressing µd as a function of T in ^{o}C and P in kPa imposed on it.
8. The derived regression equation (eq. 3) could be used with enough confidence in predicting the dynamic coefficient of friction for feed material resembling the tested material or any other material, which

could be produce the extruders under high pressure and temperature values and applying within the domain tested in this research work.

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الملخص العربى

تقدير معامل الاحتكاك الديناميكي لبعض مواد العلف الداخلة فى تصنيع المصبعات تحت قيم مختلفة من الضغوط ودرجات الحرارة

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يتم تصنيع بعض مواد العلف على هيئة مصبعات بإستخدام الباثق، الذي يعتمد في أدائة علي زيادة درجة الحرارة والضغط نتيجة لاحتكاك المادة الغذائية الخام بمعدن الوحدة الفعالة للباثق، وأيضاً نتيجة للطاقة المستهلكة في التشكل البلاستيكي للمادة والطاقة المستهلكة في تحول البروتين من صورتة العادية الي الطورة النسيجية ، لذلك فإن الطاقة المستهلكة والتي تولد الضغط العالي.

لذلك فان هذة الدراسة تهدف الي تقدير معامل الإحتكاك الديناميكي تحت قيم مختلفة من الضغوطودرجات الحرارة لستة مواد وهي: جريش الذرة الصفراء ، الردة، كسب بذرة القطن، كسب فول الصويا، واثنان مخلوط من المواد السابقة والتى تستخدم مع الحيوانات الكبيرة وذلك مع معدن الجزء الفعال للباثق وهو صلب 50.

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وللوصول لهدف الدراسة، فقد تم تطوير جهاز لتقدير مقاومة الحركة الإنزلاقية للمواد تحت الضغوط نتيجة لتأثير معامل الإحتكاك الديناميكي إعتماداً علي الأحمال الكبيرة التي الواقعة على العينة المراد قياسها.

وقد تمت الدراسة عند عشرة مستويات للضغوط وهي 9، 18، 27، 42، 53، 65 ، 75 ، 88، 97، 109 كيلوبسكال و ستة مستويات لدرجات الحرارة، وهي 30، 50، 75 ، 100، 125، 150درجة مئوية لستة مواد مختلفة في التركيب البنائي لها.

و قد بينت الدراسة ما يلي:

١. يقل معامل الإحتكاك الديناميكي بزيادة الضغط.
٢. يقل معامل الإحتكاك الديناميكي بزيادة درجة الحرارة للمواد.
٣. أقصي قيمة لمعامل الإحتكاك الديناميكي كان 0.505 للردة عند ضغط 9 كيلوبسكال، و درجة حرارة 30 درجة مئوية.
٤. أقل قيمة لمعامل الإحتكاك الديناميكي كان 0.105 لكسب القطن وفول الصويا ومخوط من مواد العلف عند ضغط 109 كيلوبسكال، و درجة حرارة تتراوح من 100 الى 150 درجة مئوية.
٥. كان لكل من الضغط ودرجة الحرارة تأثير علي معامل الإحتكاك الديناميكي .
٦. تم التوصل الى اشكال بيانية باستخدام برنامج الاكسيل وذللك للتنبؤ بقيم معامل الاحتكاك الديناميكى لمواد العلف التى تم اختبارها.
٧. تم التوصل الي معادلة تعبر عن معامل الإحتكاك الديناميكي كدالة لكل من درجة الحرارة و الضغط الواقع عليها بوحدات الكيلوبسكال في صورة معادلة بطريقة الإنحدار الخطي وذلك لكل مادة من المواد المختبرة الستة.
٨. كذلك تم التوصل الي معادلة إحصائية بطريقة الإنحدار الخطي للتنبؤ بمعامل الإحتكاك الديناميكي تحت الضغوط العالية كالتي تحدث في الباثق إعتماداً علي مقدار الضغط الواقع علي المادة مقدراً بالكيلوبسكال - ودرجة الحرارة مقدرة بدرجة مئوية - ونسب المكونات الكيمائية للمادة وهي نسبة البروتين ونسبة الرماد المحتوى الرطوبى – وذلك لأي مادة لها نفس الشكل للمواد التي تمت الدرلسة عليها.