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DEVELOPMENT OF AN OIL EXPRESSION MACHINE TO SUIT PRODUCTION OF LIVESTOCK FEED PELLETS

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ABSTRACT

This research aims to test the feasibility of using a small expression machine for oil extraction (expeller) as a dual-purpose machine for mixing and forming livestock feed pellets. The effect of some parameters such as, screw revolving speeds (50,95,135 and 190 r.p.m), die hole diameters (10, 14 and 18 mm) and average moisture contents of raw materials (10.65, 13.3 17.2 % dry basis) on machine productivity (ton/h), and energy requirements (kW.h/ton). Also, the effect of machine parameters on mixing efficiency (%) and pellets quality (pellets hardness) during the pelleting operation were also considered.

The results revealed that, optimum values for the operations conditions were obtained at 135-r.p.m screw revolving speed; 14.0 mm die hole diameter and 13.3 % (d.b) raw material average moisture content. At these levels maximum machine productivity of (0.174 ton/h), minimum energy consumption (33.07 kWh/ton), mixing efficiency (75.9%), and pellets hardness (13.2 N) were obtained.

INTRODOUCTION

The Egyptian ministry of Agriculture and Land Reclamation has launched many technological programs in all desciplines to cut – down on the food gap between production and consumption. Among desciplines of high priority is the feeding of livestocks.

To obtain a well-balanced feed with appropriate additives it must be processed as pellets, wafers or cubes, to ensure suitable density, less amount of dust and minimum size for good durability and storage. Many types of machines are available to do this work. Most of them are complex and expensive since they incorporate devices to facilitate processing. Providing these machines in simple and cheap form would encourage and expand on their use.

Dobie (1960) showed that there are three basic designs for wafering machines as follows; reciprocating or plunger type; roller type; and screw type. He indicated that, most of these machines operate reasonably well with average moisture content of material up to 25 %. He found that the density of pellet is closely related to the pressure applied to the raw material. He found that also in commercial pellet mills, instantaneous pressures have been measured up to 448.16 MPa, which produce pellets with a density in bulk of 640.74 to 720.83 kg/m3 or up to 1041.20-kg / m3 actual densities.

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On the other hand, Young et al, (1963) reported that the mechanical actions of the various components of conveying and handling equipment damage pellets. Durability analyses involve injury into the nature of the forces that cause pellet damage during handling and transporting. These forces may be divided into three general classes. Impact, compression and shear.

Balk (1964) showed that moisture content is the most important single factor affecting the energy required for dehydrating, grinding and pelleting coastal Bermuda grass. Meanwhile, Susawa (1978) mentioned that moisture contents of materials at 16 to 18% are desirable, but moisture contents of the products have to be below 14% to avoid fungi infestations during the storage.

Conway (1971) concluded that factors influencing the extrusion process include the extruder design and the raw materials used, as well as various operating factors. The extruder design controls the function efficiency and capabilities of the extruder.

Carl and Denny (1979) used grain and forge, often with the addition of a binding material to form compacted pellets for animal feed.

While Simmons (1963), and Mohsenin and Zaske (1976) stated that extrusion requires more energy and is more suitable for application while, compaction requires less energy.

According to the Egyptian standard specification for prepared animal feeds and feedstuffs (Egyptian organization for standardization, 1978), compressed feeds are sized into 4 categories as follows:

- Size (1): < 2 mm in diameter ranked: powder or mash, which was used for all types of poultry, and birds.
- Size (2): from 2 - 5 mm in diameter, which was used for rabbits, goats and fishes
- Size (3): from 5 - 10 mm in diameter for small animals (<6 months).
- Size (4): from 10 - 22 mm in diameter for large animals (> 6 months).

Ramadan (1980) developed and tested a pelleting machine to produce pellets from different mixtures of berseem and molasses mixed with calcium oxide. He concluded that, the most efficient percentage of the mixture was two parts of molasses to one part of calcium oxide in mass. He added that the optimum range of moisture content for the final material under pressure ranged from 12 to 14%. These results were in line with most of the standard requirements.

David (1990) stated that specific energy of compression of dry matter is essentially independent of crop moisture. He also added that the electricity consumption is likely to be in the range 15 kW. h/ton for 11 mm cubes to 50 kW h/ton for 2.4 mm pellets, depending on the material and scale of operation.

Hassan (1994) used a small mix-milling unit, which is considered a very suitable technique for feed preparation in individual farms. He added that farm animal and poultry feed mixers performance is more sensitive to different factors such as auger speed, auger size (diameter and pitch) mixing time, the mixture components and the timing of mixing in respect to milling process. He also found that the optimum auger speed is ranging from 160 to 200 r.p.m.

Heim and Gluba (1996) studied pelleting commercial feed mixtures in a continuous drum-pelleting machine under different operating conditions. The distribution of pellet size in the final product was affected by all variable operating factors, but moisture content was most significant.

Kolief (1996) constructed a prototype of pelleting machine (plunger type) to process livestock feed pellets from berseem hay, sugar beet tops and cottonseed with other components. His results indicated that the lowest values of energy requirements were obtained at 17.56% moisture content, 20 mm. of outlet diameter and crank arm speed of 0.38 m/s for the three different types of pellets (cottonseed, sugar beet tops and berseem hay). Also, he concluded that increasing moisture content led to decrease the pellets hardness and stability of pellets.

Lo et al. (1998) found that the feed moisture content affect the extruder size and surface characteristics. The products extruded at higher moisture content (19.6 % w.b.) had a smoother surface than those extruded at lower moisture content (17 % w.b.) which showed a rougher surface. They added that breaking strength increased from 3.62 to 7.72 N. as moisture content increased from 17 to 19.6 %, respectively.

Kaddour (1999) constructed and tested a pelleting machine (roller type) to produce pellets for Rabbits from carrot tops and squash leaves with other additives. The obtained results showed that the lowest energy requirement was 42.14 kW.h/ton; at mixing speed of 70 r.p.m. and raw materials fineness degree of 4 mm using residues diet and relief die. The highest pelleting efficiency, pellets durability, and pellets bulk density were obtained at mixing speed of 70 r.p.m. and raw materials fineness degree of 1 mm using residues diet and relief die.

Ismael (2001) developed and tested a pelleting machine (screw type) to produce pellets for poultry from some processing residue (haricot, okra and pea wastes) with other components. The obtained results showed that the energy consumed in mixing, compressing and cutting of ration containing haricot, okra and pea wastes were 38.11, 28.94, and 24.25 kW.h/ton respectively at pellet diameter 5 mm for the best physical proportion of the pellets.

There are at least six advantages of feeding pellets versus the same formula in mash form. They are; better feed to grain conversion, eliminates selective feeding, more economical storage and transportation, better handling and flow-ability, reduction or elimination of feed losses from wind carry-off, and destruction of salmonella organisms from animal feeds as described by Mac North (1984), Ali and Dimian (1988).

The main objectives of the present study were to:

- Modify and test an expression machine for oil extraction as a dual purpose for mixing and forming livestock feed pellets.
- Study the effect of some processing parameters such as, screw revolving speeds (50,95,135 and 195 r.p.m), die hole diameter (10, 14 and 18.00 mm) and moisture contents of raw materials (10.65,

13.30 and 17.20), on mixing efficiency (%), machine productivity (ton/h), energy requirements (kW.h/ton), and pellets quality (pellets hardness).

MATERIALS AND METHODS

To fulfill the objective of this study, an expression machine for oil extraction from oilseeds (expeller), which was developed and constructed at the workshop of Agric, Engineering Research Institute (AEnRI) Dokki, Giza? (Al-Ashry, 1999) has been adapted, modified and tested for the work of this paper. The technical specifications and operating parameters of the developed pressing machine is shown in Table (1) and Fig (1).

Table (1) Technical specifications of the developed pellteing machine:

Item	Specifications
Main Dimensions:	
- Overall length, cm;	136.5
- Overall width, cm;	61.5
- Overall height, cm;	155
- Total mass, Kg.	513
Screw:	
- Length, cm;	56
- Diameter, cm;	10
- Pitch (trough width), cm;	5
- Peak height (trough depth), cm;	1.5
- Flights No.;	10
Hopper:	
- Length, cm;	35
- Average diameter, cm;	30
Power source;	Three phase electric motor
- Power req, HP (kW);	10 (7.5)

The original die outlet head has a chuck like outlet that may be changed and replaced by an outlet ring die has ten round holes (Fig. 2) for forming forage pellets by extrusion process, where the function of the chuck of the original outlet die to permit a final adjustment of pressure and capacity in order to secure the lowest possible oil content of the cake.

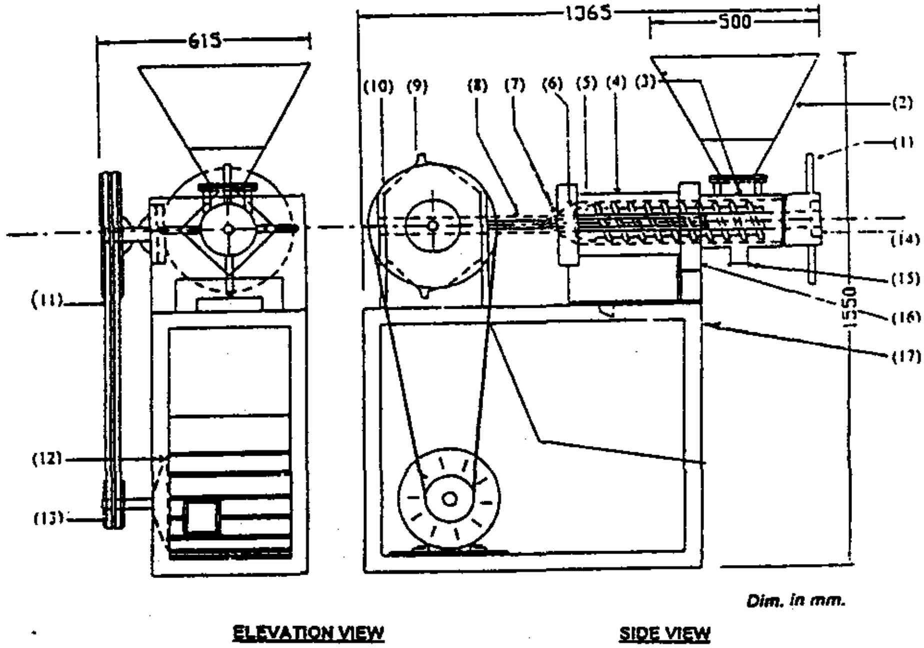
All components of the experimental ingredients have 3 mm fineness degree, except linseed cake having 4.2-mm. fineness degrees.

The percentages of each component ingredient in the experimental pellets were as follows:

Linseed cake 33%, ground corn 25%, wheat bran 33%, common salt (Sodium chloride) 0.25%, premix 0.35%, molasses 5% and 3.4% of limestone.

- Procedures and measurements:

- Before pelleting operation, the hopper was filled with meal ingredient.
- The pelleting machine was run.
- The consumed time from the instant of dropping until the instant of complete discharge was measured.



1- Handle lever,	2- Feed hopper,	3- Feed end,	4- Cage,
5- Extrudal screw,	6- Outlet die,	7- Meal discharge end,	
8- Horizontal shaft,	9- Gear box,	10- Driving pulley,	
11- V-belt,	12- Electric motor,	13- Motor pulley,	
14- Bearing,	15- Sliding plate,	16- Cage bracket,	17- Frame.

Fig. (1): A SCHEMATIC DIAGRAM FOR MODIFIED EXPRESSION MACHINE.

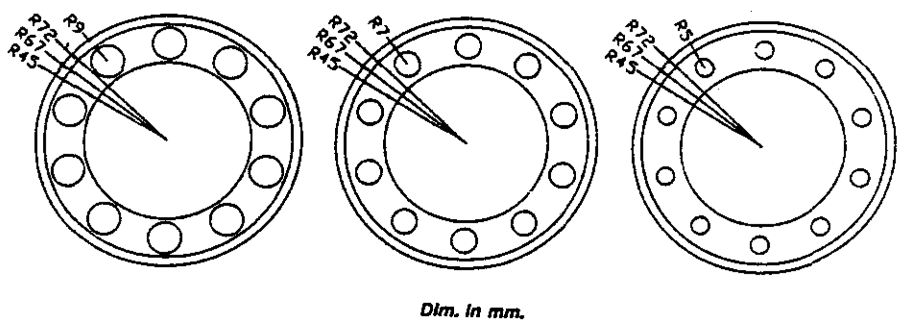


Fig. (2): THE MODIFIED OUTLET DIE

- Samples were taken periodically from the machine outlet and placed in air oven at 65 C until their weight was established.
- After drying the amount of pellets were noted.
- An average of three replicates of this procedure was taken and the amount of feed pellets was determined. Then the machine productivity (ton/ h) and energy (kW.h/ ton) were estimated for each test. The quality of the feed pellets (pelleting hardness) and mixing efficiency (%) was also considered.

- Estimation of machine productivity:

Machine productivity (M_P) was calculated using the following formula:

$$\text{Machine productivity } (M_P) = P_W / t \qquad \text{(ton/h)}$$

Where:

P_W = pellets weight, (ton);

t = the time consumed in operation (h).

- Estimation of mixing efficiency:

The following formula was used to estimate the mixing efficiency (η_M) of the feed pellets as follows:

$$\eta_M = C_{Pa} / C_{Pb} * 100 \qquad (\%)$$

Where:

C_{Pa} = the percentage of crude protein after pelleting,

C_{Pb} = the percentage of crude protein before pelleting.

- Estimation of energy requirements:

Total consumed power (kW) under machine working load was estimated by using Wattmeter (700-k type) having an accuracy of + 1%. Then, the power was estimated from the knowledge of line current strength in Amperes (I) and potential difference values. Then the actual power of the machine (P) was then estimated according to (Kurt, 1979) as follow:

$$P = \sqrt{3} \cdot I \cdot V \cdot \eta \cdot \cos\Theta / 1000 \qquad \text{kW}$$

Where:

I = line current strength in Amperes;

V = potential difference (voltage) being equal to 380 V;

η = mechanical efficiency assumed (95 %);

cos Θ = power factor (was taken as 85%).

Specific energy requirements (kW. h / ton), was calculated by multiplying the consumed power (kW) by the time period (h) and then dividing by the machine productivity (ton).

- Moisture content determination:

- Moisture content of feed pellets before and after processing were determined according A.O.A.C. (1994). The standard air oven method using 25 gm samples placed in air oven at 130 C for 16 hours was used to determine moisture content.
- The desired moisture level of pellets component ingredients was adjusted by drying or rewetting.

- Determination of pellets Hardness:

A portable hardness Tester 174866 Kiyo Seisakusho, LT.D. was used to determine the rupture force in Newton.

RESULTS AND DISCUSSION

In order to evaluate the modified machine performance, as well as mixing and pelleting efficiency during actual pelleting tests, the different criteria of feed pellets, such as quality properites and other factors related to energy requirements and machine productivity during pelleting operation must be taken into consideration.

- Pelletizer Productivity:

The observations reported in Fig. (3) show the effect of screw revolving speeds, die hole diameters of extruder and average moisture content of pellets components on the machine productivity .

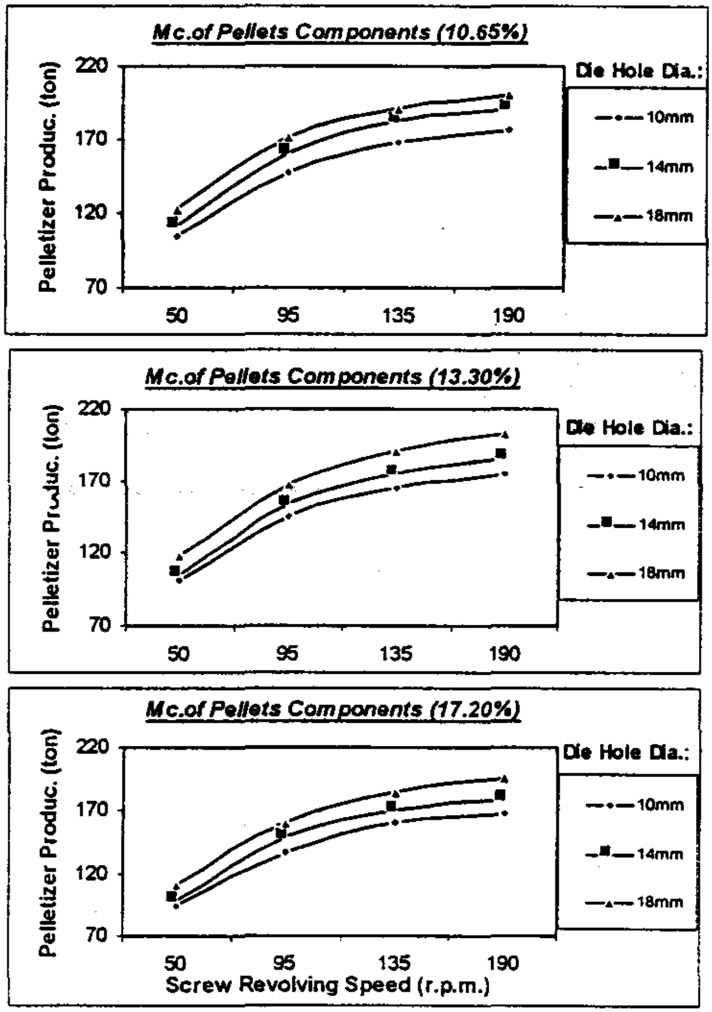


Fig.(3): Pelletizer productivity as affected by different screw revolving speeds and different die hole diameters at different moisture contents of pellets components.

The data reveled that at any average moisture contents of pellets components, the productivity rate of extruder increased as the screw revolving speeds and die holes diameters increased. On the other words, at 13.3% average moisture content of pellet components, the results indicated that increasing screw revolving speeds from 50 to 190 r.p.m cause a corresponding increase in the pelletizer productivity from 0.101 to 0.174, from 0.105 to 0.186 and 0.118 to 0.203 ton/h. at die hole diameters of 10, 14 and 18mm respectively. Meanwhile, the data indicated that pelletizer productivity tends to decrease as average moisture content of pellets increased from 10.65 to 17.20 %, and increased as die hole diameters increase from 10 to 18 mm. (Fig. 3). This increase in pelletizer productivity with the increase in the screw revolving speeds and die holes diameters, may be attributed to the decrease in the time needed for ration pelleting. Meanwhile, decreasing machine productivity as average moisture content of pellets components increased from 10.65 to 17.20 % may be due to increase the ration adhesion over the screw with increasing the screw revolving speeds.

Generally, when pellets operation was conducted at 190 r.p.m revolving speed and 10.65% avg. moister content of pellets components the maximum values of machine productivity was found to be 176.0, 190.52 and 200 kg/h at die hole diameters of 10,14 and 18 mm. respectively.

- Power and Energy Requirements:

Table (3) and Fig. (4) shows the power and energy requirements as affected by different screw revolving speeds, die hole diameters of extruder and average moisture contents of pellets components..

Table (3): Power requirements as affected by different screw revolving speeds, die hole diameters and pellets components moisture contents

Mc %	Die hole Diameter (mm)	Screw Revolving speed r.p.m.			
		50	95	135	190
		Power Requirements (kW.)			
10.65	10	3.29	5.08	6.02	6.62
	14	3.13	4.83	5.44	6.47
	18	2.97	4.45	5.16	6.17
13.30	10	3.38	5.20	6.22	6.88
	14	3.18	5.0	5.76	6.63
	18	3.05	4.58	5.33	6.45
17.20	10	3.65	5.36	6.66	7.28
	14	3.35	5.12	6.34	6.93
	18	3.16	4.79	5.67	6.42

It is remarkable that the power and energy requirements for extrusion operation increased as the screw revolving speeds and average moisture content increased, while it decreased with increasing die hole diameters of pellets. On other words, at 13.3% average moisture content of pellet components, the results indicated that increasing screw revolving speeds from 50 to 190 r.p.m cause a correspoding increase in the pelletizer power consumption from 3.38 to 6.88, from 3.18 to 6.63 and from 3.05 to 6.45 kW at die hole diameters of 10, 14 and 18mm respectively (Table. 3).

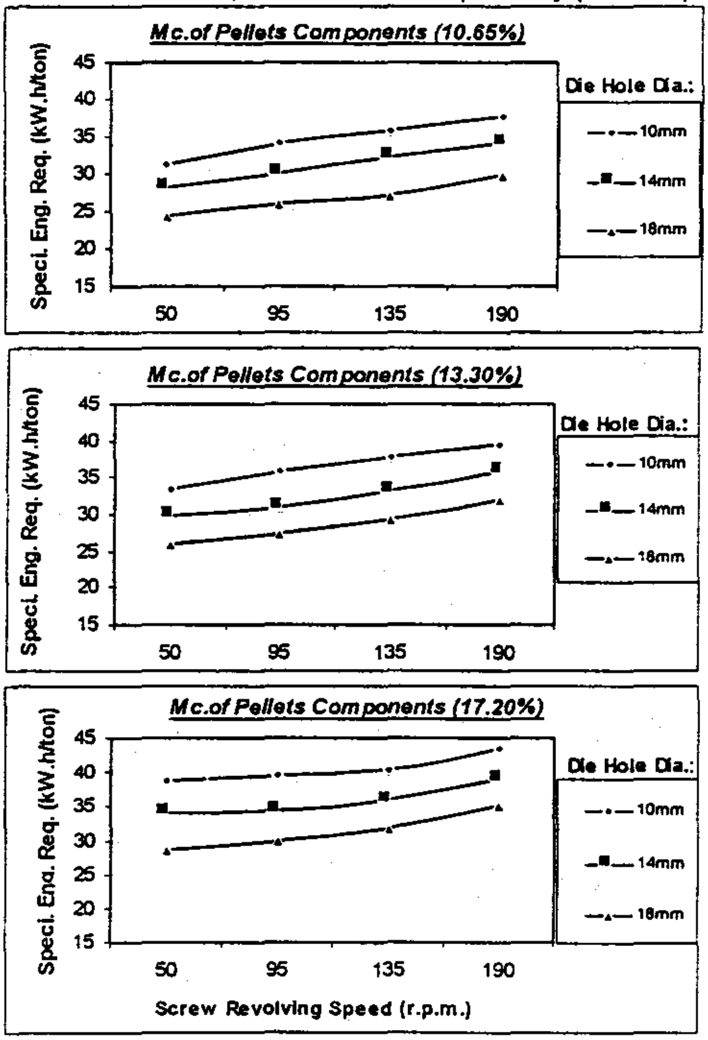


Fig.(4): Specific energy requirements as affected by different screw revolving speeds and different die hole diameters at different moisture contents of pellets components.

The same trend of increase in the specific energy requirements (kW.h/ton) as a function of a corresponding increase in screw revolving speeds from 50 to 190 r.p.m and pellet components moisture content from

10.65 to 17.2 % at any die hole diameters in the range of 10 to 18 mm was observed. On the other hands, at 13.3% average moisture content of pellet components, the results reveled that increasing screw revolving speeds from 50 to 190 r.p.m cause a correspoding increase in the pelletizer energy consumption from 33.35 to 39.52, from 30.33 to 35.70 and from 25.82 to 31.84 kW.h/t. Meanwhile, it can be seen that under the same screw revolving speeds and pellet components moisture contents, the specific energy requirements (kW.h/ton.) decreased as die hole diameters increased in the range of 10 to 18 mm. as shown in Fig (4).

- Pellets Hardness:

Hardness of feed pellets was tested to throw light on the effect of mechanical action during the pelleting process under different treatments.

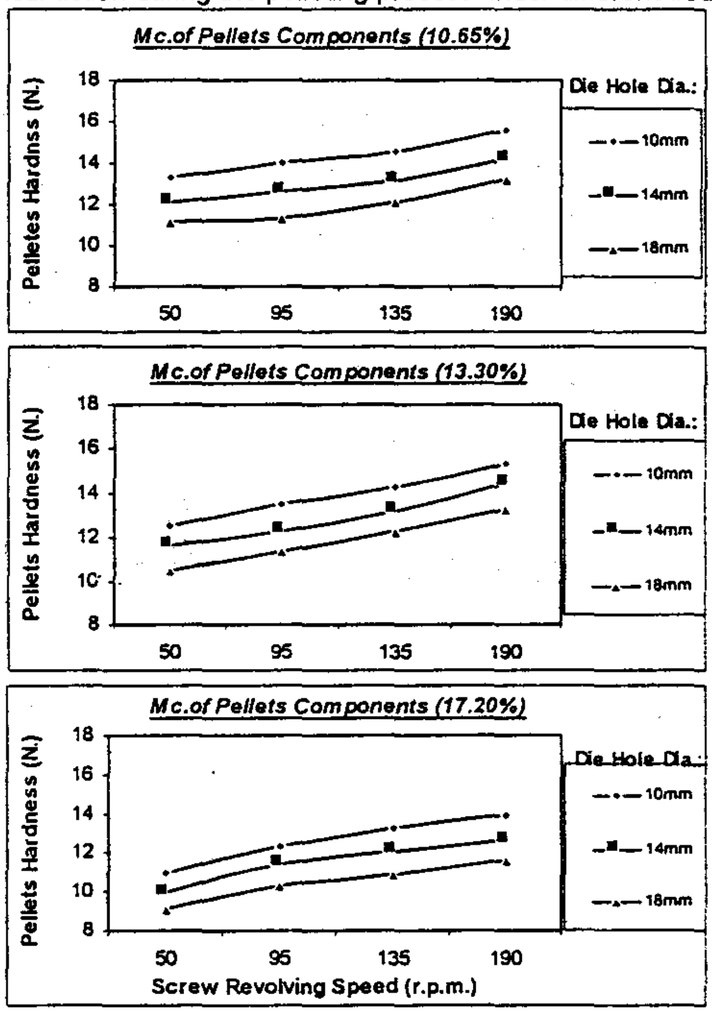


Fig.(5): Pellets hardness as affected by different screw revolving speeds and different die hole diameters at different moisture contents of pellets components.

Hardness of pellets was measured at the outlet die and after pellets drying to find out its ability to break-up. It can be seen from Fig. (5) that the hardness of pellets increased as the screw revolving speeds increased from 50 to 190 r.p.m, while it decreased with the increasing in die hole diameters from 10 to18 mm. and average moisture content of pellets from 10.65 to 17.20 %.

On the other hand, there is an inversely proportion between pellets hardness and both of pellets diameter and average moisture content of pellets, while a direct proportion were found between pellets hardness and screw revolving speeds as shown in fig (5).

The results indicated that as the diameters of pellets increased from 10, 14 and 18 mm the hardness of pellets increased from 13.30 to 15.6, from 12.05 to 14.20 and from 10.35 to 13.25 (N) at 10.65 % average moisture content of pellets and as the screw speeds increased from 50 to 190 r.p.m, respectively.

However, at screw revolving speed of 190 r.p.m and by increasing moisture content of pellets components from 10.65 to 17.20 %, the hardness of pellets decreased from 15.6 to 13.9, from 13.53 to 12.60 and from 13.25 to 11.57 (N) at die hole diameter of 10, 14, 18 mm. respectively (Fig. (5).

- Mixing Efficiency:

Mixing efficiency is considered one of the most important functions for mixing and consequently the quality of produced pellets.

The obtained results (Fig. 6) indicated that mixing efficiency increased as screw revolving speed increased from 50 to 135 r.p.m, this increased was followed by a corresponding decrease in pellets mixing efficiency as the screw revolving speed increased from 135 to 190 r.p.m.

The highest mixing efficiency (81.95%) was obtained at a screw speed of 135 r.p.m and 10-mm die hole diameter at 13.30 % average moisture content of pellet. While the lowest mixing efficiency (60.4 %) was obtained using screw speed of 190 r.p.m. and 18 mm. die hole diameter at 17.20 % average adhesion moisture content of pellet components, (Fig. 6).

This decreased in mixing efficiency with the increase in screw-revolving speed from 135 to 190 r.p.m, may be due to the slip increase between the plug and the channel wall with increasing the screw speed.

At the same time, the mixing efficiency decreased by increasing both of die hole diameters from 10 to 18 mm. and raw material average moisture contents from 10.65 to 17.20 % as shown in Fig. (6).

The results indicated that at 135 r.p.m screw revolving speed and as die hole diameters increase from 10 to 18 mm. the mixing efficiency decreased from 81.29 to 69.64, from 81.95 to 70.87, and from 75.91 to 63.92 % at raw material average moisture content of about 10.65, 13.30 and 17.20 % respectively.

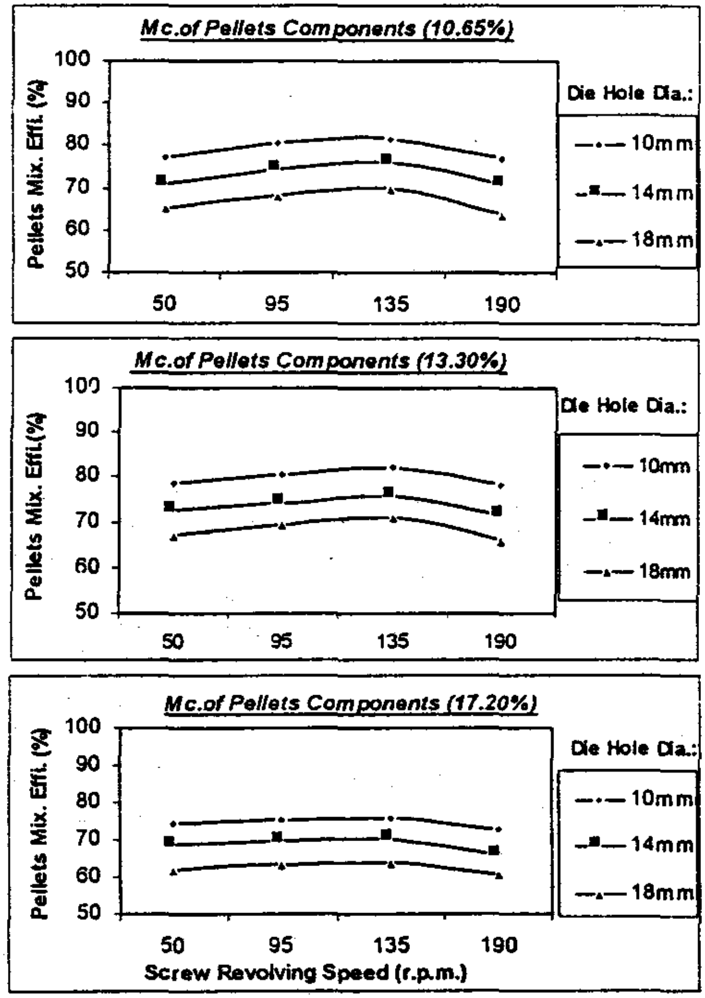


Fig. (6) : Pellets mixing efficiency as affected by different screw revolving speeds and different die hole diameters at different moisture contents of pellets components.

CONCLUSION

1. The results showd that it is possible to use the expression machine after making some modifications on the outlet die in the belleting process.
2. The optimum operating conditions of extruder were found to be as follows:

   screw revolving speed of 135 r.p.m, die hole diameter of 14mm and raw materials moisture content 13.3% where gave the best result of productivity rate, energy consumption, mixing efficiency and hardness of pellets.

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المراجع العربية:

ماك نورث (١٩٨٤)٠ دليل الإنتاج التجاري للدجاج ٠ الجزء الأول الطبعة الثانية، الدار العربية للنشر والتوزيع

الهيئة المصرية العامة للتوحيد القياسي (١٩٨٧) ٠المواصفات القياسية المصرية ٩٨٧/٣ ـ الأعلاف المصنعة ومواد العلف الخام٠

الملخص العربي

تطوير آلة عصر البذور الزيتية لتلائم إنتاج الأعلاف الحيوانية المضغوطة

د ٠ كريم السيد صالح حجازي* د٠ عبده شوقي العشرى** د. ماجدة محمد عبد الرحمن **

يهدف هذا البحث إلي تطوير وتقييم آلة صغيرة محلية الصنع تستخدم لاستخلاص الزيت من البذور الزيتية لتلائم إنتاج الأعلاف الحيوانية المضغوطة، وذلك كهدف إضافي لتشغيل الآلة، مما سينعكس بدوره علي خفض تكاليف تشغيل الآلة نظرا لزيادة ساعات تشغيلها وقد تم تعديل فتحة التصرف لتناسب تشكيل أصابع العلف الناتجة.

كما تم دراسة تأثير بعض العوامل التشغيلية التي تؤثر على كفاءة أداء خلط وبثق العلف المشكل باستخدام الآلة المعدلة وأثر ذلك علي إنتاجية الآلة (طن/س)، وكفاءتها (%)، والاستهلاك النوعي للطاقة (كيلووات٠س/طن) أثناء عملية الكبس و اشتملت الدراسة على أربعة مستويات لسرعة بريمة الضغط (٥٠ ـ ٩٥ ـ ١٣٥ ـ ١٩٠ لفة/دقيقة) وثلاث مستويات لقطر ثقوب فتحة خروج العلف (١٠ـ ١٤ ـ ١٨ مم٠) وثلاث مستويات مختلفة لرطوبة المواد الخام للعليقة المراد كبسها(١٠,٦٥ ـ ١٣,٣ ـ ١٧,٢ % - أساس جاف)

أظهرت نتائج الدراسة المتحصل عليها أن العوامل المثلى لتشغيل الآلة كانت باستخدام سرعة قدرها (١٣٥ لفة/دقيقة) لبريمة الضغط، ومحتوى ر طوبى متوسط لمواد العليقة قدره (١٣,٣ % - أساس جاف)، وذلك باستخدام فتحات قطرها (١٤ مم) لثقوب (الداى) حيث أعطت آلة الكبس عند تشغيلها تحت هذه الظروف أعلى إنتاجية (٠,١٧٤ طن/ساعة)، وأقل طاقة مستهلكة (٣٣,٠٧ كيلووات٠س/طن)٠ كما كانت كفاءة خلط العلف (٧٥,٩%)، ودرجة صلابة أصابع العلف المشكل بطريقة البثق (١٣,٢ نيوتن) .

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*باحث أول بمعهد بحوث الهندسة الزراعية - الدقي - جيزة .
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