Original Research Article

DESIGN, FABRICATION AND PERFORMANCE EVALUATION OF INDIGENOUS FISH FEED PELLETIZING MACHINE FOR LOW INCOME FARMERS IN NIGERIA.

ABSTRACT

The design, fabrication and performance evaluation of a fish feed pelletizing machine for low income farmers was carried out with the view to encourage local technology, as most of the fish feed pelletizing machines available are imported. The fish feed pelletizer is powered by an electric motor and it works by the rotation of a screw auger which propels the feed mix through a die. The screw auger is enclosed in the auger casing and is propelled by an electric motor with the aid of belt and pulleys. This auger is fed through a hopper, which is able to hold a large quantity of the feed mix at a time. The machine was tested using different die diameters of 2mm, 4mm and 6mm. The test was conducted at different moisture content of 10%, 15%, 20%, 25%, 30% and 35% wet basis.The machine test results showedthat the pelletizing efficiency increases as moisture content and die diameter increase. The machine throughput also increases with both moisture content and die diameter. Highest efficiency of 98% was obtained when the moisture content was maintained at 25% wet basis and the feed materials were made to pass through 6mm die diameter. The total cost of the design and construction of this pelletizing machine was one hundred and five thousand naira (N105, 000.00) which is still reasonably affordable by small scale famers.

Key words: Design, fabrication, performance evaluation,fish feed, locally made, pelletizing machine.

1.0 INTRODUCTION

In Africa, fish is a significant source of animal protein accounting for up to 80% of daily animal protein intake (FAO, 2007). Fish is an important part of the household diet in Nigeria which is the most populous nation in Africa. Fish makes up around 40% of the country's protein intake, with fish consumption at 13.3 kg/person/per year. Total fish production per year is more than 1 million metric tons (313,231 metric tons from aquaculture and 759,828 metric tons from fisheries). The majority of this fish is consumed domestically, while around 10% is exported (World Fish, 2015).

The supply of fish in Africa is in crisis, the sub-Saharan African (SSA) region is the only region of the world where there is either no notable increase in per capita supply is declining and the apparent per capita fish consumption is the lowest in the world (World Fish Centre, 2005).A report by Daily Trust (2018), stated that Nigerian fish production dropped in 2017. This was attributed to high cost of fish feeds, poor market, non-access to credit facilities, aquatic pests and diseases, among others. High cost of fish feeds happens to be the major setback to production of fish in Nigeria. Due to devaluation of naira by Nigerian government in 2016, in the last two years, fish farmers have shown more preference for locally produced fish feed as they can no longer afford to buy imported feed.Studies have shown that, the challenges in making fish feeds in Nigeria are not in sourcing the ingredient but on the techniques involved in formulation and processing (Anyadike et al 2014).There are two types of pellet making machines that are known universally. These are the disc-die type, and ring die type, (Kaankuka and Osu, 2013). Asians and Europeans have produced pelletizing machines of these types. Most fish feed pelletizing machines imported from Europe and America, process fish feeds by extrusion and these feeds exhibit floating characteristics. The downside is that the machines are not affordable by low income aquaculture farmers. Local production of fish feed is very crucial to the development and sustainability of aquaculture in Africa especially, in the rural areas. For aquaculture to thrive and to bridge the already existing wide gap between fish demand and supply, the vital role of locally produced fish feed in reducing production cost, thereby making fish far attractive to both private and commercial investors and ultimately boost fish production cannot be overemphasized. In other to meet the demand for fish in the market, there is need to increase the production of fish in the market. Considering the low production by the Fish farmers, this has been traced to the inadequate fish feed which is caused by the high cost of importing fish feed and fish feed making machine in the market. Hence there is need to improvise a domestic locally fabricated machine which will help meet up with the demand of fish feed in the production of fish for adequate protein in the food chain. Technological advanced pelletizing machine imported from Europe and America are too expensive and complex to operate by small and medium scale fish and livestock farmers in

Nigeria. Therefore, it is necessary to design and fabricate a pelletizer that is durable, affordable and safe to operate. Also, it is essential to have a locally made fish feed pelletizing machine which is durable and affordable to small and medium scale fish and livestock farmers in the country in order to reduce the burden of high cost of imported pelletizing machine.

Therefore,this paper is majorly about the design,construction and performance evaluation of locally fabricated fish feed pelletizing machine to produced fish feed in enhancing the development, growth and expansion of aquaculture in Africa.

LITERATURE REVIEW

A 113.1kg/h fish meal pellet processing machine which produced 4mm diameter pellet, with an average length of 6mm was designed and fabricated. Design values of 210 was used for the maxi-mum angle that the hopper wall formed with the vertical in the discharge zone, a critical stress of 1.3kPa of the ground particulate materials, and a density of 2.4521kg/m3 of theparticulate materials, were used to obtain a hopper smallest outlet diameter of 12.7cm with a capacity of 24,118cmwhich proved efficient for the pelletizing machine. Two 3-cm diameter shafts carried the speed reduction gears with the perforated disc attached to the roller cutters on one end, while at the other end a 5hp motor was connected to the speed reduction gear by pulleys with diameters of 6cm and 12cm respectively. The speed reduction was 1:5 over a motor speed of 2000rpm. The fish meal pelletizing machine utilized 4kg of ingredients to produce 3.77kg pellets at an efficiency of 94.2%. The percentage loss due to unprocessed ground particulate materials was 5.8%. The moisture content of the fish meal pellets after 7days of drying in open air was 26.5% (wet basis). When tested for floatation, the pellets stayed afloat for 9days, while the un-dried pellets only remained afloat for 2days. A combination of the weight of the twin roller cutters and the addition of some starch to the ground particulate materials assisted the compacting and gelatinization of pellet formed. This machine will be useful to medium and small scale aquaculture farmers and also reduce the need for foreign sources of fish meal in the aquaculture industry, thus conserving foreign exchange (Olusegun et al, 2017).

2.0 DESCRIPTION AND DESIGN OF THE MACHINE

2.1 Machine Description

The fish feed pelletizing machine comprises of some basic components like the hopper through which the feed meal is fed into the machine. The pelletizing chamber consists of auger or screw which propels the fish feeds towards the orifice.The fish feed pelletizing machine is powered by 5hp electric motor.The discharge output pellets are formed by compacting and forcing the fish feed through a die. The die has opening orifices through which the fish feed comes out in pellet form.Three different dies of orifice diameters of 2mm, 4mm and 6mm were produced for the machine. The orthographic drawing is presented in Figure 1(a) and 1(b) below:

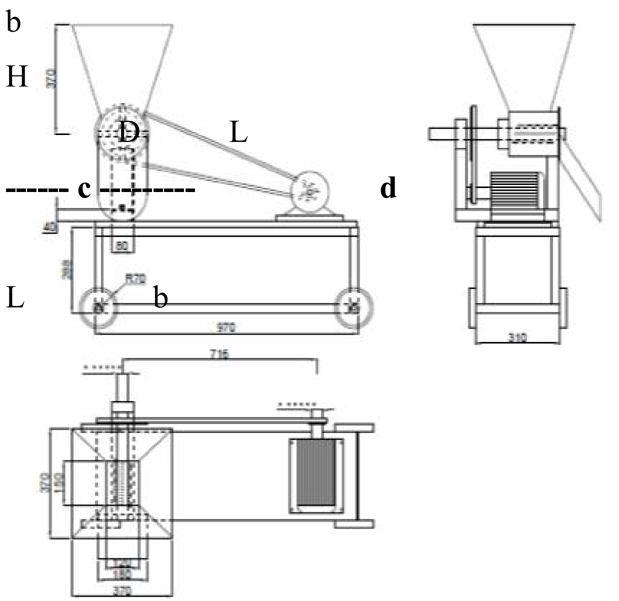


Fig 1(a): Orthographic drawing of the machine

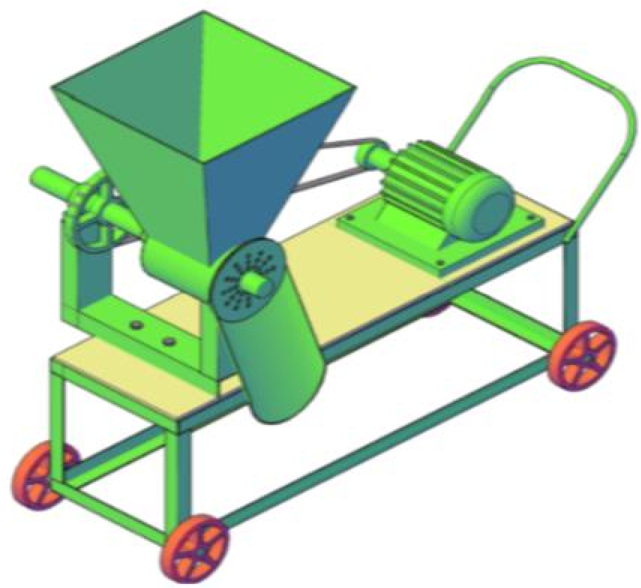


Fig. 1(b) Isometric drawing of the machine

2.2 Design Considerations and Calculations

In designing the machine, cost, corrosion, durability, overall weight and size were considered.Stainless steel was used for all parts of the machine making contact with fish feed in order to make it durable and to avoid corrosion; while the frame and other components were made with mild steel. The machine components are detachable in order to make it portable. The summary of design consideration and calculations is shown below**:**

Cost

The design of the fish pelletizing machine is aimed at using cheap and affordable materials for cost reduction and affordability of the pelletizing machine. Stainless steel and mild steel were the preferred choice of materials used.

Resilience

The component parts used posed the resilience properties to absorb energy, resist shock and impact loads. These properties were considered based on the ability of the pelletizing machine to resist any external shock or load.

Durability

The component parts selected are strong and durable with corrosion resistance and longer life span in order to give the users the expected satisfactions with profitable potentials of the fish pelletizing machine.

Hopper Capacity

This is made of mild steel plate of 2mm thick. It is the container in which the substrates (i.e. the materials to be pelletized) are fed through.

Industrial Bearing

Two industrial bearings were placed in position with bolts and nuts on three points of the shaft. The bearings were enclosed in the bearing house through which they are bolted to the bearing seat of the pelletizing chamber.

Screw Design

The degree of intermeshing is determined by the shaft center line and the desired screw distance with zero clearance fully intermeshing. The design of the screw is to compromise between power and the available volume of materials for convey.

Screw Speed: The degree of barrel fill has a direct effect on the screw speed, and the shear stress on the material to be pelletized. The screw speed is a factor for the determination of maximum volumetric output of the pelletizing machine and it is one of the main reasons why many manufacturers design machine to run at the maximum speed with mechanical tolerance usually 1400-1500rpm.

Die Design: The die area of a pelletizing machine is the section where the pelletizing of the materials occurs after the feed materials leave the pelletizing screw. It consists of transition, distribution and dies plate.

Table 1: Material selection.

S/N	MACHINE COMPONENTS	MATERIALS	FACTOR	REASON FOR SELECTION
1	Hopper	Mild Steel	Rigidity	Cheap, Available, Reliable and Durable
2	Support base	Mild Steel	Strength	Strong, Cheap,

3	Pulley	Mild Steel	Strong and Tough	Available Strong and not easily defected
4	Shaft	Stainless rod	Hard and Tough	Corrosion resistance, Strong, Availability and not easily deflected
5	Auger	Stainless Steel	Strong and ability to withstand impact stress	Corrosion resistance and Strength
6	Concave Drum	Stainless Steel	Hard and Tough	Very strong and Corrosion Resistance

Design Calculations

Hopper

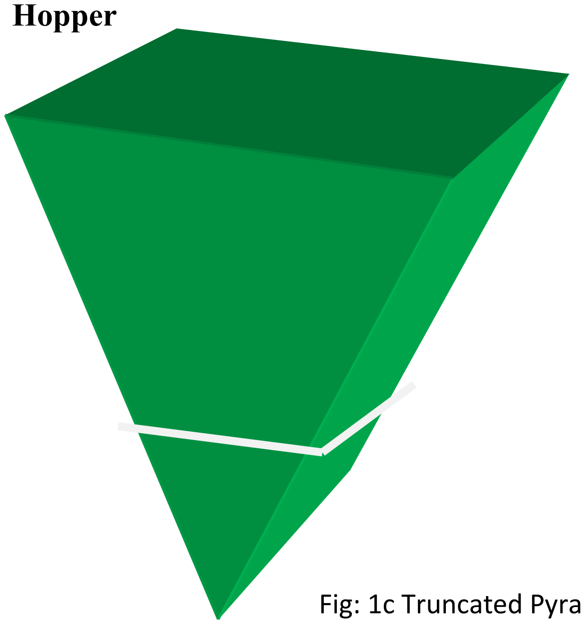


Fig: 1c Truncated Pyramid

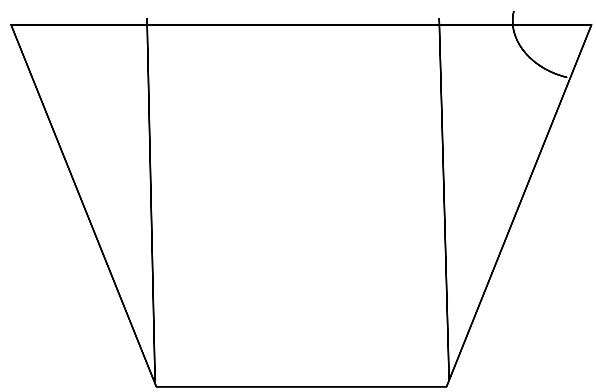


Fig: 1d

AB = 360mm

BC = 380mm

h = 350mm

FG = 135mm

$EF = 120mm$

The upper length AB of the hopper was calculated as;

$/FG/: /AB/ = 1: 3$

$1:3 = 120 \times AB$

$= 120 \times 3$

$= 360mm$

The height h, between the upper and the lower face of the hopper is calculated as;

$Tan\ 68^0 = h/120$ ……………………………………..….in fig. (Aii)

$h = 120 \times Tan\ 68^0$

$h = 297.010mm$

$h = 300mm$

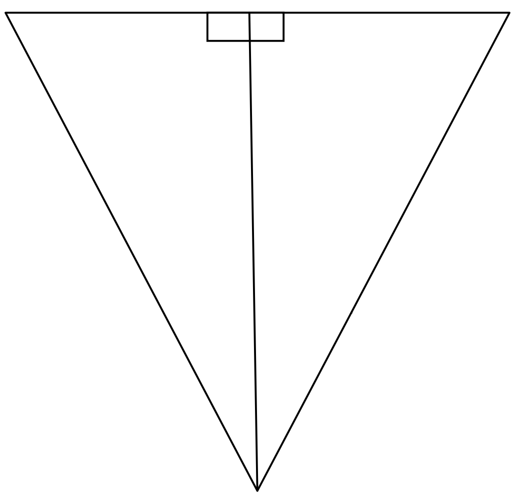


Fig. (1e) Section of hopper plate

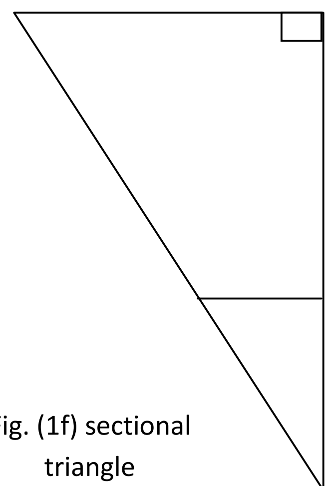


Fig. (1f) sectional triangle

$H = h + H^1$

$H = 300 + H^1$

$FJ /DI = H^1/h + H^1$

$60/180 = H^1/300 + H^1$

$H^1(180) = 60\ (300 + H^1)$

$180H^1 - 60H^1 = 1800$

$H^1 = 18\text{-}00/ 120$

$H^1 = 150mm$

Therefore total height, H = (300 + 150) mm

H = 4

Volume of hopper = Volume of larger pyramid – Volume of smaller pyramid

Volume of hopper = 1/3 base area × height

$= 1/3\ a^{2\ H} – 1/3\ b^2H^1$ …………………………………… (1)

$= 1/3\ (a^2H – b^2H^1)$

$= 1/3\ (360^2 × 450) – (120^2 × 150)$

= 19440000 – 720000

$= 18720000mm^3$

$= 18720000mm^3$

$= 18.720000cm^3$

$= 0.01872m^3$

Determination of the Driven Pulley Diameter

The diameter of motor is 65mm = 6.5cm and the motor speed for electric motor is 1400rpm (Ogunleru and Olabiyi; 2006)

Assuming the machine works averagely between 45% to 50% efficiency, the machine speed will be 650rpm (Khurmi and Gupta, 2004).

Machine pulley diameter, D_2 =?

Motor Pulley diameter, D_1 = 6.5cm

Electric motor Speed, N_1 = 1400 rpm

Machine speed, N_2 = 650rpm

Therefore;

$N_1D_1 = N_2D_2$………………………………… (2)

$$D_2 = (N_1 D_1) / N_2$$

$$= (1400 \times 6.5) / 650$$

$$= 9100 / 650$$

$$D_2 = 14\text{cm}$$

Transmission ratio is given as D_2/ D_1, (Khurmi and Gupta, 2004).

$$D_2/ D_1 = 14/ 6.5$$

$$= 2.15$$

Therefore the transmission ration is calculated as;

1: 2.15

Determination of Belt Length

In determining the length of belt, the relation is given as;

$$L = 2C + 1.57\,(D + d) + \frac{(D + d)^2}{4C} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where;

L = length of belt

C = centre distance between two pulleys

D = Larger pulley diameter

d = smaller puller diameter

For standard belt, Centre distance is given as 59cm = 590mm.

D = 14cm, previously calculated

d = 6.5cm, assumed

$$L = 2(59 + 1.57\,(14 + 6.5) + \frac{(14+6.5)^2}{4(59)}$$

$$L = 118 + 32.185 + \frac{56.25}{236} = 118 + 32.185 + 0.2383$$

$$= 150.42 \text{ cm}$$

$$= 150.42 \times 10^{-2}\text{m}$$

Determination of Belt Speed

Belt speed is represented by;

$$V = \frac{\pi DN}{60} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

Where;

V = speed of belt (m/s)

D = diameter of the smaller pulley (6.5cm = 6.5 × 10^{-2}); assumed.

N = number of revolution per minute

(Assuming the machine is to be operated at 90% maximum speed)

Actual speed will be = $1400 \times \frac{90}{100}$

= 1260rpm

Belt Speed; $V = \frac{\pi DN}{60}$

$$V = \frac{3.142 \times 6.5 \times 1260}{60}$$

$$= 10^{-2} \times \frac{25732}{60}$$

$$= \frac{257.33}{60}$$

= 4.29m/s

Determination of Belt Tension

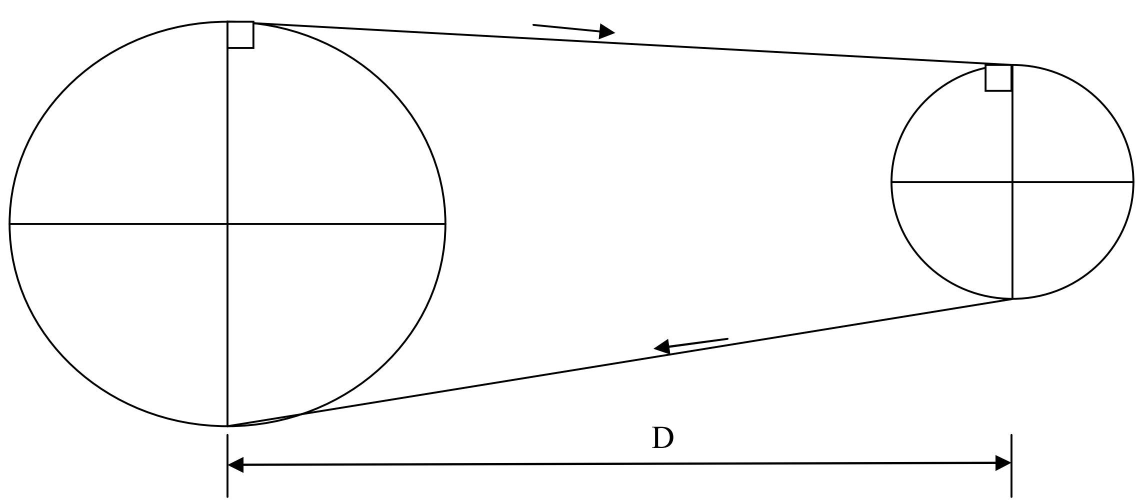


Fig (b) the belt on the drive and driven pulley.

Where,

T_1 = Belt tension on the tight side

T_2 = Belt tension on the slack side

ß = Angle of inclination of the belt

ϖß = Angle of wrap on the bigger pulley

ϖS = Angle of wrap on the smaller pulley

$$\text{Sin } ß = \frac{R-r}{C} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where,

C = Centre distance

R = Radius of bigger pulley

$$ϖS = 180^0 - 2\text{Sin}^{-1}\left(\frac{R-r}{C}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

$$ϖß = 180^0 + 2\text{Sin}^{-1}\left(\frac{R-r}{C}\right)$$ (Khurmi and Gupta, 2004)

$$ϖS = 180^0 - 2\text{Sin}^{-1}\left(\frac{70-32.5}{590}\right)$$

$= 180 – 7.3$

$= 172.7^0$

$= 3.01$ rad

$$ϖß = 180^0 + 2\text{Sin}^{-1}\left(\frac{70-32.5}{590}\right)$$

$= 180 + 7.3^0$

$= 187.3^0$

$= 3.27$ rad

For smaller pulley,

Since ϖS = 3.01 rad

Groove angle ‘θ’ = 35^0 for V-belt

Coefficient of friction 'μ' = 0.15

$$= \frac{\ell \times \mu \times \omega}{\frac{1}{2}\mathrm{Sin}\,\theta} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

$$= \frac{\ell \times 0.15 \times 3.01}{\frac{1}{2}\mathrm{Sin}\,35}$$

$\ell^{0.15} = 4.49$

For larger pulley,

Since ωß = 3.27 rad

Groove angle 'θ' = 35^0 for V-belt

Coefficient of friction 'μ' = 0.25

$$= \frac{\ell \times \mu \times \omega}{\frac{1}{2}\mathrm{Sin}\,\theta}$$

$$= \frac{\ell \times 0.25 \times 3.27}{\frac{1}{2}\mathrm{Sin}\,35}$$

$\ell^{0.25} = 15.16$

The pulley that governs the design is the one with smallest angle of wrap (Khurmi and Gupta, 2004).

$$\frac{W2}{W1} = \frac{h}{h+t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

Where,

W_1 = Nominal top width of the belt

W_2 = Nominal bottom width of the belt

t = Nominal height (thickness)

Groove angle = 35^0 as earlier stated

For standard V-belt,

W_1 = 3.125cm

Thickness = 1.875cm (assumed)

h = 1.5625 × 1/ (tan 17.5)

= 4.96cm

From equation (8), $\frac{W2}{W1} = \frac{h}{h+t}$

$W_2 = W_1h\ (h + t)$

$= 3.125 \times 4.96 / (4.96 + 1.875)$

$= 15.488 / 6.831$

$= 2.27$ cm

Area of the belt = width of the belt × thickness of the best

$= 3.125 + 2.27 / (2\times 1.875)$

$= 5.06cm^2$

$= 5.06 \times 10^{-4}\ m^2$

Density of rubber belt is 1250 Kg/m^3 (Esho, 2002)

Mass of belt = Density × Area × Length

$= 1250 \times 5.06 \times 10^{-4} \times 150.42 \times 10^{-2}$

= 0.95 Kg

Belt tension can now be determined by using,

$$T_1 = \frac{MV2}{MV2} - \frac{\ell\mu\omega}{\sin\theta/2} \ldots\ldots\ldots\ldots\ldots\ldots (9).$$

Where,

μ=coefficient of friction = 0.15

ωs=3.01rad

Mass per unit length $=1250x5.055x10^{-4}$

=0.63188kg/m

V= belt speed

= 4.29m/s

θ= angle of groove

$= 35^0$

T_1= tension on the tight side of the belt (N)

T_2= tension on the slack side of the belt (N)

Mass of belt per meter = Density x Area

$= 1250 \times 5.055 \times 10^{-4}$

= 0.63188kg/m

$T_1 - \frac{MV2}{T2} - MV^2 \quad = \frac{\ell\mu\omega}{\sin\theta/2}$ …………………………….. (9)

Recall

$T_1 - \frac{0.63188 \times (4.29)\ 2}{T\ 2} - 0.63188 \times (4.29)^2$

$= \frac{\ell 0.15 \times 3.01}{\sin 1/2\ (35)}$

$T_1 - \frac{11.63}{T2} - 11.3 \quad = 4.49$

$4.49(T_2 - 11.3) = T_1 - 11.63$

$4.49(T_2 - 11.3) + 11.63 = T_1$

$4.49T_2 - 52.22 + 11.63 = T_1$ …………………………………… (i)

Note, Power transmitted by motor, P is given as

$P = (T_1 - T_2)\ V$ ……………………………………… (10)

For 5.5hp motor power transmitted will be 4.29kw

Since 1hp = 745.699872w

1hp = 0.74569kw

5.5hp = (0.74569 x 5.5) kW

= 4.29

$4.29 = (T_1 - T_2)4.29$

$(4.29 \times 1000)\ w = (T_1 - T_2)4.29$

$4290 = (T_1 - T_2)4.29$

$(T_1 - T_2) = 4290/4.29$

$T_1 - T_2 = 1000$

$T_1 = 1000 + T_2$ …………………………………. (ii)

Putting Equation (ii) in (i) above

$4.49T_2 – 52.22 + 11.63 = 1000\ T_2$

$4.49T_2 – 40.59 \quad = 1000 + T_2$

$4.49T_2 – T_2 – 40.59 \quad = 1000$

$3.49T_2 – 40.59 \quad = 1000$

$3.49T_2 \quad = 1000 + 40.59$

$= 1040.59$

$$T_2 = \frac{1040.59}{3.49}$$

$T_2 \quad = 298.16N$

From equation (ii)

$T_1 \quad = 1000 + T_2$

$= 1000 + 298.16$

$= 1298.16N$

Resultant belt tension; $T_1 + T_2$

$= 1298.16 + 298.16$

$= 1,596.32N$

The resultant torque T, is given as

$$T = (T_1 – T_2)\ r_p$$

Where r_p is the radius of the bigger pulley (m)

$$T = (1298.16 + 298.16)\ 7 \times 10^{-2}$$

$$T = (1298.16 + 298.16)\ 0.07$$

$$T = 36.7\ Nm$$

3.3.6 Determination of the Pulley Weight

Radius of the driven pulley,

$r = 7cm$

$= 7 \times 10^{-2}m$

Density of the mild steel, ℓ 7820kg/m^2

Width of the pulley,

$h = 2cm$

$=2 \times 10^{-2}m$

Volume of the pulley $= \pi r^2 h$

$V = 3.142 \times (0.07)^2 \times (0.02)$

$= 308 \times 10^{-4}m^3$

Mass = density x volume

$= 7820 \times 3.08 \times 10^{-4}$

$= 2.4086kg$

$= 2.41kg$

Pulley weight = m x g; where; g = 9.81m/s

$= 2.41 \times 9.81$

$= 23.64N$

3.3.7 Determination of Pelletizing Rod's Weight

Diameter of the rod = 25mm

= 0.025m

Length of the rod = 45mm

= 0.045m

Volume of the rod $= \pi r^2 h$

Where,

r = 00.125

$V = 3.142 \times (0.0125)^2 \times 0.045$

$V = 2.2092 \times 10^{-5} m^3$

Since the density of mild steel is $7820kg/m^3$

Mass of the rod = 7820 x 2. 2092 x 10^{-5}

m = 0.1727kg

Weight = mg

= 0.1727 x 9.81

= 1.694N/m

3.3.8 Design Procedure for Screw Conveyor (Auger)

Length of the shaft cover by the auger = 180mm

` = 0.18m

WO = 2.5 friction factor of the material on mild steel ℓ = 0.40

Efficiency for v – belt transmission μ = 0.92

Factor of inclination of screw shaft to horizontal; at angle ß = 0, C = 1.0

Screw diameter, D = 125mm

= 0.125m

V, speed of the screw shaft is the speed of machine which is 650rpm

Pitch of the screw, s = 50mm

= 0.05m

Loading efficiency, ¼ or 0.25

Bulk density of convey materials ℓ = $1.20tons/m^3$ (Kolawole, 2006)

Capacity of conveyor Q = 15 $\pi D^2 sv\varphi\ell c$……………….……………….. (11)

Q = 15 x 3.142 x $(0.125)^2$ x 0.05 x 650 x 0.25 x 1.2 x 1.0

= 7.17996 tons/hr

= 7.18 tons/ hr

Power requirement to drive the screw and the shaft under no loading;

PE = YW ………………………………………………………………… (12)

Where $Y = \frac{1}{2} Iow^2$ ………………………………………………………… (13)

And, $w = \frac{2\pi n}{60}$, $n = 650$ rpm

Io = second moment of the pelletizing rod.

$$W = \frac{2\pi n}{60}$$

$$= \frac{2 \times 3.142 \times 650}{60}$$

$= 68.08$rd/sec

$Io = 1/12\ m\ (a \times b)$

Where,

m = mass of the rod

= 2.41kg

a = breadth of thin plate conveyor

= 125mm

= 0.125m

b = length of thin plate conveyor

= 140mm

= 0.14m

$Io = 1/12 \times 2.41\ (0.125 \times 0.14)$

$= 0.0035146$

$Y = \frac{1}{2} IoW^2$

$= \frac{1}{2}(0.0035146)\ (68.08)^2$

= 8.1448Nm

= 8.145Nm

PE = YW

$= 8.145 \times 68.08$

$= 554.51$watts

$= 0.5545$kw

Power requirement to drive the screw and shaft under loading;

$$\frac{PLQL}{367} \times \frac{(Wo + \sin ß)}{\mu} \text{……………………………………………} (14)$$

Where;

Q = capacity of conveyor,

L = length of the shaft covered by screw conveyor and rods

Wo = material factor which is 2.5

F = factor of inclination of screw shaft to horizontal at ß = 0

μ = efficiency for v-belt transmission

Q = 10.8 ton/hr.

L = (0.14 + 0.25)m

= 0.39m

μ = 0.92

$$P_L = \frac{10.81 \text{ x } 0.39/367\ (2.5)}{0.92}$$

= 4.2159/367 x 2.5 x 1.087

= 0.0312kw

Total power requires P_L + PE

Tp = 0.0312+1.5256

= 1.5568kw

Therefore, 3hp motor of 2.25kw is recommended

Torque on a screw shaft (auger)

$$M = 975 \times \frac{H}{n} \text{……………………………………………………..} (15)$$

Where,

H = horse power in watts

= 2.25kw

n = speed of the machine

= 650rpm

$M = 975 \times \frac{2.25}{650}$

= 3.38Nm.

Load propulsion speed

$V = \frac{Sn}{60}$………………………………………………………. (16)

Where,

S = pitch

= 50mm

= 0.05m

n = shaft revolution per minutes

= 650rpm

$V = \frac{0.05 \times 650}{60}$

= 0.65m/s

Load per meter length of conveyor

$q = \frac{Q}{3.6v}$ ……..………………………………………………. (17)

Where,

q = load per meter length of conveyor

Q = conveyor's capacity

= 10.81 tons/hr

V = load propulsion speed

= 0.65m/s

$$q = \frac{10.81}{3.6 \text{ x } 0.65}$$

= 4.62N

Axial thrust on screw

P = qlμ ………………………………………………………….. (18)

Where,

p = axial thrust on screw

q = load per meter length of conveyor

l = length of the screw conveyor

= 140mm

= 0.14m

μ = coefficient of friction of feed on mild steel

= 0.40

P = 4.62 x 0.14 x 0.40

= 0.25872kgN

= 0.25872 x 9.81

= 2.538N

Determination of Conveyor Weight

The conveyor is made of mild steel with length (0.14 + 0.25) = 0.39m

Height (width) = 0.25m

Thickness = 0.125m

Volume of the conveyor material = L x b x t ………………………………………….. (19)

Where;

L = length of conveyor

b = width of conveyor

t = thickness of the rod

$v = L \times b \times t$

$= 0.39 \times 0.25 \times 0.125$

$= 0.0121875m^3$

$= 1.2187 \times 10^{-3}m^3$

Mass of conveyor, $m = \ell v$ .... (20)

Where,

ℓ = density of mild steel

$= 7820kg/m^3$

V = volume of the material

$= 1.2187 \times 10^{-3}$

Mass $= 7820 \times 1.2187 \times 10^{-3}$

$= 9.53kg,$

$W = mg$

$= 9.53 \times 9.81$

$= 93.5N/m$

As uniformly distributed load (UDL)

$$= \frac{\text{mass}}{\text{length of the screw conveyor}}$$

$$= \frac{9.53}{0.14}$$

$= 68.07N/m$

Shaft Design

In shaft design consideration, a solid shaft is used due to the following reasons;

(a) To enhance the torsion rigidity of the shaft
(b) To withstand the axial loads acting on the shaft
(c) To ease the conveyance of feed constituents during pelletizing operation.

These are the loading on the shaft;

(i) Torsion load imposed from the energy input

(ii) Bending moment imposed by various points along the shaft

Forces acting on the shaft are;

(a) The distributed loads of pelletizing rods and auger
(b) The bearing reactions
(c) The weight of pulley
(d) The shaft weight

The weight of shaft is given as m x g ………………………….. (21)

Where,

m = mass of shaft in kg

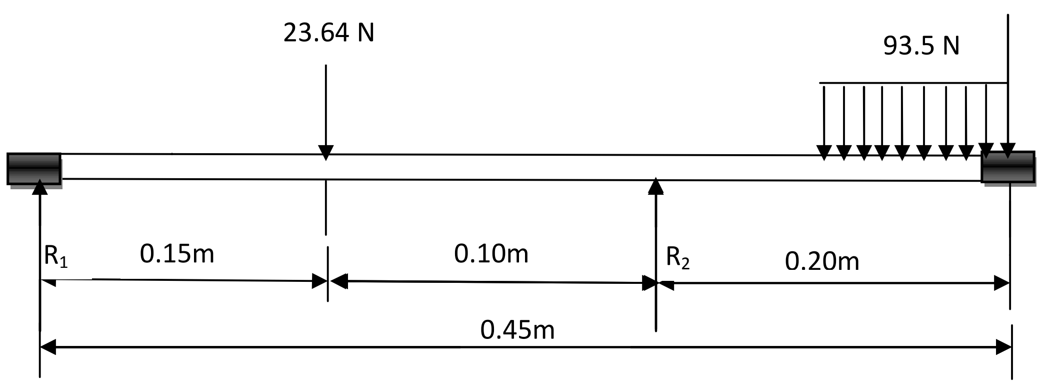
g = acceleration due to gravity

= 9.81m/s

m = 4.34 x 9.81

= 42.566N

= 42.57N



For Vertical Loading

$R_{AV1} + R_{AV2} = 23.64$ …………………………………….... (i)

Taking moment vertically about R_{AV1}

$$= -0.15\,(23.64) + 0.25\,(R_2) - 0\,(0.45)$$

$$= -0.15\,(23.64) + 0.25\,(R_2)$$

$$= -\,3.546 + 0.25\,(R_2)$$

$$0.25R_2 = 3.546$$

$$R_2 = \frac{3.546}{0.25}$$

$$R_2 = 14.184N$$

Substitute R_2 into equation (i) above

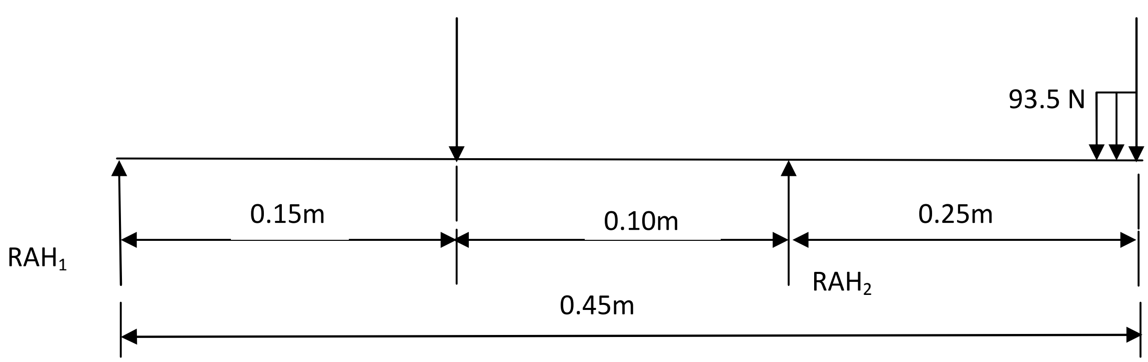
$$R_{AV1} + R_{AV2} = 23.64$$

$$R_{AV1} + 14.184 = 23.64$$

$$R_{AV1} = 23.64 - 14.184$$

$$R_{AV1} = 9.456N$$

For Horizontal Loading



$R_{AH1} + R_{AH2} = 93.5$

Taking moment along horizontal axis

$0.25 (R_{AH2}) – 93.5 (0.45) = 0$

$0.25 R_{AH2} = 42.075$

$R_{AH2} = \frac{42.075}{0.25}$

$R_{AH2} = 168.3N$

Put $R_{AH2} = 168.3$ in equation (ii)

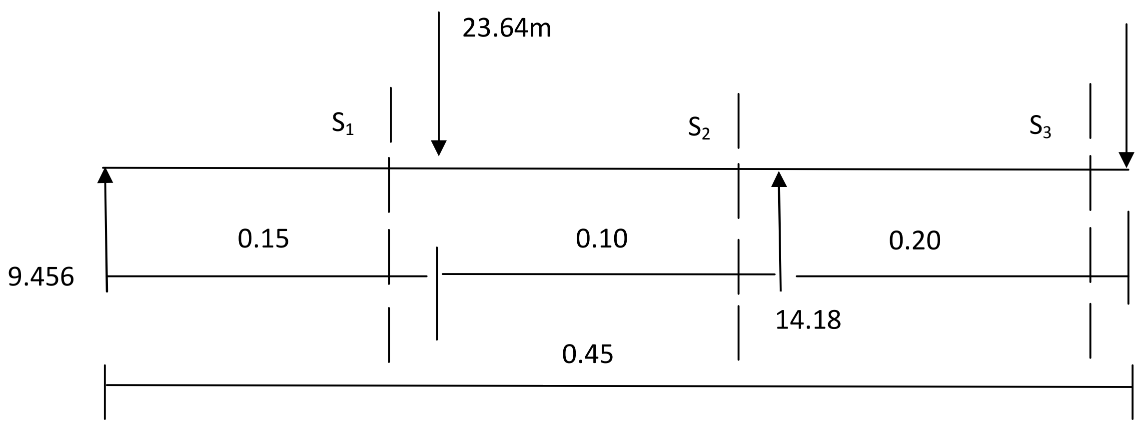
$R_{AH1} + R_{AH2} = 93.5$

$R_{AH1} + 168.3 = 93.5$

$R_{AH1} = 93.5 – 168.3$

$R_{AH1} = -74.8N$

Loading along Vertical Axis



Considering span 1

$MS_1S_1 = 9.456 x$

at $x = 0.15$

$MS_1S_1 = 9.456 \times 0.15$

$MS_1S_1 = 1.4184Nm$

Considering span 2

$MS_2S_2 = 9.456 x – 23.64 (x - 0.15)$

at $x = 0.25$

$= 9.456 \times 0.25 – 23.64 (0.25 - 0.15)$

$= 9.456 \times 0.25 – 23.64 (0.10)$

$= 2.365 – 2.364$

$= 0.001Nm$

Considering span 3

$MS_3S_3 = 9.456 x– 23.64 (x - 0.15) + 14.184 (x – 0.25)$

At $x = 0.45$

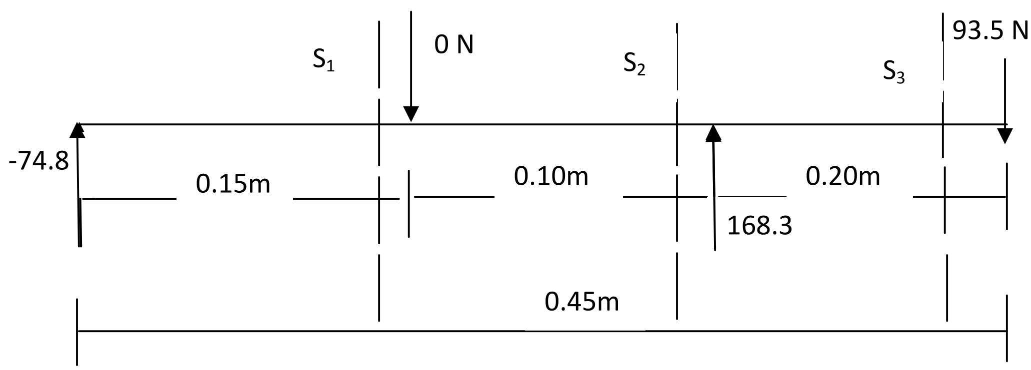
$= 9.456 (0.45) – 23.64 (0.30) + 14.184 (0.20)$

$= 4.2552 – 7.092 + 2.8368$

$= 7.092 – 7.092$

$= 0$

Loading along Horizontal Axis



Consider Span 1

$M_{S1S1} = -74.8 (x)$ at $x = 0.15$

$= -74.8 \times 0.15$

$= -11.22$ Nm

Considering Span 2

$M_{S2S2} = -74.8(x) – 0 (0.15)$ at 0.25

$=-74.8(0.25) – 0$

$= -18.7$ Nm

Considering Span 3

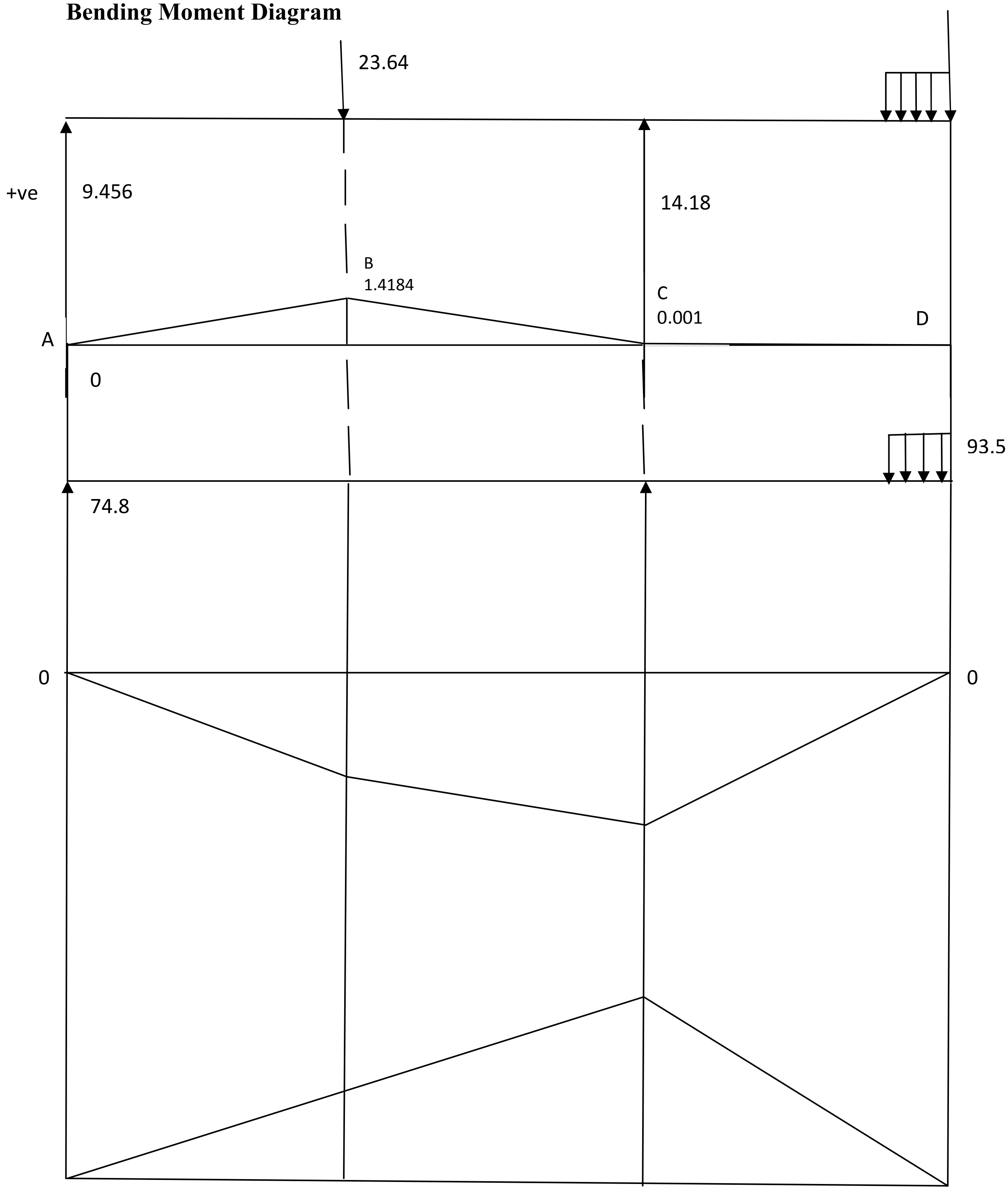
$M_{S3S3} = -74.8\ (0.45) + 168.3\ (x - 0.20)$

$= -33.66 + 33.66$

$= 0$

1

Bending Moment Diagram



Resultant Bm at B

$=\sqrt{(1.418)^2 + -(-11.22)^2}$

$= \sqrt{(127.90}$

= 11.309 Nm

Resultant Bm at C

$= \sqrt{(0.001)^2 + (75.05)^2}$

$= \sqrt{5632.50}$

= 75.05 Nm

Mb_{max} = 75.05 Nm

Mb = 75.05 Nm

$Mt = (T_1 – T_2) R$

$T_1 = 1298.16$

$T_2 = 298.16$

R = 70 mm

= 0.07m

Mt = (1298.16 N – 298.16 N) × 0.07m

= 1000 N × 0.07 m

Mt = 70Nm

Kb = 1.5

Kt = 1.0

$d^3 = 16/\pi Ss \sqrt{(Kt \times Mt) 2 + (Kb \times Mb) 2}$

$= 16/ (40 \times 10^6) \sqrt{(1.0 \times 70)^2 + (1.5 \times 75.05)^2}$

$= 1.2733 \times 10^{-7} \times 132.5636852$

$= 1.6879 \times 10^{-5}$

$d= {}^3\sqrt{1.6879 \times 10^{-5}}$

$d = 2.565 \times 10^{-2}$ m

d = 25.65 mm

Therefore 25mm diameter was choosen.

3.0 PERFORMANCE TEST, RESULTS AND DISCUSSION

3.1 Machine Test Procedures

The fish feed was prepared using the standard feed formula. The fish feed content includes: maize, cassava, GNC, SBM, Fish meal, Oyster shell, premix, bone meal, lysine,oil, methionine and salt. The methods of feed formulation vary from one region to another, however it involves the combination and blending together of feed ingredients (based on individual formula) into nutritionally balanced and economically sound diet that can be used in required amount to provide the level of production desired in fish cultivation. Normally, the protein level in formulated feeds is about 30–32 percent for the nursery stage (5–20 g). This value decreases with increasing fish size, the lowest value (22–26 percent) occurring at a size of >500 g. Similarly, the lipid level of the diet changes with fish size appropriate to the requirement, which varies from 4–6 percent. Two essential amino acids which are often supplemented in the feed are methionine and lysine. Different kinds of vitamin C are also used in MPF – for instance, "stay C", which is stable at high temperature has been used in extruded pellets. Furthermore, calcium and phosphorus may be added to the diets. The FMF usually has a low protein content. The diet is usually formulated from local ingredients such as fishmeal, trash fish, soybean meal, soybean cake, rice bran, broken rice, cassava, dry fish, etc. The formulation varies with the size of the fish (FAO, 2018).

Examples of feed formulations used to culture catfish.

Ingredient	% of feed						
	Fry feed	Fingerling feed	Food fish feed				
	(50%)a	(35%)	(32%)	(32%)	(28%)	(28%)	(26%)
Soybean meal (48%)a	–	44.2	41.6	47.0	30.1	35.4	28.3
Cottonseed meal (41%)	–	10.0	10.0	10.0	10.0	10.0	5.0
Menhaden meal (61%)	74.2	8.0	4.0	–	4.0	–	4.0
Corn grain	–	27.6	32.1	30.3	33.6	31.9	35.3
Wheat middlings	20.4	7.5	10.0	10.0	20.0	20.0	25.0
Dicalcium phosphate	–	0.5	0.6	1.0	0.6	1.0	0.7
Catfish vitamin mix[b]	include	include	include	include	include	include	include
Catfish mineral mix[b]	include	include	include	include	include	include	include
Fat/oil[c]	5.0	2.0	1.5	1.5	1.5	1.5	1.5

a Values in the parentheses represent percentage protein.
b Commercial mix that meets or exceeds all requirements for channel catfish.
c Sprayed on finished feed pellet to reduce feed dust ("fines").

Source: University of Minnesota AgEcon - July 2006

Plate 1: The machine showing pelletizingoperation

Plate 2: Pelletized fish feed of 2mm diameter.

Plate 3: Pelletized fish feed of 4mm diameter.

Plate 4: Pelletized fish feed of 6mm diameter.

The prepared feed were mixed with water to obtain different moisture contents 10, 15, 20, 25, 30 and 35 percent wet basis. The blended or granular fish feeds were loaded into the machine at input quantity of 2.0kg. The pelletized feeds were then collected through the orifice and the time for each pelletizing operation was taken and recorded. The feed came out in a pellet strand form as shown in Plate 1.Plates 2, 3 and 4 showing the different sizes of pelletized fish feed from dies of 2mm, 4mm and 6mm diameters respectively.Pellets are small particles typically created by compressing original materials. Pellets are majorly in single shape. Some pellets are a small, compressed, hard chunk of matter, usually round "small ball" or small short cylindrical shape.The reason for producing the fish feed in pellet form is to enable the fishes have easy access and proper consumption of the feeds during feeding.The weight of feed collected through the dies was measured and recorded.

3.2 Result

The results obtained duringpelletizing operation at different moisture content and die diameters are presented in Table 2, 3 and 4. The efficiency, throughput and percentage loss were calculated using the following relationships:

i. $$\text{Efficiency} = \frac{Quanity\ of\ \ Pelletised(kg)}{Input\ Quantity(kg)} \times 100\%$$

ii. $$\text{Throughput} = \frac{Input\ Quantity(kg)}{Time\ of\ \ Pelleti\sin g(hr)}$$

Table 2: Result of pelletizing operation at different moisture contents with 2mm die diameter

Moisture content	Sample weight (kg)	Time (s)	Quantity pelletized (kg)	Quantity wasted (kg)	Efficiency (%)	Throughput (kg/hr)
10	2	637	1.56	0.44	78	11.30
15	2	395	1.60	0.40	80	18.22
20	2	372	1.62	0.38	81	19.35
25	2	246	1.66	0.34	83	29.27
30	2	195	1.60	0.40	80	36.92
35	2	152	1.50	0.50	75	47.37

Table 3: Result of pelletizing operation at different moisture contents with 4mm die diameter

Moisture content	Sample weight (kg)	Time (s)	Quantity pelletized (kg)	Quantity wasted (kg)	Efficiency (%)	Throughput (kg/hr)
10	2	235	1.78	0.22	89	30.64
15	2	211	1.82	0.18	91	34.12
20	2	196	1.88	0.12	94	36.73
25	2	155	1.90	0.10	95	46.45
30	2	120	1.88	0.12	94	60.00
35	2	108	1.80	0.20	90	66.67

Table 4: Result of pelletizing operation at different moisture contents with 6mm die diameter

Moisture content	Sample weight (kg)	Time (s)	Quantity pelletized (kg)	Quantity wasted (kg)	Efficiency (%)	Throughput (kg/hr)
10	2	107	1.80	0.20	90	62.29
15	2	94	1.88	0.12	94	76.60
20	2	83	1.92	0.08	96	86.75
25	2	83	1.96	0.04	98	86.75
30	2	78	1.92	0.04	96	92.31
35	2	74	1.90	0.10	95	97.30

The result obtained during operation at different volume of water for 400ml, 500ml, and 600ml were also recorded accurately. Further analyses of the result were taken as follows; Tables 5, 6,7, 8, 9, 10, 11, 12 and 13 shows the result of testing data collected during the testing of the machine.

Sample weight plus water = Input in Kilogram

Quantity pelletized = Output in Kilograms

Quantity wasted = Weight of materials remained in the machine in Kilograms

Time spent on the machine operation = T (seconds)

Total = TT

Average = A

Table 5: Pelletizing result of 2mm diameter die with 400ml of water = 0.4 Kg

S/N	MOISTURE CONTENT	SAMPLE WEIGHT (Kg)	SAMPLE WEIGHT PLUS WATER (Kg)	TIME (S)	QUANTITY PELLETIZED (Kg)	QUANTITY WASTED (Kg)	EFFICIENCY (%)	THROUGHPUT (Kg/hr)	% LOSS
1	26.1	1.0	1.4	1112	1.2	0.2	85	0.38	14.28
2	24.5	1.4	1.8	1746	1.5	0.3	83	0.31	16.67
TT	50.6	2.4	3.2	2858	2.7	0.5	168	0.69	30.95
A	25.3	1.2	1.6	1429	1.35	0.25	84	0.345	15.47

									5

Table 6: Pelletizing result of 2mm diameter die with 500ml of water = 0.5 Kg

S/N	MOISTURE CONTENT	SAMPLE WEIGHT (Kg)	SAMPLE WEIGHT PLUS WATER (Kg)	TIME (S)	QUANTITY PELLETIZED (Kg)	QUANTITY WASTED (Kg)	EFFICIENCY (%)	THROUGHPUT (Kg/hr)	% LOSS
1	18.1	1.0	1.5	395	1.2	0.3	80	1.10	20.00
2	15.7	1.4	1.9	637	1.7	0.2	89	1.00	10.50
TT	33.8	2.4	3.4	1032	2.9	0.5	169	2.10	30.5
A	16.9	1.2	1.7	516	1.45	0.25	84.5	1.05	15.25

Table 7: Pelletizing result of 2mm diameter die with 600ml of water = 0.6 Kg+

S/N	MOISTURE CONTENT	SAMPLE WEIGHT (Kg)	SAMPLE WEIGHT PLUS WATER (Kg)	TIME (S)	QUANTITY PELLETIZED (Kg)	QUANTITY WASTED (Kg)	EFFICIENCY (%)	THROUGHPUT (Kg/hr)	% LOSS
1	24.3	1.0	1.6	272	1.3	0.3	81	1.72	18.75
2	25.0	1.4	2.0	495	1.8	0.2	90	1.31	10.00
TT	49.3	2.4	3.6	767	3.1	0.5	171	3.03	28.75
A	24.65	1.2	1.8	383.5	1.55	0.25	85.5	1.515	14.375

Note;

1ml of water = 0.001 Kg

$$\text{Efficiency} = \frac{\text{Quantity Pelletized}}{\text{Sample + water}} \times 100$$

$$\%\text{Loss} = \frac{\text{Quantity Wasted}}{\text{Sample + water}} \times 100$$

$$\text{Throughput} = \frac{\text{Quantity Pelletized}}{\text{Time}} \times 60 \times 60$$

Average efficiency = (84 + 84.5 + 85.5)

= 84.6 %

Table 8: Pelletizing result of 4mm diameter die with 400ml of water = 0.4 Kg

S/N	MOISTURE CONTENT	SAMPLE WEIGH	SAMPLE WEIGH	TIME (S)	QUANTITY PELLETIZED (Kg)	QUANTITY WASTED	EFFICIENCY (%)	THROUGHPUT (Kg/hr)	% LOSS

		T (Kg)	T PLUS WATER (Kg)			(Kg)			
1	23.4	1.0	1.4	108	1.25	0.15	89	4.17	10.7
2	24.1	1.4	1.8	195	1.60	0.20	88.9	2.95	11.1
TT	47.5	2.4	3.2	303	2.85	0.35	177.9	7.12	21.8
A	23.75	1.2	1.6	151.5	1.425	0.175	88.95	3.56	10.9

Table 9: Pelletizing result of 4mm diameterdie with 500ml of water = 0.5 Kg

S/N	MOISTURE CONTENT	SAMPLE WEIGHT (Kg)	SAMPLE WEIGHT PLUS WATER (Kg)	TIME (S)	QUANTITY PELLETIZED (Kg)	QUANTITY WASTED (Kg)	EFFICIENCY (%)	THROUGHPUT (Kg/hr)	% LOSS
1	**23.8**	**1.0**	**1.5**	**120**	**1.05**	**0.45**	**70**	**3.15**	**30**
2	**20.3**	**1.4**	**1.9**	**235**	**1.60**	**0.30**	**84.2**	**2.45**	**15**
TT	**44.1**	**2.8**	**3.4**	**355**	**2.65**	**0.75**	**154.2**	**5.6**	**45**
A	**22.05**	**1.4**	**1.7**	**177.5**	**1.325**	**0.375**	**77.1**	**2.8**	**22.5**

Table 10: Pelletizing result of 4mm diameterdie with 600ml of water = 0.6 Kg

S/N	MOISTURE CONTENT	SAMPLE WEIGHT (Kg)	SAMPLE WEIGHT PLUS WATER (Kg)	TIME (S)	QUANTITY PELLETIZED (Kg)	QUANTITY WASTED (Kg)	EFFICIENCY (%)	THROUGHPUT (Kg/hr)	% LOSS
1	**28.2**	**1.0**	**1.6**	**196**	**1.5**	**0.1**	**94**	**2.8**	**6.25**
2	**24.8**	**1.4**	**2.0**	**211**	**1.8**	**0.2**	**90**	**3.1**	**10**
TT	**53**	**2.4**	**3.6**	**407**	**3.3**	**0.3**	**184**	**5.9**	**16.25**
A	**26.5**	**1.4**	**1.8**	**204**	**1.65**	**0.15**	**92**	**2.95**	**8.125**

Note;

1ml of water = 0.001 Kg

$$\text{Efficiency} = \frac{\text{Quantity Pelletized}}{\text{Sample + water}} \times 100$$

$$\%\text{Loss} = \frac{\text{Quantity Wasted}}{\text{Sample + water}} \times 100$$

$$\text{Throughput} = \frac{\text{Quantity Pelletized}}{\text{Time}} \times 60 \times 60$$

$$\text{Average Efficiency} = \frac{(88.95 + 77.1 + 92)}{3}$$

$$= 86.01\ \%$$

Table 11: Pelletizing result of 6mm diameter die with 400ml of water = 0.4 Kg

S/N	MOISTURE CONTENT	SAMPLE WEIGHT (Kg)	SAMPLE WEIGHT PLUS WATER (Kg)	TIME (S)	QUANTITY PELLETIZED (Kg)	QUANTITY WASTED (Kg)	EFFICIENCY (%)	THROUGHPUT (Kg/hr)	% LOSS
1	**23.5**	**1.0**	**1.4**	**83**	**1.2**	**0.2**	**86**	**5.2**	**14.2**
2	**14.5**	**1.4**	**1.8**	**107**	**1.6**	**0.2**	**89**	**5.4**	**11.1**

TT	**38**	**2.8**	**3.2**	**190**	**2.8**	**0.4**	**175**	**10.6**	**25.3**
A	**19**	**1.4**	**1.6**	**145**	**1.4**	**0.2**	**87.5**	**5.3**	**12.65**

Table 12: Pelletizing result of 6mm diameter die with 500ml of water = 0.5 Kg

S/N	MOISTURE CONTENT	SAMPLE WEIGHT (Kg)	SAMPLE WEIGHT PLUS WATER (Kg)	TIME (S)	QUANTITY PELLETIZED (Kg)	QUANTITY WASTED (Kg)	EFFICIENCY (%)	THROUGHPUT (Kg/hr)	% LOSS
1	23.2	1.0	1.5	94	1.25	0.25	83	4.8	16
2	15.1	1.4	1.9	74	1.70	0.2	89	8.2	10.5
TT	38.3	2.8	3.4	168	2.95	0.45	172	13	26.5
A	19.15	1.4	1.7	84	1.475	0.225	86	6.5	13.25

Table 13: Pelletizing result of 6mm diameter die with 600ml of water = 0.6 Kg

S/N	MOISTURE CONTENT	SAMPLE WEIGHT (Kg)	SAMPLE WEIGHT PLUS WATER (Kg)	TIME (S)	QUANTITY PELLETIZED (Kg)	QUANTITY WASTED (Kg)	EFFICIENCY (%)	THROUGHPUT (Kg/hr)	% LOSS
1	23.4	1.0	1.6	78	1.4	0.2	88	6.5	12.5
2	14.8	1.4	2.0	83	1.9	0.1	95	8.2	5
TT	38.2	2.8	3.6	161	3.3	0.3	183	14.7	17.5
A	19.1	1.4	1.8	80.5	1.65	0.15	91.5	7.35	8.75

Note;

1ml of water = 0.001 Kg

$$\text{Efficiency} = \frac{\text{Quantity Pelletized}}{\text{Sample + water}} \times 100$$

$$\%\text{Loss} = \frac{\text{Quantity Wasted}}{\text{Sample + water}} \times 100$$

$$\text{Throughput} = \frac{\text{Quantity Pelletized}}{\text{Time}} \times 60 \times 60$$

$$\text{Average Efficiency} = \frac{(\text{2mm die efficiency + 4mm die efficiency + 6mm die efficiency})}{3}$$

$$\text{Average Efficiency} = \frac{(87.5 + 86 + 91.5)}{3}$$

$$= 88.33\ \%$$

The table 14, 15 and 16 below shows the relationship between the efficiency and thewater content, **Table 14; Relationship between Efficiency and water content on 2mm die.**

S/N 2mm Die 1 at 1.0kg	S/N 2mm Die 1 at 1.4kg

1	Water content	400ml	500ml	600ml	1	Water content	400ml	500ml	600ml
2	Efficiency	85	80	81	2	Efficiency	83	89	90

Table 15; Relationship between Efficiency and water content on 4mm die.

S/N	**4mm Die 1 at 1.0kg**				**S/N**	**4mm Die 1 at 1.4kg**			
1	Water content	400ml	500ml	600ml	1	Water content	400ml	500ml	600ml
2	Efficiency	89	70	94	2	Efficiency	88.9	84.2	90

Table 16; Relationship between Efficiency and water content on 6mm die.

S/N	**6mm Die 1 at 1.0kg**				**S/N**	**6mm Die 1 at 1.4kg**			
1	Water content	400ml	500ml	600ml	1	Water content	400ml	500ml	600ml
2	Efficiency	86	83	88	2	Efficiency	89	89	95

The table 17, 18 and 19 below shows the relationship between the efficiency and feed rate,

Table 17; Relationship between Efficiency and feed rate on 2mm die.

S/N	400ml		500ml		600ml	
Feed Rate	**1.0**	**1.4**	**1.0**	**1.4**	**1.0**	**1.4**
Efficiency	**85**	**83**	**80**	**89**	**81**	**90**

Table 18; Relationship between Efficiency and feed rate on 4mm die.

S/N	400ml		500ml		600ml	
Feed Rate	**1.0**	**1.4**	**1.0**	**1.4**	**1.0**	**1.4**
Efficiency	**89**	**88.9**	**70**	**84.2**	**94**	**90**

Table 19; Relationship between Efficiency and feed rate on 6mm die.

S/N	400ml		500ml		600ml	
Feed Rate	**1.0**	**1.4**	**1.0**	**1.4**	**1.0**	**1.4**
Efficiency	**86**	**89**	**83**	**89**	**88**	**95**

Figure 6; The Graph of the relationship between the efficiency and the water content of 2mm die,

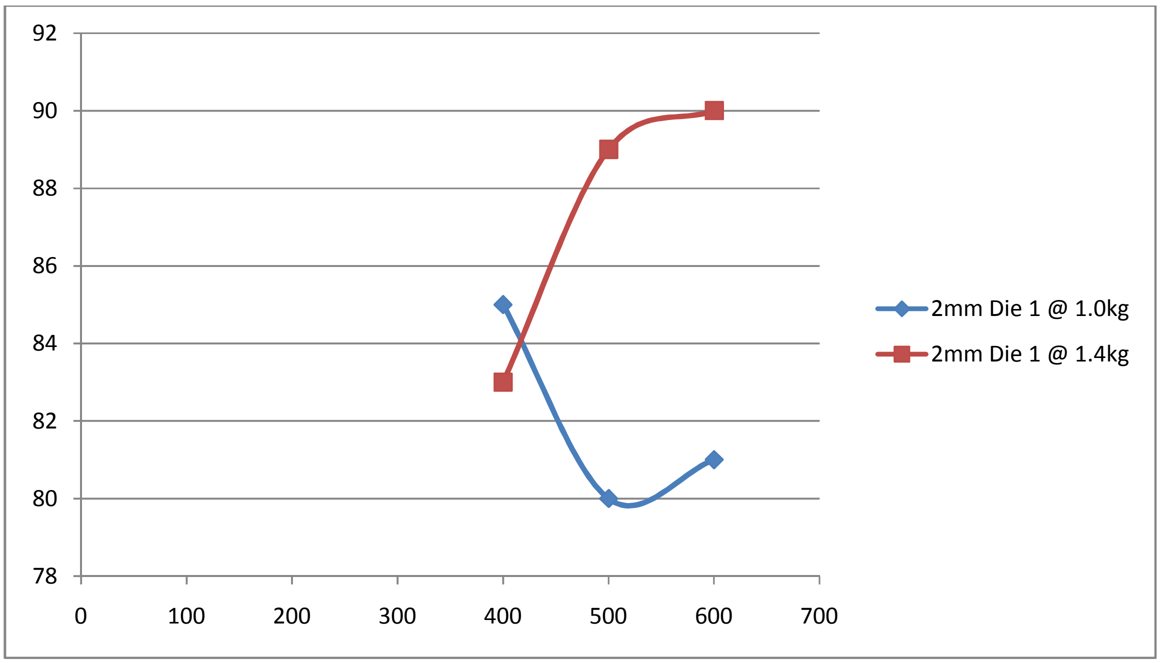


Figure 7; The Graph ofthe relationship between the efficiency and the water content of 4mm die,

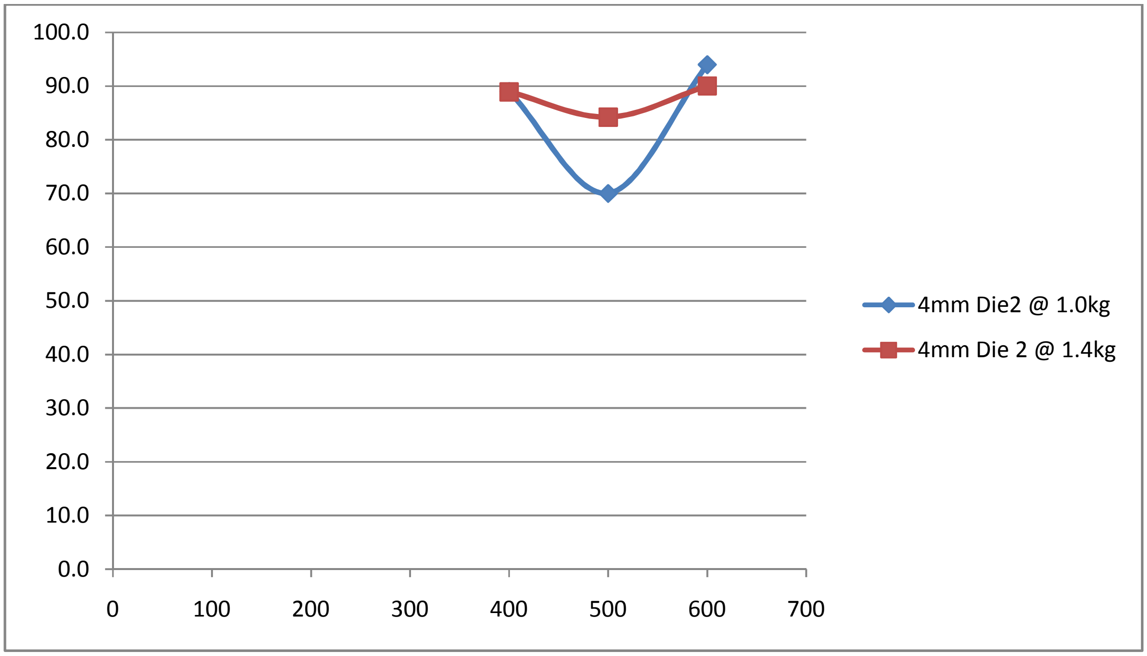


Figure 8; The Graph ofthe relationship between the efficiency and the water content of 6mm die,

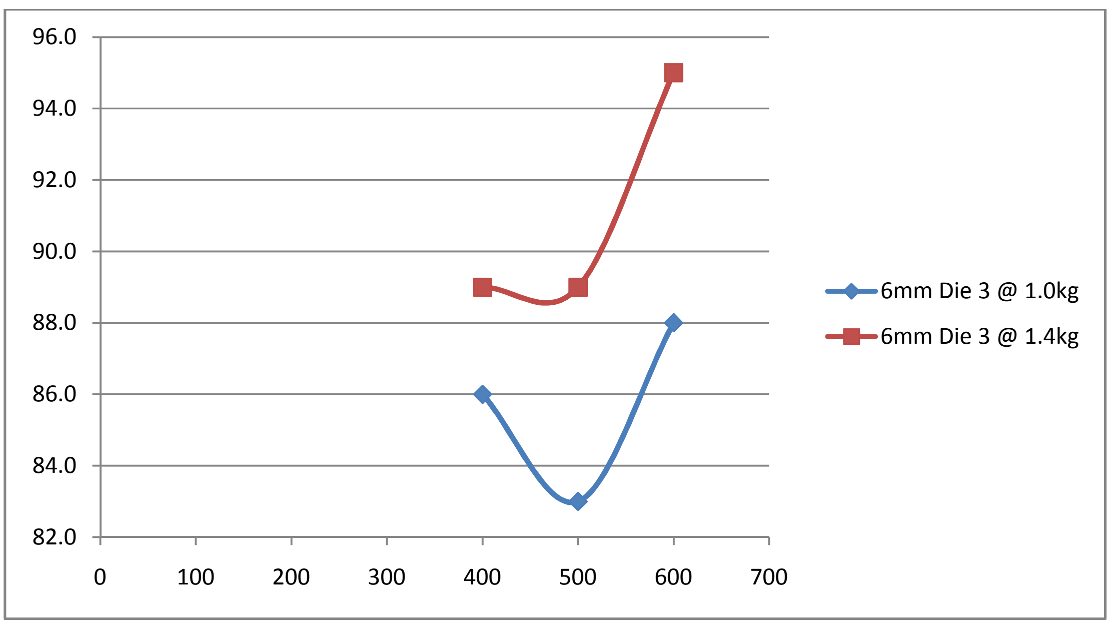


Figure 9; The Graph of the relationship between the efficiency and the feed rate at 2mm die;

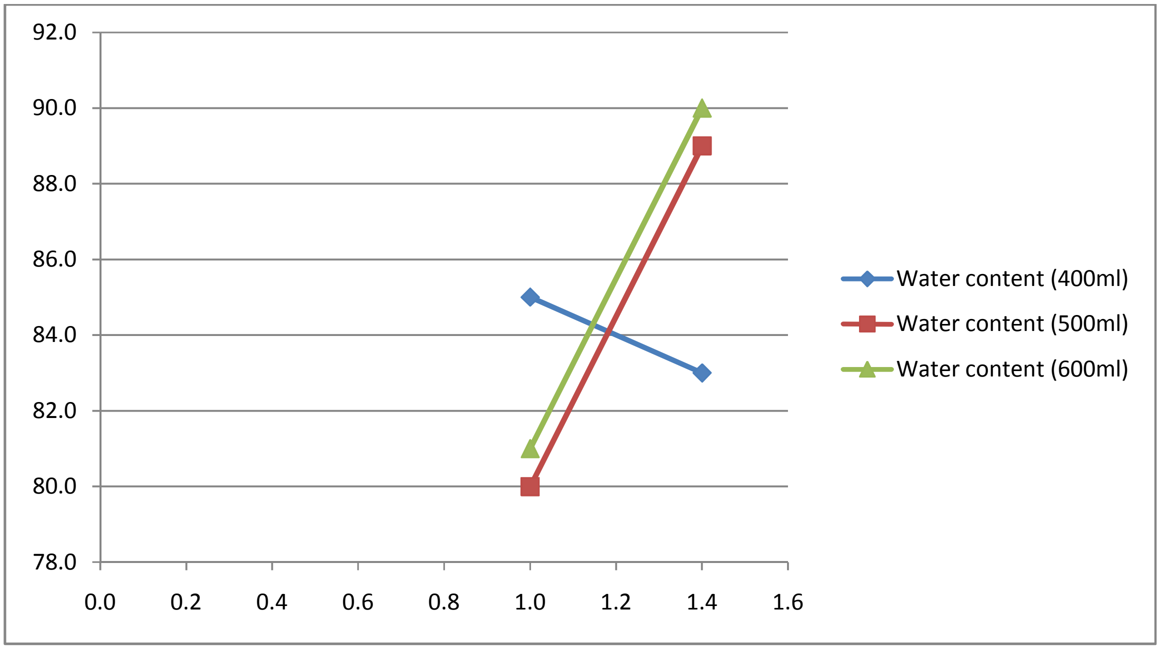


Figure 10; The Graph of the relationship between the efficiency and the feed rate at 4mm die;

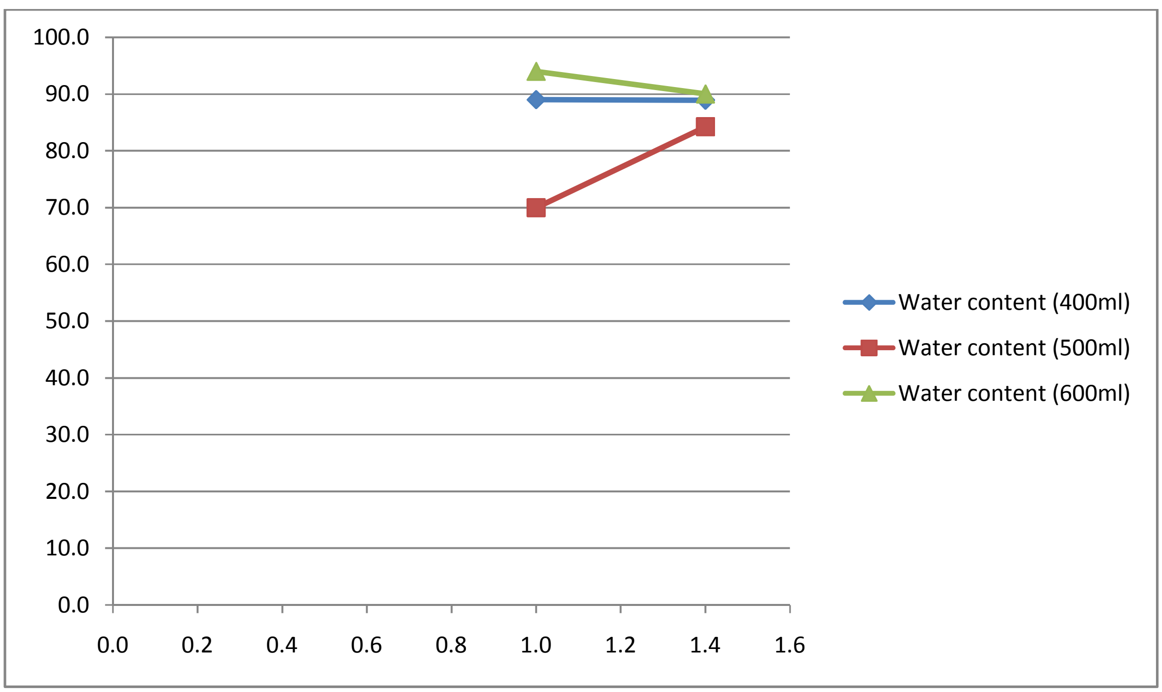
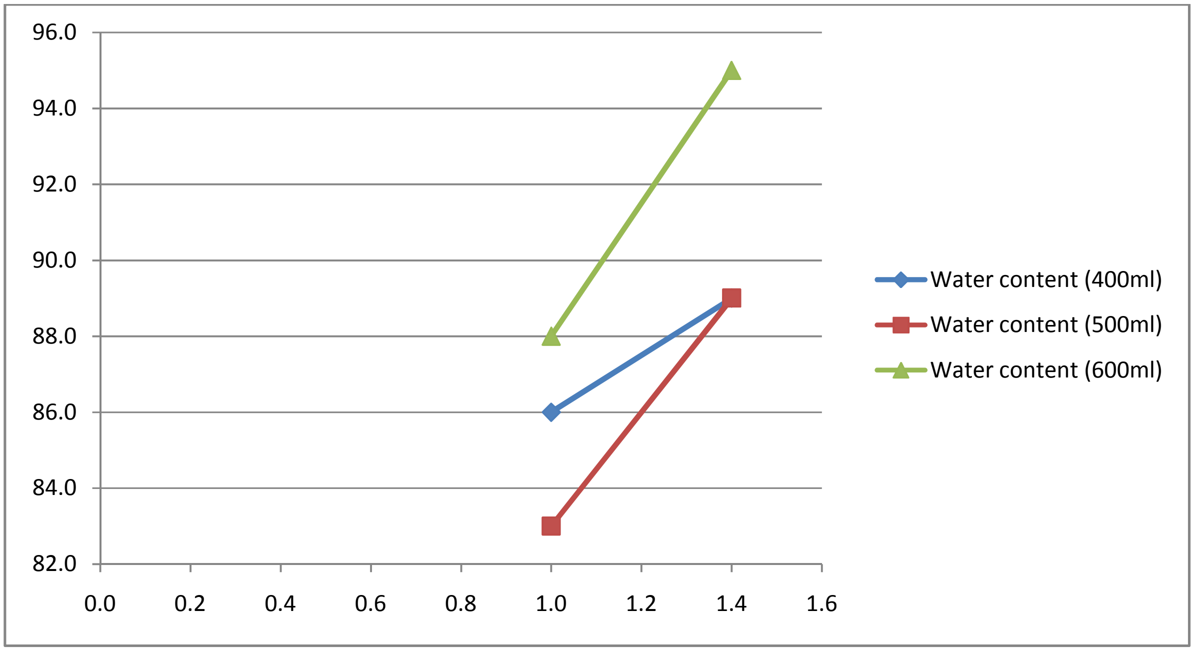


Figure 11; The Graph of the relationship between the efficiency and the feed rate at 6mm die;



3.3 Discussion

The maximum machine efficiency is 91.5% at 600ml of water for the 6mm pellet orifice size. This may be due to relatively easy passage offered for the fish feed to feed due to its large size. The efficiencies of the machine with 4mm and 2mm orifice size are 86.01% and 84.6% respectively while the average total efficiency is around 88%. This also is applicable to its capacity. Hence, the composition of the feedstock is very important to its pelletization. From table 13, the optimum feedstock to water is 600ml of water to 1.4kg of dry feed.

Comparing the relationship between the quantities of water used to the quantity of dry feed, the graph illustrates that the efficiency of the machine when 600ml of water is added to dry feed is at its optimum level. Hence the quantity of water used in mixing the dry feed has an impact on the production thereby influencing the efficiency of the machine.

It was also observed that the pelletizing efficiency increases with moisture content at around 25% when the efficiency of the machine started to decrease. This may be due to clogging of wet feed between the barrel and the die disc as moisture content increases. For the moisture content of the fish feed ranging from 10% to 35%, the highest efficiency of pelletizing was obtained at 25% moisture for all the die diameters as seen in Table 2, 3 and 4. 6mm die gave the highest value at 98% efficiency. This is comparable to the result obtained by Olusegun et al (2017). It was also observed that both the pelletizingefficiency and throughput of the machine increases with die diameters. This may be due to relatively easy passage offered for the fish feed as the die diameter increases. This also agrees with the result obtained by Abubakre et al (2014). Kaankuka and Osu (2013) who developed a revolving die and roller fish feed pelletizer also reported that pellets forming rate does decrease as moisture content decreases. The overall assessment of the machine showed that pelletizing operation at 25% moisture content using 6mm die diameter gave the highest efficiency of 98% and throughput of 86.75kg/hr.

4.0 CONCLUSION

In this research work, a fish feed pelletizer was designed and fabricated using locally available materials. The indigenous machine was tested using diesof different diameters and at different moisture content. The test results obtained shows that the pelletizing efficiency increases as moisture content and die diameter increase. The machine throughput also increases with both moisture content and die diameter. Highest efficiency of 98% was obtained when the moisture content was maintained at 25% wet basis and the feed materials were made to pass through 6mm die diameter.

4.1 RECOMMENDATIONS

a) The feed stuff should not be too dry or too wet during pelletizing operation.
b) Government should subsidize and encourage the mass production of indigenous fabricated machines andmake it affordable to local farmers.
c) There is need to orientate fish farmers about the formulation of nutritionally balanced, high quality feeds.
d) Further analysis or test should be carried out on the machine with other compositions of feedstock.
e) The machine should be operated by well-trained local operator for smooth operation and in order to achieve best output.

5.0 REFERENCES

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