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Design, Fabrication and Performance Evaluation of Screw Conveyor Type of Pig feed Mixing Machine

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***Abstract*—A screw conveyor type of pig feed mixing machine was designed, fabricated, and evaluated. The machine comprises the following major components; hopper, frame, mixing chamber, Mixing bar, screw conveyor chamber, screw conveyor, shaft, Electric motor, and pulleys. The uniqueness of this screw conveyor type of pig feed mixing machine lies in the uniqueness of its design where the mixing process and the dispensing process of mixed feed were carried out in one run of operation. Some design parameters such as the capacity of the hopper, the volume of the mixing chamber, shaft diameter, the power required were calculated for. The result derived from the calculated design parameters were used for the fabrication. The performance evaluation of the machines was determined in terms of the throughput of the machine, the machine efficiency, and its ability to mix various components of the feed. The machine was tested using feed ingredients that carefully divided into four equal weight of 15 Kg of fine rice bran, 5 Kg of corn brand, 2.5 Kg of the palate, and 2.5 Kg of coarse ground corn replicated thrice at four mixing durations of 5, 10, 15 and 20 min. The performance test shown that the average mixing time of feed ingredients in the mixing chamber was 12,5 min, the average time for a batch production process was 18.750 min, the average production rate was 1.4 Kg/min, and the average machine's efficiency was 97% indicated that the mixing machine can be of tremendous usage to feed mixing. In terms of the machine ability to mix various components of feed the test revealed that the average degree of mixing in respect of the four mixing durations considered at 90,708 % attained at the average of 12.5 minutes of mixing time. The higher mixing performance for the mixing machine's was 15 minutes plus 6 minutes of conveyed time. It was revealed that the degree of mixture approach to its equilibrium level at 15 minutes of mixing time with 97.460 % degree of mixing. Therefore, further mixing time will not produce a better degree of mixing.**

Keywords—screw conveyor, mixing machine, degree of mixture

I. INTRODUCTION

Recently the pig farms in East Nusa Tenggara have a very important role in supporting the community's economy, especially in rural areas. Around 80% of rural households in this province raise pigs. The Central Bureau of Statistics of East Nusa Tenggara Province records that in 2019 Kupang regency has 418.075 pigs (19,5%) [1]. That makes Kupang Regency as the leading sector in pork producer by far. East center south regency is second with 138.014 pigs (6,6%) and Ngada Regency third with 129.231 pigs (6,2%) and followed by other regencies in this province.

The provision of feed in a livestock business is a determining factor for the success of the production process in addition to providing superior seeds, management procedures, and disease prevention. The biggest production cost for the pig farm breeders is the cost of feed, which reaches 65-80 percent of the total production cost [2]. Undisputedly, manual handling in the mixing of basic ingredients of pig feed has its associated disadvantages. For those reasons, machinery and technology intervention is needed for the purposed of mixing basic ingredients to turn into feeding the pig, make it cost-effective.

The mixing of feed in particular has an importan role in feed preparation where it is the means through which two or more ingredients were blended and mixed in such way that makes the feed capable to fulfil the nutritional requiremnets of the target live stock.

Based on the preliminary study conducted by the author in Kupang Regency of East Nusa Tenggara Province, most of medium and large scale pig breeders in this area still employ crude techniques for mixing their pig feeds, for example, some still use hand and basins to mix the feed ingredients, some also use shovels to mix the feed on open concrete floors, all of which labor-intensive and hazardous.

Edwin Hattu, et al. [3], conducted a study in designing of a mixer and transport of pig feed. Their study aimed to make a device that can mix and transport pig food directly from cooking pots to the cages which are safe distance in terms of human health. This device is quite simple but its ability is very limited making it less appropriate to be applied in a large-scale of pig breeding.

Abdul Basyir, et al. [4], conducted a study to design and fabricate a cattle feed mixer machine with a vertical circulation system using a screw conveyor. The feed ingredients were flowed vertically by the screw conveyor to the mixing tube, then the mixing blade located in the tube is rotated to blend the feed ingredients. This machine can mix animal feed ingredients with a capacity of 63 kg per batch, their design preference were planning the engine speed and driving power, planning the main components of the machine used, and finally making the draft work plan.

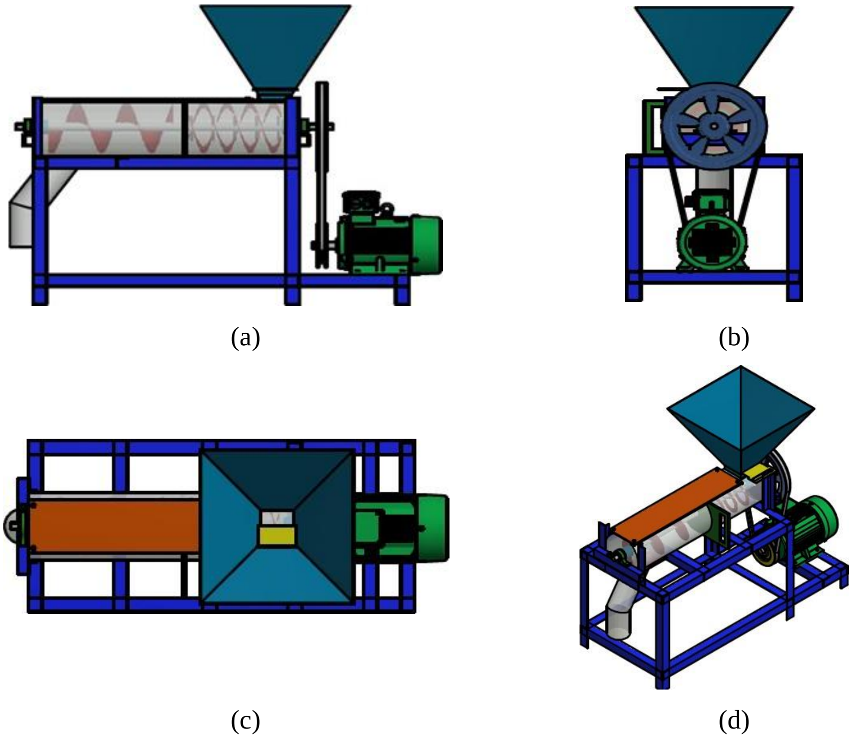

Fig. 1. Design of Machine; (a) Front View, (b) Side View), (c) Top View, (d) Perspective view.

Makange, et al. [5] tested an animal feed mixing machine using a feed component divided into 3.5 kg for maize bran, 1.25 kg for cotton/sunflower cake, 0.15 kg for lime, 0.075 kg for bone meal and 0.018 kg for salt replicated thrice at two mixing durations of 10 and 20 min. the average CV was 5.93% which shows a significant reduction in feed components for the samples tested.

II. MATERIALS AND METHODS

The following factors were put into accounts during the proces of materials selection whic is: locally available, safety, strength, reliability, stability, size and shape, power consumption, ease to maintenance, and ease of operation. The screw conveyor type of pig feed mixing machine as shown in figure 1 consisted of the following parts: hopper, frame, mixing chamber, Mixing bar, screw conveyor chamber, screw conveyor, shaft, Electric motor, and pulleysr, and discharge chute. The uniqueness of this screw conveyor type of pig feed mixing machine lies in the uniqueness of its design where the mixing process and the dispensing process of mixed feed were carried out in one run of operation.

III. DESIGN CALCULATION

A. Hopper

The volume of a truncated pyramidal shape of hopper (Vh) can be calculated by using equation (1).

$$Vh = \frac{1}{3} t \{A + B + \sqrt{A.B}\} \quad (1)$$

Where: Vh= hopper volume, t = the height of the truncated pyramid, (m), A = the areas of the parallel top (m2), B = the area of parallel botom (m2).

B. Mixing Chamber

Mixing chamber is a cylindrical shaped, the volume of the cylinder calculated by using eq. (2).

$$V = \pi r^2 L \quad (2)$$

Where: r = radius of the cylinder (m), H = Length of thecylinder (m).

C. Shaft

When the shaft is subjected to combined twisting moment and bending moment, then the shaft must be designed based on the two moments simultaneously [6]; the diameter of the shaft can be determined using eq. (3)

$$T_e = \frac{\pi}{16} x\ 60\ d^3 \quad (3)$$

Where: T_e = equivalent twisting moment (Nm), d = Diameterof the shaft (m),

- The equivalent twisting moment (T_e) is determined using eq. (4)

$$T_e = \sqrt{M^2 + T^2} \quad (4)$$

Where: M = Maximum bending moment (Nm), T = torque transmitted by the shaft (Nm), Maximum bending moment (M) is determined using eq (5).

$$M = Fs \; x \; L \tag{5}$$

Where: Fs = Force acting on the shaft (N),

- The Fs is determined using eq (6)

$$Fs = Ms \; x \; g \tag{6}$$

Where: Ms = Total mass acting on shaft (Mass of ingredient + mass of the mixing bar + Mass of the screw conveyor) (Kg), g = acceleration due to gravity (Kgm/sec2), and L = shaft lenght (m)

- Torque transmitted by the shaft (T), can be determined using eq (7)

$$T = \frac{P \; x \; 60}{2\pi N} \tag{7}$$

Where: P = Power (Watt), N = Rotating Speed (Rpm)

D. *Screw Conveyor*

Main parameters of the screw conveyor can be calculated as follows [7].

- Required Screw conveyor diameter

$$D = \sqrt[3]{\frac{4Qx1000}{60x60\pi \; x \; 0.8n\psi\gamma C}} \tag{8}$$

Where: D = Required Screw diameter (m), Q = Required capacity (Kg/Min), n = Screw rotation (Rpm), ψ = through loading efficienci (0,4 for free flowing non abrasive material), γ= bulk weight (Ton/m3), C = Inclination angle (in this case the horizontal screw comveyor C=1)

- Required capacity of the conveyor (Q)

  The capacity of the conveyor is computed uses equation (9) as

$$Q = 60.60.1000n.\phi.P.\rho(D^2 - d^2)\frac{\pi}{4} \tag{9}$$

Where: Q = Conveyor capacity (Kg/min), n = Number of screw rotation (Rpm), ϕ= factor introduced for inclined conveyor = 1, P = Conveyor Pitch (m), ρ = Bulk density of ingredients (Kg/m3) its around 607 – 780 Kg/m3 [8].

- Screw Pitch (S) = 0,7D (m) (for free flowing non abrasive material)
- Number of Pitch = Pn= L/S

  Where L = the leght of the conveyor (m)

E. *Electric Motor*

The electric motor provides power to the machine. It converts electric power to mechanical power, it provides the rotational motion and power needed to rotate the shaft through belt and pulley. The horsepower of the electric motor needed can be calculated as follow [7].

$$P = \frac{QL\omega_o}{367} \tag{10}$$

Where: P = power required (KW), Q = required capacity (1ton/hour), L = the length of the conveyor (m), ωo= 2.5 for free-flowing nonabrasive material.

F. *Power Transmission*

V belt and pulley arrangements are adopted to transmit power from the electric motor to the shaft of the mixing machine. Main parameters of the power transmission can be calculated as follows [6].

- Pulley Diameter

$$D2 = \frac{N1 \; X \; D1}{N2} \tag{11}$$

Where: D2 = diameter of the pulley connected to the shaft (mm), D1 = diameter of the pulley connected to the electric motor, N1 = speed of electric motor (Rpm), and N2 = speed of the pulley connected to the shaft (Rpm).

- Belt length

  Equation (12) can be used to determine the length of thebelt.

$$t = 2C + 1{,}257(d1 + d2) + \frac{(d1 - d2)^2}{4C} \tag{12}$$

Where: t = belt lenght (m), C = centre distance between pulley (m), d1 = pitch diameter of the pulley connected to the motor (m), d2 = pitch diameter of the pulley connected to the shaft.

- Belt Speed

  The belt speed is calculated uses eq. (13)

$$V = \frac{\pi D1N1}{60.000} \tag{13}$$

Where: V = belt speed (m/s), D1 = diameter of the pulley connected to the electric motor (m), and N1 = speed of the pulley connected to the shaft (Rpm).

IV. FABRICATION

A. *Hopper*

A hopper is a truncated pyramidal shaped where the feed ingredients is poured into, before the mixing process, the materials will go through to the mixing chamber by the use of gravity to resist flow. The hopper is made from a mild steel sheet of 1,5 mm thickness. The hopper is constructed with the following dimensions: the height of the truncated pyramid = 500mm, the areas of the parallel top (300 x 300 = 90000mm2), the area of parallel botom (150 x 150 = 22500mm2).

B. *Mixing Chamber*

The mixing chamber is a place where the mixing processof feed ingredients is carried out by the rotating shaft joined with the mixing bar. Mixing chamber is a cylindrical shaped made from galvanized pipe with inside diameter of 210 mm, and 250 mm in lenght.

C. Screw Conveyor Chamber

The screw conveyor chamber is a chamber where the mixing ingredients flowed throug to the discharge chute by the rotating screw conveyor that welded on the shaft. The conveyor chamber is a cylindrical shaped made from galvanized pipe with inside diameter of 210 mm and 750 mmin lenght. Both the mixing chamber and the screw conveyor chamber was constructed from a continued galvanized pipe that separated by the trap door.

D. Mixing Bar

The mixing bar is the part responsible for mixing the feed ingredients, the mixing bar is assembled by electric arc welding and connected to the rotating shaft. The mixing bar type is a rainbow type that allows the material to move forward to the screw conveyor section. The important thing to consider when designing a mixing bar is the flight outside diameter. Adequate clearance between the flight diameter and the mixing chamber diameter is considered in the design to avoid clogging and proper mixing of the feed ingredients.

E. Screw Conveyor

A screw conveyor consists of a shaft mounted screw rotating in a through and of the drive setting the shaft in rotary motion. As the shaft rotates, the mixed feed ingredients from the mixing chamber are moved forward by the thrust of the screw or flights. The screw conveyor is joined by electrical arc welding and connected to the rotating shaft. The screw conveyor is made fof low carbon steel sheet of 3 mm thickness.

F. Supporting Frame

A frame is a free standing structure designed to carry all components of the mixing machine. The designed frame should be support the total weight of the machine without collapse. The key prerequisite in the design of the machine frame is that it maintains the proper relatives position of the units and parts mounted on it over a long period of service condition. The designed stand frame should be to support the machine without collapse. The frame is made of low carbon steel of angle iron, 75 × 75 × 8 mm in cross section.

G. Shaft

To ensure satisfactory strength and rigidity when the shaftis transmitting power during operation and under loading condition then the shaft should be properly desegned. In this design, the solid shaft was used to support the rotating mixer bar and rotating screw conveyor and subjected to torsion and transverse or axial loads, acting in combination. The shaft made of low carbon steel rod with the maximum shear stressof 60 MPa.

V. Principal Operation of the Machine

60% of fine rice brand, 20% of corn brand, 10% of factory feed in the form of palate, and 10 % of coarse ground corn (with the average size of 2 mm) was purchase from the local market were prepared and put in a basin or a bucket. The machine is switched on by gently pushing the start button to run the electric motor. With the help of an operator, then the feed ingredients are properly fed into the machine through its hopper. The feed materials are then moved through to the mixing chamber where the feed components are blending by the rotated mixing bar that connected with the machine shaft. In a defined duration of time, the trap door located between the mixing chamber and the screw conveyor chamber is opened while the machine is still being operated to allow the materials moving through by the rotational effect of the screw conveyor and discharge the mixing materials through the discharge chute and the mixing materials are collected.

VI. Performace Evaluation

The performance evaluation is a vital step in the process of machine development. After the design, fabricated and assembling process, testing is necessary to determine the machine performance, exposed problems, and area of improvement. The targeted evaluation was the throughput of the machine, the machine efficiency, and its ability to mix various components of the feed.

The procedure of evaluation described as follows; before the mixing process is carried out, 100 Kg of ingredient that consists of 60 Kg of fine rice bran, 20 Kg of corn brand, 10 Kg of factory feed in the form of the pallate, and 10 Kg of coarse ground corn was introduced as the tracer for the purpose of testing the mixing performance. All ingredients were prepared and put in a basin or a bucket. The feed ingredients carefully divided into four equal weight of 15 Kg of fine rice bran, 5 Kg of corn brand, 2.5 Kg of pallate, and 2.5 Kg of coarse ground corn. In this test, four mixing duration of 5, 10, 15, and 20 minutes were considered for the ingredients to be mixed in the mixing room. After the desired of mixing time was achieved, then the trap door located between the mixing chamber and the conveyor chamber was opened to allow the mixture flowed through to the discharge chute pushed by the rotating conveyor. At the end of each test, then the average time per batch of mixing, the mass of mixture discharge from the chute was recorded.

An important parameter to evaluate the performance of the machine was its ability to mix various components of feed and produce homogenous feed. the test was conducted and replicated thrice according to the standard test procedure for farm batch feed mixers developed by ASAE Standard [9]. Four mixing duration of 5, 10, 15, and 20 Minutes used in this experiment. At the end of each test run ten samples of 250 g were drawn randomly from each replicated, then an easy-to-analyze component which is coarse ground corn was carefully separated and filtered from other components among the samples to be weight.

The following procedures were used for the performance test: (1). Put the first replicate in the mixing machine and operate it for 5 min. (2). Measure out of ten different samples of 250g of the homogenised mixture. (3). Separate the coarse ground corn from each sample and measure the mass of the coarse ground corn for each sample. (4). Compute the mean weight of coarse ground corn. (5). Determine the standar deviation using equation (18). (6). Determine the coefficient of variation using equation. (17). (7). Determine the percentage of mixing level using equation. (16). This procedures were repeated for 10, 15 and 20 minutes of machine operation.

A. *The Production Rate*

The production rate of the machine can be evaluated uses equation (14) as follow

$$Pr = \frac{Wo}{To} \tag{14}$$

Where: Pr = production rate (Kg/Min), Wo = weight of mixing feed discharge from the chute (Kg), To = time neededto mix and convey the feed in one batch (Minute)

B. *Machine Efficiency*

The efficiency of the machine can be evaluated uses equation (15)

$$\epsilon = \frac{TWo\ (Kg)}{TWi\ (Kg)} x100 \tag{15}$$

Whwre: c = machine efficiency (%), Twi = total weight of ingredients fed in to the hopper (Kg), and Two = total weightof mixing feed discraege from the cute (Kg).

C. *Percentage of Mixing level*

The percentage of mixing level obtained by using equation (16), (17), and (18) developed by ASAE Standards, (ASAE S380 DEC1975, R2007), as described folow:

$$\%DM = (1 - cv)\ x\ 100 \tag{16}$$

$$CV = \frac{S}{x} \tag{17}$$

$$S = \sqrt{\frac{\Sigma(X-x)^2}{n-1}} \tag{18}$$

Where: %DM = percentation of mixing level, CV = coevisient of variability, S = standard deviation, X = weight of coarse ground corn in the samples, x = mean value of coarse groud corn in the samples, and n = number of samples.

VII. Results

The result obtained from designed calculation are shown in table 1. All calculation derived from the equation 1 to 13 as explained in the design calculation section.

TABLE I. DESIGNED CALCULATION RESULT

S/N	Design Parameters	Value Obtained	Unit
1	Hopper Volume	0.110	m^3
2	Maximum weight of feed components fill in hopper	71.71	Kg
2	Mixing Chamber Volume	0.0865	m^3
3	Screw chamber volume	2.596	m^3
4	Diameter Of Shaft	25	Mm
5	Required conveyor capacity (theoriticly)	41897	Kg/Hour
6	Screw Conveyor Diamater	200	mm
7	Screw Pitch	100	mm
8	Drive Pulley Diameter	100	mm
9	Driven Pulley Diameter	280	mm
10	Belt Length	610	mm
11	Power required to operate the machine	1342.26~ 1491.4	Watt

Parts of the screw conveyor type of pig feed mixing machine were fabricated and assembled ready for the performance test. The performance test was conducted base on the procedures explained in the performance evaluation section. The targeted performance test value calculated using equations 15 and 19 as described above. The test results are shown in Table II to Table VI.

Table II gives the result of production rates and machine efficiency calculated from the performance test.

TABLE II. PRODUCTION RATES AND MACHINE EFFICIENCY

S/N	Total Mass Fed in to the hopper (Kg)	Mixing Time in the mixing chamb er (Min)[a]	Time takes to discharge (Min)[b]	Total Mass Discharge fromThe Chute (Kg)	Produc tion rate (Kg/Min)	Machine efficiency (%)
1	25	5	12	23.500	1.958	94.000
2	25	10	16	24.500	1.531	98.000
3	25	15	21	24.500	1.167	98.000
4	25	20	26	24.500	0.942	98.000
Σ	100	50,000	75,000	97.000	5.599	388,000
Avg	25	12.500	18.750	24.250	1.400	97.000

[a] Time for the ingredients to mix in the mixing room

[b] the entire time needed one bath mixing process (Time takes to discharge)

Table III. to Table VI. gives the computed result of the performance test that showed the average weight of coarse ground corn recovered from each of the samples, the coefficients of variation, and the degree of mixing for the mixing period of 5, 10, 15, 20 min successively in respect of the three replicated tests.

TABLE III. MIXING MACHINE'S PERFORMANCE IN 5 MINUTES OFMIXING TIME

Replicate	Mean Weight of Coarse GroundCorn (g)	Coevicient of Variation	Degree of Mixing (%)
1	13.900	0.232	76.762
2	15.350	0.245	75.477
3	13.400	0.212	78.761
Σ	42.650	0.690	231.000
Avg	14.217	0.230	77.000

TABLE IV. MIXING MACHINE'S PERFORMANCE IN 10 MINUTES OF MIXING TIME

Replicate	Mean Weight of Coarse GroundCorn (g)	Coevicient of Variation	Degree of Mixing (%)
1	17.400	0.071	92.858
2	18.200	0.095	90.466
3	19.250	0.106	89.378
Σ	54.850	0.273	272.702
Avg	18.283	0.091	90.901

TABLE V. MIXING MACHINE'S PERFORMANCE IN 15 MINUTES OF MIXING TIME

Replicate	Mean Weight of Coarse GroundCorn (g)	Coevicient of Variation	Degree of Mixing (%)
1	24.850	0.021	97.869
2	24.650	0.035	96.546
3	24.450	0.020	97.966
Σ	73.950	0.076	292.381
Avg	24.650	0.025	97.460

TABLE VI. MIXING MACHINE'S PERFORMANCE IN 20 MINUTES OF MIXING TIME

Replicate	Mean Weight of Coarse GroundCorn (g)	Coevicient of Variation	Degree of Mixing (%)
1	24.300	0.024	97.585
2	24.450	0.028	97.198
3	24.700	0.026	97.439
Σ	73.450	0.078	292.222
Avg	24.483	0.026	97.407

Table VII gives the summary result for the mixing machine performance.

TABLE VII. SUMMARY RESULT FOR THE MIXING MACHINE'S PERFORMANCE

Mixing duration (min)		Replicates/ Coeeficient of Variatio, (CV)			Average CV	Degre of Mixing
		1	*2*	*3*		
	5	0.232	0.245	0.212	0.230	77.033
	10	0.071	0.095	0.106	0.091	90.933
	15	0.021	0.035	0.02	0.025	97.467
	20	0.024	0.028	0.026	0.026	97.400
Σ	50	0.348	0.403	0.364	0.372	62.833
Avg	12,5	0.087	0.101	0.091	0.093	90.708

VIII. OBSERVATION AND DISCUSSION

The result of the production rate and the machine's efficiency is shown in Table II. It was observed that the average mixing time in the mixing chamber was 12,5 min, the average time for a batch production process was 18,750 min, the average production rate was 1,4 Kg/min, and the average machine's efficiency was 97 %.

The production rate was found higher (1,958 Kg/min) for the 12 minutes of one batch operation time, and decreased to be 1,531 Kg/min, 1,167 Kg/min, and 0,942 with a corresponding mixing time of 16 min, 21 min, and 26 min. The result further indicated that the production rate decreased with the increase of mixing time of ingredients in the mixing room, while the time needed for one batch operation had no significant effect on the production rate.

The machine's efficiency was counted to be lower (94 %) at 5 minutes of mixing time. Along with the increase of mixing time of 10 min, 15 min, and 20 min the efficiency is pagged at 98%. It is observed that the total mass of mixing feed discharge from the discharge chute was stood at 24.5 Kg. Results from the test carried out experienced that some feed ingredients are remain to stay in the mixing chamber due to the mixing bar was not able to push all the mixing feed into the conveyor chamber. This experiences resulted from the clearance between the mixing chamber, the diameter of the mixing bar, and the diameter of the screw conveyor were large.

Table III shows the average weight of coarse ground corn recovered from the samples drawn from the mass of mixed ingredients was 14.217 g with the average coefficient of variability (CV) of 0,230 in 5 minutes of mixing time. The result showed that variation in the composition of ingredients among samples tested ranges from 0,212 to 0,232 with an average CV of 0,230, thus the average degree of mixing achieved is 77.00%.

Table IV. presents the mixer's performance in 10 minutes of mixing time, it shows that the degree of mixer rose from 77.000% in Table III to 90.901% in Table IV due to an increase of mixing time that doubled from 5 min to 10 min. This describes that in a mixing operation, non-uniformity among components in the mixture decreases with the time of mixing until equilibrium mixing is attained.

Table V. gives the performance test of the machine during a mixing duration of 15 min. From the table, the average degree of mixing was 97,460%, the computed average coefficient of variations at 0,025, and the average weight of coarse ground corn at 24,650 g. Due to the increase of mixing time from 10 minutes to 15 minutes, the degree of the mixer also rose from 90,901% to 97,460% which portrays an impressive improvement of about 6,555% reduction in non- uniformity of ingredients among samples. This result further indicates the degree of mixture approach to its equilibrium level that increases from 77 % at 5 minutes increase by 14 % at 10 minutes and by 6,555 % in 15 minutes.

Table VI. presents the performance of the machine during a mixing time of 20 minutes. Compares to the result obtained during the mixing time of 15 minutes it shows that only small differences of 0,053 % in the level of mixing degree. This result indicated that after the equilibrium of mixing time is achieved, further mixing time will not increase the degree of mixing.

The summary result for the mixing machine's performance is shown in Table VII. This table indicated that the average degree of mixing in respect of the four mixing duration considered at 90,708% attained at the average of 12,5 minutes of mixing time. The result further indicated that the higher mixing performance for the mixing machine's was 15 minutes plus 6 minutes of conveyed time.

IX. Conclusion

This study was conducted to design, fabricated, and performance evaluation of the screw conveyor-type of pig feed mixing machine. Base on the designed parameters, and the experimental findings it can be concluded that :

- The machine comprises of the following major components; hopper, machine frame, mixing chamber, Mixing bar, screw conveyor chamber, trap door, screw conveyor, shaft, Electric motor, discharge chute, and machine frame. Some design parameters such as capacity of the hopper, the volume of the mixing chamber, shaft diameter, the power required, etc. were calculated for
- The average mixing time of feed ingredients in the mixing chamber was 12,5 min, the average time for a batch production process was 18,750 min, the average production rate was 1,4 Kg/min, and the average machine's efficiency was 97 %. indicated that the mixing machine can be of tremendous usage to feed mixing.
- In a mixing operation, non-uniformity among components in the mixture decreases with the time of mixing until equilibrium mixing is attained. It was revealed that the degree of mixture approach to its equilibrium level at 15 minutes of mixing time with 97,460 % degree of mixing.Further mixing time will not produce a better degree of mixing.

X. Recommendation

Based on the experimental results, the following recommendations are made:

- The use of a conveyor system may be considered for use as this will ease delivery of materials out from the mixer chamber
- Further research should be carried out to determine the effect of shaft rotation on the performance of the machine's.
- To maximize the production rate of the machine, then the machine must be operated in full mixer chamber capacity, hence in this experiments the samples of 25 Kg of the feed ingredients only two-third of the mixing chamber capacity filled.

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