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DEVELOPMENT AND MANUFACTURE OF LOCAL PADDLE MIXER FOR RABBITS FORAGE PREPARATION

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ABSTRACT

A paddle mixer was designed, fabricated and tested to improve the mixing homogeneity in premix feed processing. It operates at low speed and has large impellers, which sweep the whole vessel to mix high viscosity material in laminar flow. The fabricated mixer was evaluated and tested among the studying effects of some engineering and operating parameters on the mixing homogeneity and energy requirement. These parameters include the batch volume ratio (0.5, 0.75 and 1.0), mixing time (5, 10, 15, and 20 min.), impeller peripheral speed (0.86, 1.73, 2.6, and 3.47 m/s), blade setting angle (15, 30 and 45 degree) and batch moisture content (16.06 %, 20.12 %, and 24.03 %). The results indicated that increasing the time 15 min more had a negative effect on the process, causing component segregation, and an increase in energy requirement. Peripheral speed of the mixer should be 0.86-1.73 m/s. To prepare the best mixture conditions, it is recommended to keep the blade resting angle on mixing shaft in the range from 15º to 30º. To achieve an adequate mixing homogeneity, vessel mixer must have a batch volume ratio (V_b/V_v) as close to 0.75 as possible. A moisture content of 16.06 % gave the best mixing homogeneity. The mixing time has not to exceed 15 minutes, blade setting angle in the range from 15º to 30º and mixing speed should be equal 1.73 m/s, to avoid extra cost in energy consumption. The developed model that can be used for predicting mixing homogeneity is expressed as follows:

$$CV = 45.08\,(pvd/\mu)^{0.1}\,(V_b/V_m)^{0.02}\,(\theta)^{-0.063}\,(gt^2/h)^{-0.045}$$

Based on the experimental results, the best mixing homogeneity (CV= 1.2 %) with the lowest energy requirement (2.11 kW.h/ton) could be obtained with impeller speed of 1.73 m/sec, mixing time 15 min., blade setting angle 30 degree, batch volume ratio 0.75 and batch moisture content of 16.06%.

INTRODUCTION

The demand for animal protein in Egypt is expected to increase progressively with the overabundance of population growth. The humanity is still suffering from shortage in animal protein due to its high cost. In Egypt rabbit is considered one of the major protein sources. But, feeding and selecting the proper rabbit diet is one of the most serious problems facing rabbit producers. Rabbit needs a relatively high amount of protein in its diet, while it is considered as the most important and expensive part of the diet. Therefore, encouraging production of local animal protein sources should be given much consideration, in order to improve the production of new and non-conventional sources of protein for animal feeding and to face the acute high in roughage price resulting from high price of synthetic diets. Also, feed additives should be present to provide the appropriate level of protection from disease and other maladies. The level must be controlled so as be neither deficient nor toxic. In all cases, proper mixing is of great significance in preparing an animal feed for satisfactory hygiene and high quality.

Malhotra and Mujumdar (1990) stated that the best operating parameters for producing animal forage with using the paddle-type mixer are the agitator rotational speed 20-40 rpm, bed to blade height ratio 2-6, blade height 2.5-5 cm, vessel diameter 0.25 and 0.5 m, wall to blade clearance 2.3-8 mm and moisture content 0-100 %.

Malhotra *et al.* (1988) indicated that to examine overall particle mixing patterns in horizontal vessels stirred by paddle-type blades. Proper selection, design and scale-up of mechanically stirred vessels handling granular solids require an understanding of the flow dynamics of the solids.

Broadbent *et al.* (1993) used a shovel-type mixer. It contained two main plough blades separated by 180º mounted upon a horizontal mixing shaft with a fixed rotation frequency of 4 Hz, along with a scraper blade at each also separated by 180º. The internal diameter and length of the mixing bowl and the radius of the blade tip from the center of the mixing shaft were 188 mm, 175 mm and 92 mm, respectively. The clearance distance of the blade from the wall of the mixing bowl was 2 mm.

Ismail (2002) indicated that the increase of mixing blade radius increases the amount of agitated mass of vessel, consequently improving the mixing efficiency. The mixed mass speed is directly proportional to mixing blade radius. Increasing the mixing blade radius from 10 to 15 cm increases the mixing blade speed by about 1.59 %.

Bockisch *et al.* (1992) stated that the exact mixing of animal feed is required to avoid selective intake by the animal. They recommended that the mixing time has not exceed 8 min. to avoid extra cost in labor and energy consumption.

Author *et al.* (1996) showed that from the point of view of energy consumption of the work, quality of fodder and mixing time, paddle mixers were the best for mixing maize silage, straw and bulky fodder. The demand for energy per unit mass was 1.07 kW.h/ton. A fodder cart with paddle mixer achieved the best quality feed within 9-minute period. Increasing the time 9-minute more had a negative effect on the process, causing component segregation, and an increase in energy consumption. Peripheral speed of the mixer should be 0.25-0.92 m/s.

King (1972) suggested that mixing machines can be classified into two kinds: those in which significant kinetic energy is imparted to the material to be mixed and those in which it is not. The former category is commonly referred to as "high speed mixers", which have relatively small impellers, and are designed to mix low viscosity materials by promoting a turbulent flow field throughout the vessel. By contrast, "low speed mixers" have large impellers, which sweep the whole vessel to mix high viscosity material in laminar flow.

Aly and Dimian (1988) stated that the use of horizontal mixers are more suitable when there is need to mix the wet and dry substances together while it is difficult to the other types.

Williams (1983) designed a mixer with four mixing blades mounted on a shaft, the blades taking the form of steel strips wound around the shaft in a continuous spiral, revolve at 30 rpm in a U-shaped chamber. Two of these spirals fit inside the other two, which has the effect of conveying the ingredients and forwards until they are thoroughly mixed.

Lindley (1991) stated that the mixing of solid particulate materials is a common and ancient operation. There is a general understanding of what happens in the process. But the details of forces and mechanisms have not been completely developed into design procedures.

Harnby (1992) stated that the most mixers could be grouped according to the mixing mechanisms, thus, solid mixers may be broadly classified as trembler mixers. Although most connective mixers operate at low rotational speeds, typically 15 to 60 rev/min. Some mixers operate at much higher speeds up to 1000 rev/min.

Godfery (1985) reported that understanding of the science of mixing is poor, there is a great need for design equations and techniques for comparison of performance. The main considerations are rate of mixing, power requirements, efficiency, design methods, and scale-up criteria.

Gorsuch (1986) reported that there was a need for research into the mixing of materials deferring characteristics, and that the real need is for a level of understanding that will allow performance to be predicted and modeling based on a knowledge of the characteristics of the mixer and properties of the materials. The flow of fluids in all types of mixers is complex and difficult to describe connotatively. Consequentially fundamental methods of predicting mixing rate or power consumption is currently both complex and inaccurate.

Lindley (1991) indicated that proper mixing is a great significant operation in preparing an animal feed for satisfactory hygiene and high quality. Under laminar flow conditions, inertial forces quickly die out under the action of high viscosity. Therefore rotating impellers must occupy a significant proportion of the vessel if adequate bulk motion is to be achieved. The viscous material is introduced between two parallel plates that move relative to one another; the particles of the ingredients are pulled apart, distributed and then allowed to mix agglomerate.

So, the objectives of this study were as follows:

1- Design and construction of a simple, reliable and economical paddle mixing unit to be used for rabbits feed preparation.
2- Study the most important operating factors affecting the performance and energy requirements of the proposed mixer.
3- Perform a simulation modeling to obtain a prediction equation of mixing homogeneity as a function of studying parameters.
4- Define the best interaction among the studying parameters that would give the best mixing homogeneity with minimum energy requirement.

MATERIAL AND METHODS

A rotating paddle impeller mixer was developed to improve the mixing homogeneity in premix feed processing. It was selected as large impellers to sweep the whole vessel and mix high viscosity materials in laminar flow.

The designed mixer formed of U-shaped chamber made of stainless steel of 4 mm thickness as shown in Fig. (1), the internal diameter and length of the chamber are 75 and 100 cm, respectively. The third area of upper part is coverless side with dimensions of 35 x 75 cm. The outlet open was fixed at the middle bottom of the chamber with 25x30x35 cm width, hight, and long, respectively. It was adapted to be closed by a gate when mixing is running. Mixing process carried out by two groups of six large paddle impellers mounted upon a horizontal mixing shaft opposite each other, which has the effect of conveying the ingredients and forwards until they are thoroughly mixed. The dimensions of mixing shaft are 122 cm long and 5.5 cm diameter. A square rubber blade of 20 x 7 cm was fixed at the tip of each impeller. The blades could be tilted with a varying angles up to 45º. The radius of the blade from the center of the mixing shaft is 37 cm. Two scraper blades are mounted on the middle of mixing shaft with a flat blades used for scavining the mixed material after finishing the mixing operation.

All these parts were fixed on a simple frame made of U shape steel of 80 x 40 x 4 mm. The operated parts are drived by an electric motor of 5.5 hp through sprocket and chains. Therefore, this machine is a totally enclosed batch mixer. Where, mixing is occurring in a multimode composite mixing; the convective mixing along the rotating shaft, the shear mixing by the velocity gradient in the feed, and the special diffuse mixing.

The ingredients of experimental ration was prepared from different materials as sources of plant protein, then put in the vessel for mixing.

The properties of ingredients that perform the diet are shown in Table 1.

Table 1: Some properties of the rabbit experimental ration.

Composition, %		Sizes, mm	Density, kg/m^3	Coefficient of friction
Clover hay	= 37 %	< 0.7 mm = 23.64 %	427.66	rubber sheet = 0.81
Yellow corn seeds	= 25 %	0.7-1.4 mm =16.6 %		steel sheet = 0.65
Soy bean meal	= 18 %	1.4-2 mm =16.92 %		
Wheat brean	= 11.2 %	2-3.35 mm = 37.3 %		
Molasses	= 5 %	>3.35 mm = 5.54 %		
Limestone	= 2.0 %			
Salt	= 1.5 %			
Premix	= 0.3 %			

According to the obtained knowledge from Animal Production Research Institute.

The studied mixer was evaluated and tested within studying the influence of some engineering and operating variables on its product quality. The following parameters were studied for mixer evaluation:

1- Impeller speed:

Four different levels of impeller peripheral speeds of 0.78, 1.55, 2.32 and 3.10 m/s were studied. A hand digital photo tachometer (Model:DT-205 B) was used to determine the rotational speeds of mixing shafts.

2- Batch volume ratio:

It is important to have a proper capacity for adequate blending without excessive mixing time. To investigate the maximum efficiency, the mixer performance was evaluated under different ratios of batch to mixing vessel volume. The mixing vessel was filled with batch as ratios of 0.5, 0.75 and 1.0 of its volume.

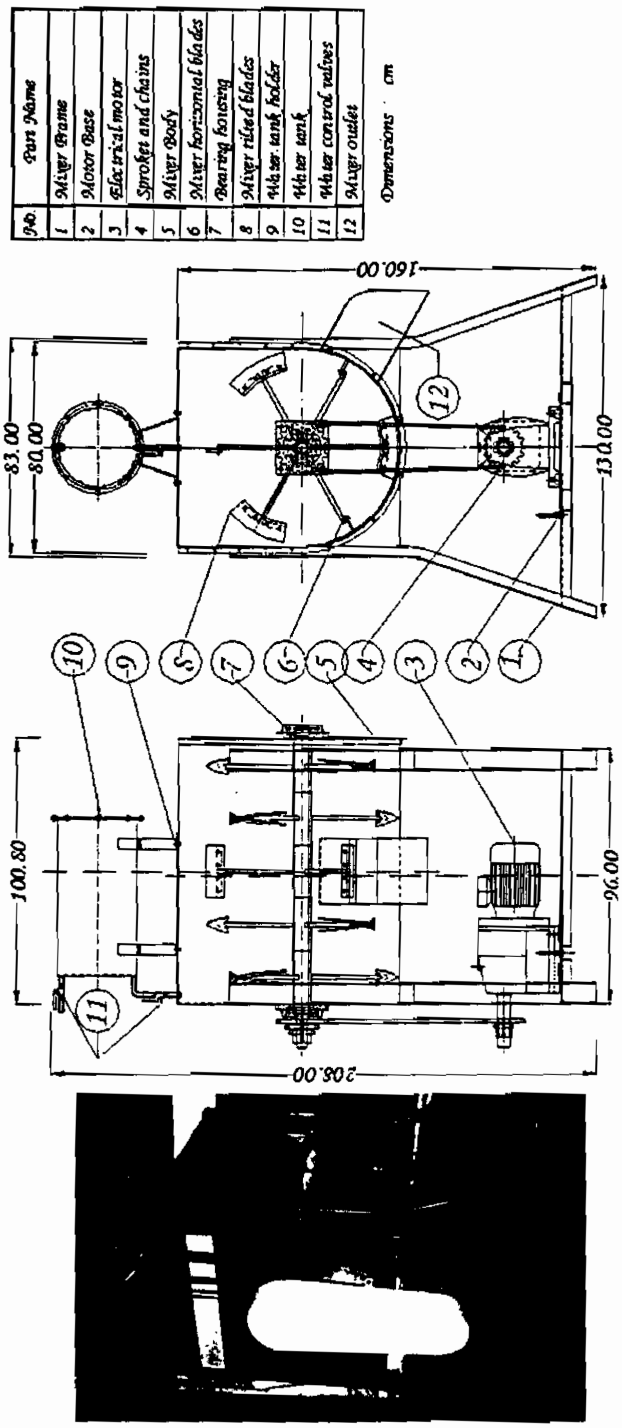

Fig. (1): Plate and Schematic diagram of batch mixer for rabbits forage preparations.

3- Mixing time:

The performance of designed mixer was evaluated under four different levels of mixing time (5, 10, 15 and 20 minutes).

4- Blade setting angle:

Three different angles of blade setting were chosen as 15, 30, 45 degree around vertical axis.

5- Moisture content:

Free-flowing powders tend to segregate if there are differences in particle size and density. In this case, a non-segregate mixer will be chosen for the best mixing results, when powders are not free-flowing because they are moist. Therefore, the mixer performance was evaluated using three samples of ration with three different moisture contents including 16.06%, 20.12 % and 24.03 %.

It was measured by using oven dryer methods at 105 °C for 24 hr.

To evaluate the studied mixer performance the following measurements were considered:

1- Mixing homogeneity:

Mixing homogeneity is an important criterion of feed quality control, while the coefficient of variation (CV) is an indicator for mixing homogeneity. After a mixing experiment, 16 samples were taken from different locations in the mixer at evenly spaced points in time. The crude proteins before and after mixing were determined for each sample in the laboratory of feed animal institute. The crude protein percent was calculated according to the following formula:

Where:

Cp_a = Crude protein after mixing, %;

Cp_b = Crude protein determined according to its ingredients before mixing, %.

The coefficient of variation for crude protein (mixing homogeneity) among the 16 samples was determined as follows:

$$CV = \frac{\delta}{\bar{X}} \times 100 \quad ,\%$$

where:

CV = coefficient of variation, %;

δ = standard deviation;

$\bar{X}$ = mean of crude protein percent.

2- Energy requirement:

In order to measure the energy requirement for operating the designed mixer unit, a super clamp meter-300 k was used for measuring the current strength and potential difference before and during experiments. The consumed power was calculated according the following formula (Ibrahim, 1982):

$$Total\ consumed\ power, (kW) = \frac{\sqrt{3}\ \ I\ \ V\ \eta\ \ \cos\theta}{1000}$$

Where:

I = Line current strength in amperes.
V = Potential difference (Voltage) being equal to 380 V.
Cos θ = Power factor (being equal to 0.84).
$\sqrt{3}$ = Coefficient current three phase.
η = Mechanical efficiency assumed (90 %).

The energy requirement in (kW.h/ton) was calculated by the following equation:

$$Energy\ consumed = \frac{P}{Q} = kW.h/ton$$

Where:

P = The consumed power to mixing ration, kW.
Q = Machinery line productivity, ton/h.

RESULTS AND DISCUSSION

1- Mixing homogeneity:

Genarelly the mixing homogeneity is greatly affected by impeller peripheral speed as shown in figure (2). It can be reported that the coefficient of variation decreased (mixing homogeneity improved) from 6.01 to 5.12 % with increasing the impeller speed from 0.78 to 1.55 m/s. Meanwhile when speed increased from 1.55 to 3.10 m/s lead to increase CV up to 15.15%. The reason was that the tendency to segregate is determined by the balance between external and interparticulate force in a mixture.

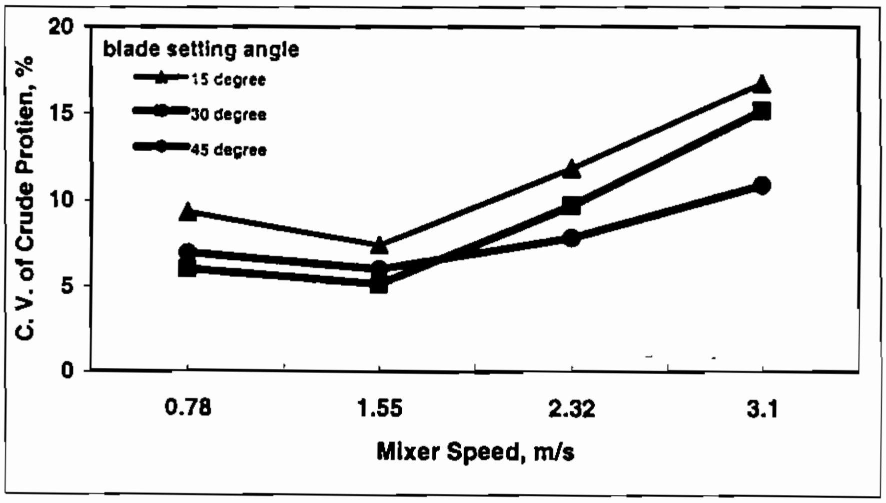

Fig. 2: Effect of impeller peripheral speed and blade setting angle on the mixing homogeneity.

External force can be characterized by an average shear rate which is positively related to the rotational speed of the impeller. Segregation occurs because of the varying response of different particles to these external force. If the external force predominate, then the powder is free flowing and the segregation potential is high and thus delay the mixing homogeneity.

From the same figure it can be indicated that the mixing homogeneity was positively related to blade setting angle. Where at low impeller speed (1.73 m/s) the lowest percentage of variation (5.12 %) was recorded at 30 degree setting angle. Also at high speed (3.47 m/s) the lowest CV (10.88 %) was obtained at setting angle of 45 degree.

The results cleared that the adequate mixing homogeneity could be achieved at 1.73 m/s impeller speed and blade setting angle as close to 30 degree as possible.

Figure (3) shows that the batch moisture content had a negatively effect on the mixing homogeneity. Where increasing moisture content from 16.06 % to 20.12 % and 24.03 % tends to increase CV from 1.2 % to 2.87 % and 5.12 %, respectively. It can be concluded that the 16.06 % moisture content gave the best mixing homogeneity among the four different impeller speeds. Because at proper humidity an adsorbed film of liquid will cause a force of attraction between particles that are in contact. Interparticulate binding forces, due to moisture, tend to prevent segregation. Meanwhile, at high humidity, large amount of liquid between the particles will result in the formation of interparticulate liquid bridges increasing the cohesion. Also moist particles can coat the wall of the mixer, will significantly increase agglomerate strength. and thus delay the mixing process (Nienow *et al.* 1985).

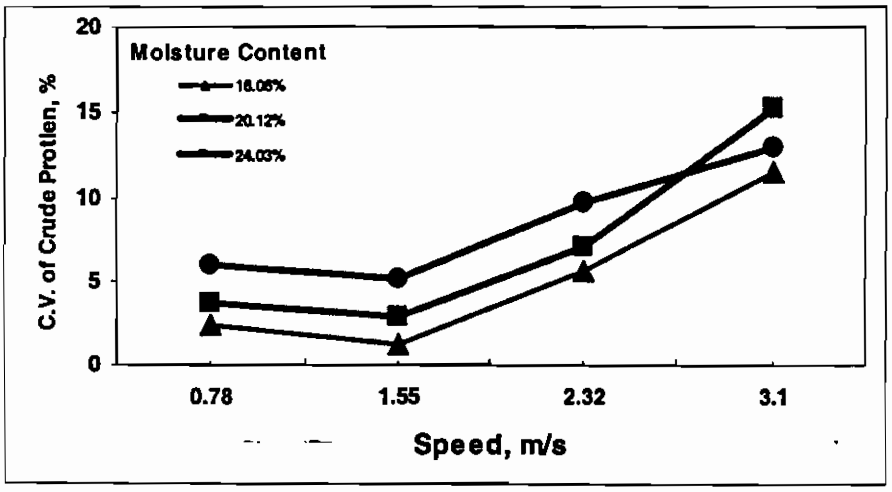

Fig. 3: Effect of impeller peripheral speed and batch moisture content on the mixing homogeneity.

Fig. (4) represents the effect of the batch volume ratio. The data indicated that at low impeller speeds (0.78 and 1.55 m/s) the batch volume ratio had significant effect on mixing homogeneity, but it had little effect at high speed (2.32 and 3.10 m/s). At 1.55 m/s impeller speed the lowest CV (5.12 %) was recorded at batch volume ratio 0.75, and increased to about 6.75 % and 9.84 % with volume ratio of 0.5 and 1.0 respectively. Meanwhile at 3.10 m/s impeller speed the CV is around 16 % for the three ratios of batch volume.

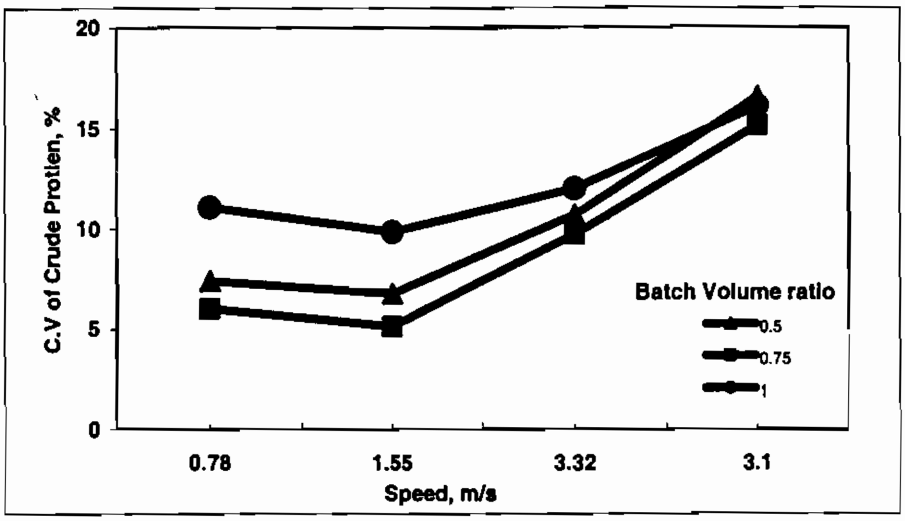

Fig. 4: Effect of impeller peripheral speed and batch volume ratio on the mixing homogeneity.

While Figure 5 illustrates that the mixer performance was affected profoundly by the mixing time. Where increasing the mixing time from 5 to 15 minutes leads to decrease the CV from 8.26 % to 3.76 %. Meanwhile above 15 minute the mixing homogeneity dropped dramatically. When the mixing time increased from 15 to 20 minute the CV increased from 3.76 % to 6.28 %. From the same figure, it can be seen that at low value of impeller speed (0.78 and 1.55 m/s), when the mixing time increased from 5 minute to 10 and 15 minute the CV decreased from 8.26 % to 6.5 % and 3.76 %, respectively. But, more 15 minutes the CV increased to 6.28 % when mixing time increased to 20 minute. Meanwhile, at high impeller speed (2.32 and 3.10 m/s), the mixing time had little effect on the mixing homogeneity. The general trend is the mixing homogeneity increased as mixing time increased. Accordingly, using 15 minute mixing time may be better in case of impeller speed of 1.55 m/s. This result is due to when mixing proceeds beyond the optimum time an ordering, rather than mixing, of the particle occurs. Force applied to powders develops strain in the materials and causes particle dilation. An initially satisfactory mixture may segregate readily and resulted insufficient mixing homogeneity.

The Reynolds number is found to be the main factor affecting the mixing homogeneity. From figure 6, it is clear that the Reynolds number had little effect on the mixer homogeneity at number range under 82.64, and had high negative effect at number range over 82.64. Where increasing the Reynolds number from 82.46 to 165.77, CV increased from 1.2 % to 11.52

%. This due to at Reynolds number under 82.64 the mixed material is in laminar flow, but over 82.64 it is in turbulent flow. Turbulent-flowing materials tend to segregate and thus delay the mixing process. Finally, we can propose that to obtain the optimum mixing homogeneity, Reynolds number should not be exceed 82.64.

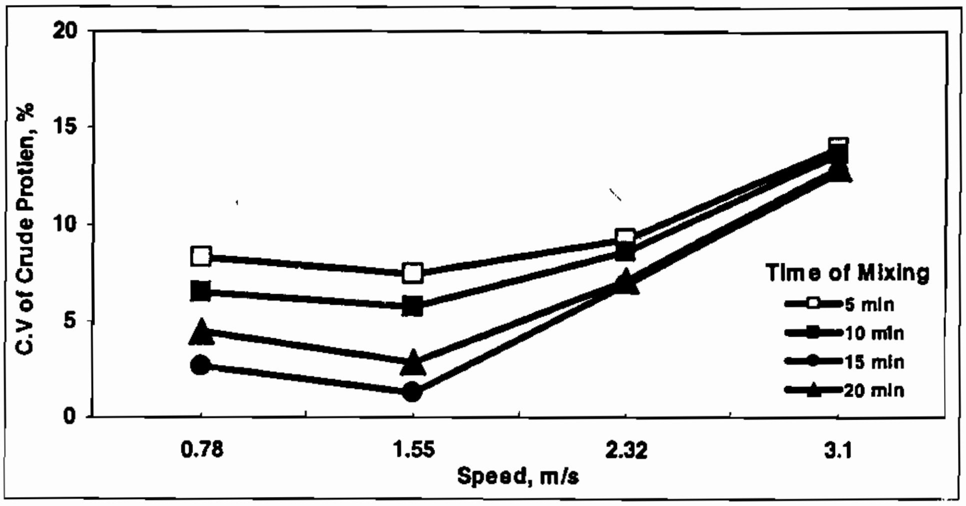

Fig. 5: Effect of impeller peripheral speed, and mixing time on the mixing homogeneity.

The analysis of variance (ANOVA) for the coefficient of variation is presented in table 2. It is clear that the coefficient of variation was highly correlated to the independent variables used. The determination factor, R^2 was found to be 0.87. The general form of the equation used in this analysis was a function of batch volume ratio (V_b/V_m), Reynolds number ($\rho vd/\mu$), blade setting angle (θ) and mixing time (gt^2/h). A model that can be used for predicting coefficient of variation (CV) was performed according to *Buckingham Pi theorem* (Clenn, 1950). Based on the experimental data, the developed model can be expressed as follows:

$$CV = 45.08\,(\rho vd/\mu)^{0.1}\,(V_b/V_m)^{0.02}\,(\theta)^{-0.063}\,(gt^2/h)^{-0.045}$$

where:

CV = coefficient of variation, %
V_b = batch volume, m^3
V_m = mixer vessel volume, m^3
ρ = feed density, (427.66 kg/m^3)
v = impeller peripheral speed, (0.86, 1.73, 2.6 and3.47 m/s)
d = vessel diameter, m
μ = feed viscosity, (7.43, 15.23, and 23.3 kg/m.s)
θ = blade setting angle, (15, 30, and 45 degree)
g = gravitational acceleration, (9.81 m/s^2)
t = mixing time, (300, 600, 900 and 1200 s)
h = bed height, m

The advantage of this model is that it can be used to generate numerous of predicted data for mixing homogeneity under the effect of many independent variables. It may be noticed from the equation the coefficient of variation (CV) was positively related to batch volume ratio (V_b/V_m) and Reynolds number ($\rho vd/\mu$). But it was negatively related to blade setting angle (θ) and mixing time (gt^2/h). Based on the experimental results, an optimum combination of independent variables can be summarized for Reynolds number, batch volume ratio, blade setting angle and mixing time as 82.64, 0.75, 30 degree and 15 minute, respectively.

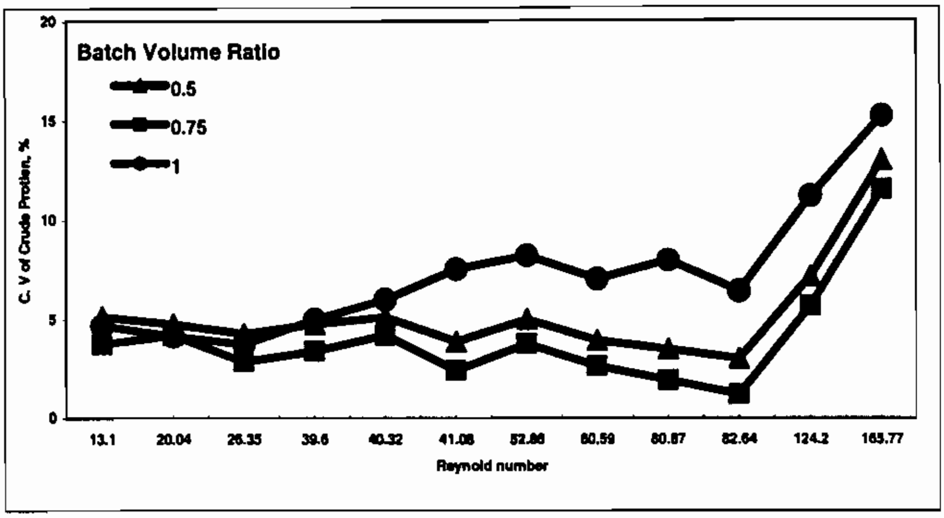

Fig. 6: Effect of Reynolds number and batch volume ratio of the mixing homogeneity.

Table 2: Analysis of variance for mixing homogeneity.

ANOVA

S.V.	df	SS	MS	F	Significance F
Regression	4	0.821	0.205	46.4744	2.02743E-32
Residual	427	1.886	0.004		
Total	431	2.708			

2- Energy requirement:

The experimental data indicated that the blade setting angle had significant effect on the mixing energy requirement. From figure 7, the energy requirement was inversely related to the setting angle. Where the energy requirement was 2.22, 2.11 and 1.98 kW.h/ton at blade setting angle of 15, 30 and 45 degree respectively. The lowest energy requirement (1.98 kW.h/ton) was accomplished with blade setting angle of 45 degree and highly increased by about 6.5 % and 12% with setting angle of 30 and 15 degree, respectively.

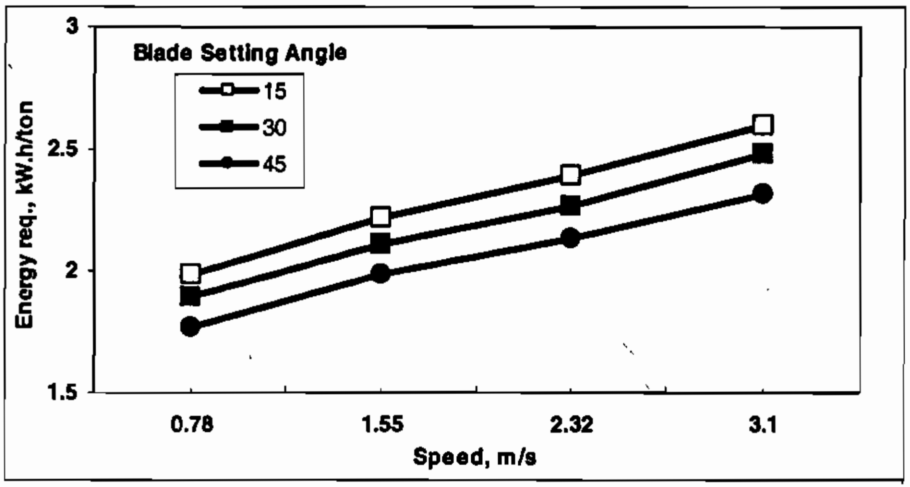

Fig. 7: Effect of impeller peripheral speed and blade setting angle on energy requirement.

From figure 8 it can be indicated that the energy requirement (kW.h/ton) was highly affected by the batch volume ratio. The energy requirement was inversely proportional to batch volume ratio. Where the lowest energy (2.13 kW.h/ton) was recorded at 1.0 volume ratio. Meanwhile the highest energy (4.18 kW.h/ton) resulted from 0.5 volume ratio. Generally when the batch volume ratio increased from 0.5 to 0.75 and 1.0 the energy requirement (kW.h/ton) decreased by about 33% and 49%, respectively. It can be concluded that, the batch volume should not be less than 0.75 of mixing vessel volume to achieve the optimum mixing efficiency and minimum energy requirement.

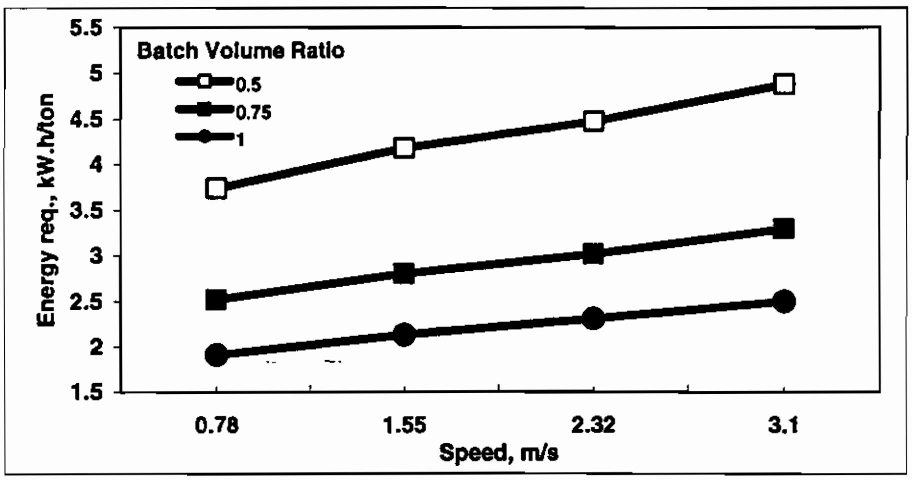

Fig. 8: Effect of impeller peripheral speed and batch volume ratio on energy requirement.

Figure 9 shows the energy requirement for different values of impeller peripheral speed and mixing time. Results clearly showed that the energy requirement highly increased by increasing impeller peripheral speed and mixing time. The energy requirement was 1.89 kW.h/ton and increased to 2.48 kW.h/ton (increased by about 31 %) when the impeller speed increased from 0.86 to 3.47 m/s. Also the same figure indicated that the mixing time had high positive effect on the energy requirement. Where the energy was 1.61, 1.89, 2.11, and 2.31 kW.h/ton when the mixing time was 5, 10, 15, 20 minute respectively. It can be concluded that the mixing energy requirement increased by about 43% when the mixing time increased from 5 to 20 minute.

Moreover, the results of mixing processes denoted that over mixing may both waste energy and be counter-productive. Also the use of speed 1.73 m/s is more beneficial because the energy requirement was decreased by about 8 % and 15 % than in case of mixing speed 2.6 m/s and 3.47 m/s respectively with increasing in mixing homogeneity. For this reason it could be concluded that the mixing unit can be used at impeller peripheral speed of 1.73 m/s, mixing time of 15 min, 16.06 % moisture content and 30 degree blade setting angle.

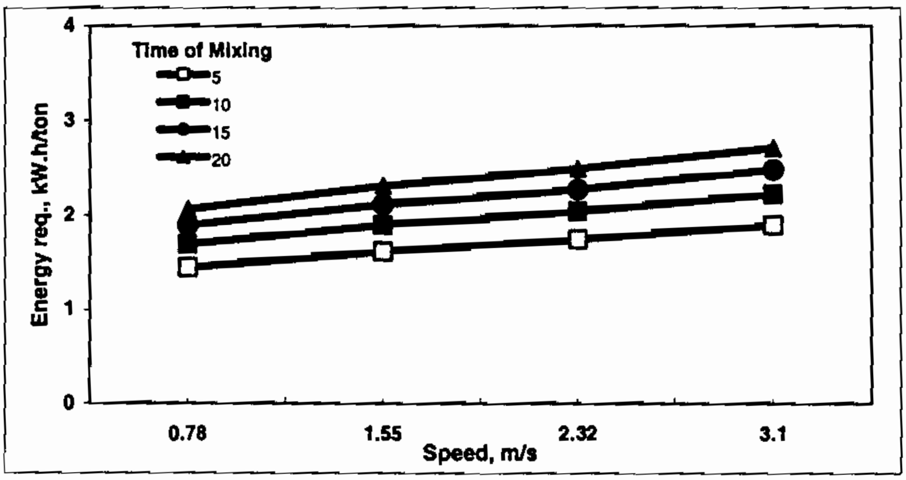

Fig. 9: Effect of impeller peripheral speed and mixing time on energy requirement.

Conclusion

The important results as mentioned in the obtained data were summarized in the following points:

1- It can be reported that the coefficient of variation decreased (mixing homogeneity improved) from 6.01 to 5.12 % with increasing the impeller speed from 0.86 to 1.73 m/s. Meanwhile when speed increased from 1.73 to 3.47 m/s lead to increase CV to 15.15%.

2- To prepare the best mixture conditions, it is recommended to keep the blade resting angle on mixing shaft in the range from 15º to 30º.

3- It can be indicated that the 16 % moisture content gave the best mixing homogeneity, where increasing moisture content from 16.06 % to 20.12 % and 24.03 % tends to increase CV from 1.2 % to 2.87 % and 5.12 %, respectively.
4- This study has shown that to achieve an adequate mixing homogeneity, vessel mixer must have a batch volume ratio (V_b/V_v) as close to 0.75 as possible.
5- When the mixing time increased from 5 to 15 minutes leads to decrease the CV from 8.26 % to 3.76 %. Meanwhile above 15 minute the mixing homogeneity dropped dramatically.
6- The lowest energy requirement (1.98 kW.h/ton) was accomplished with blade setting angle of 45 degree and highly increased by about 6.5 % and 12% with setting angle of 30 and 15 degree, respectively.
7- Results clearly showed that the energy requirement highly increased by increasing impeller peripheral speed and mixing time.
8- The mixing time has not to exceed 15 min. to avoid extra cost in energy consumption.
9- The best mixing homogeneity (CV=1.2 %) with the lowest energy requirement (2.11 kW.h/ton) by using the mixing unit with speed of 1.73 m/s, with mixing time 15 min., blade angle 30 degree, batch volume ratio 0.75 and 16.06 % moisture content.
10- As a result of test, it was concluded that the fabricated mixer met the design objectives. It is believed that this mixer, simple in design and operation, would greatly improve mixing homogeneity of feed.

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تطوير وتصنيع آلة خلط محلية لإعداد وتجهيز أعلاف الأرانب

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لاشك أننا في مصر نعاني من نقص كبير في الغذاء وذلك من حيث النوع والجودة خاصة البروتينات. وفى ظل التزايد في معدلات الاستهلاك الفردي للحوم نظرا للتغيرات في مستويات دخول الأفراد من ناحية وتغير أنماطهم الاستهلاكية من ناحية أخرى فضلا عن الزيادة المضطردة في تعداد السكان، فإن الاستهلاك المحلى للحوم يتسم بالتزايد المستمر. ولعل من أهم المشاكل التي تواجه مربي الحيوانات والطيور هو نقص العلف الحيواني. من هنا كان الاهتمام بتطوير تقنيات تجهيز الأعلاف التكميلية بهدف إنتاج غذاء حيواني جيد ورخيص الثمن. لذلك كان الهدف من هذا البحث هو:

١- تصميم وتصنيع آلة خلط محلية لأعداد وتجهيز اعلاف الأرانب.
٢- دراسة أهم العوامل الهندسية والتصميمية على الآلة المصنعة.
٣- الحصول على النموذج الرياضي بحيث يمكن أن نتنبأ بكفاة الخلاط تحت تأثير هذه العوامل.

وكانت أهم النتائج المتحصل عليها:

١- أوضحت نتائج تحليل الانحدار الخطى المتعدد ان هناك علاقة قوية بين كلا من سرعة أسلحة الخلاط ، نسبة الرطوبة ، نسبة حجم العلف إلى حجم وعاء الخلاط ، زاوية ميل الأسلحة ، وزمن الخلط حيث قدر معامل الارتباط (R^2) بحوالى ٠,٨٧٤.
٢- اظهرت النتائج التجريبية إن أفضل كفاءة خلط (CV=1.2%) بأقل طاقة مستهلكة (٢,١١كيلوات. ساعة/طن) باستخدام وحدة الخلط بسرعة ١,٧٣ م / ث ، زمن خلط ١٥ دقيقة، وزاوية سلاح الخلاط ٣٠ درجة، نسبة الرطوبة ١٦ ٪ و نسبة ملئ وعاء الخلاط بالعلف ٠,٧٥.
٣- باستخدام النتائج التجريبية أمكن الحصول على النموذج الرياضى لكفاءة الخلاط تحت تأثير العوامل التى تم دراستها خلال هذا البحث:

$$CV = 45.08\,(\rho v d/\mu)^{0.1}\,(V_b/V_m)^{0.02}\,(8)^{-0.063}\,(gt^2/h)^{-0.045}$$

٤- ثبت من التجارب إن أداء الآلة بأجزائها المصممة والمصنعة محليا كان جيدا بصفة عامة وقد حققت الهدف المطلوب ويمكن استخدمها على المستوى التطبيقي والعملي.