FABRICATION AND PERFORMANCE EVALUATION OF A CHAIN AND SPROCKET SYSTEM MANUAL FISH FEED PELLETIZER

Daniel Momngu Tiough[1]; Coolaid Ifeoma Obahi[2] & Nathaniel Nguuma Afaor[3]

[1,2,3]Department of Vocational and Technical Education, Faculty of Education, Benue State University, Makurdi, Nigeria.

Email: dantiough1@gmail.com , **Phone:** 07037897210.

Abstract

A manual fish feed pelletizer was designed and fabricated consisting of a hopper, Chain and Sprocket System (CSS), pelletizing chamber, three (3) interchangeable die plates and winding handle as its major features. The pelletizer was driven manually with the aid of a winding handle connected to a chain and sprocket system. Feed was compounded and the performance evaluation of the machine was carried out using a Chain and Sprocket System (CSS) with the three (3) interchangeable die plates. Results showed that the average mean pelletizing efficiency was 85%. In addition, the throughput capacity for CSS was with an average mean of 16.5kg/hr. Beneficiaries of this machine are the fish farmers as well as livestock farmers, research institutions, feed processing industries and Small Medium Enterprise. It was recommended that farmers should avail themselves of this machine since it is cheap and easy to operate. It does not need electricity or fuel to function. It can also be produced by entrepreneurs to make it locally available.

Keywords: fish, pellet feed, pelletizer, fabrication, sprocket, chain.

1.0 Introduction

Fish is an oviparous, vertebrate animal usually having fins and a covering scales or plates. It breathes by means of gills and lives almost entirely in water. It can be found in rivers, streams and ocean.Fish is a very good source of protein; however, it is scarce because fish farmers suffer great loses in production, growing and harvesting. This has been attributed to many factors including production of adequate, affordable and appropriate feeds. It is thought that if farmers can easily access machines to produce fish feeds, there will be an improvement in fish production. There are fish feed machines which are electrically operated or manually operated (Olugboji, Abolarin, Owolewa, & Ajani, 2015).

Fish feeds are produced in the form of pellets. This is to aid easy consumption by fishes at different stages. Pelleting is therefore necessary after the various fish feed materials are mixed in the right proportions. Atoyebi (2007), recommends that fish meal be made into pellets which contain ingredients that constitute a balanced diet for the fish. Such ingredients consist of soya beans (18-50% by weight), lipids which are fat (10-25% by weight), groundnuts and carbohydrates (15-20% by weight), and cereal, mostly maize is used in Nigeria (10% by weight). In addition, less than 5% of the following are mixed and added to the ingredients before being processed blood meal, fish cramps, palm kernel cake, cotton seed, premix that provide the vitamins and mineral source for the fish.

Its popularity has grown steadily that about 80% of all feeds produced are currently pelleted. Today, the process is widely used because of the physical and nutritional benefits it provides. The physical benefits of pelleted feed include improved ease of handling, reduced ingredient segregation, less feed wastage and increased bulk density. Nutritional benefits have been measured through animal feeding trials (Wondra, Hancock, Behnke, Hines & Stark, 1995). As to this result, the use of pelleted feed improves animal growth and feed conversion compared with a feeding meal form of diet.

The need for pelleting machines has seen significant demand even though the fish feed industry has been described as poorly developed. In Nigeria, a lot of interest has been expressed in fish farming in Nigeria over the last two decades, but the equipment used in the processing of feeds which are quite sophisticated, are mostly imported, which makes their affordability by local farmers difficult. The local fish farmers are therefore left with the option of waiting to purchase fish feeds since they cannot produce on their farm (Omitoyin, 2007). This has led many fish farmers to abandon their farms due to the high cost of feeds, while those who continue the trade experience loss and undergrowth due to

insufficient/inadequate amount of nutrient contained in the already processed purchased feed, thereby leading to loses of fish and decrease in the farmer's profit.
In order to accomplish the purpose of this research therefore, some of the following studies on other fish feed machines were also reviewed to guide the study. Burmamu, Aliyu, and Tya (2015), carried out a study on the development of manually operated fish feed pelleting machine for small scale industries which was carried out in order to discourage importation of similar machines into the country. The design materials were selected based on strength, durability, physical properties, availability of materials, and their cost. The selected materials were then cut according to engineering specifications and the machine was produced through welding and bolts and nuts connection. The machine was then tested with 3kg of mixture of fish feed where 2.65kg of the feed was recovered which gave the efficiency of 88.3%. the pelleting machine was recommended for both rural and urban fish producers since it is portable and can be operated manually. Burmamu *et al'* (2015) design differs from the present design in that why they use an electric motor for their machine this design uses the chain to increase mechanical advantage of the machine.

Ojomo, Agbetoye and Ologunagba, (2010), designed and fabricated a pelletizing machine for the production of fish feed. Power supply to the machine was 2kW, and it used a 1420 rpm single phase motor. It was observed that the pelletizing efficiency, through put capacity and the percentage recovery of the machine increased with increase in moisture content and the speed of the machine. The machine had a through put capacity of 19.7 kg/h with a pelletizing efficiency of87.6%. moisture content constituted a greater portion of variability in efficiency than speed. A unit increase in moisture content resulted in an increase of about 20% in pelletizing efficiency whereas a corresponding increase in speed only increases the pelletizing efficiency by 3%. The machine does not make use of steam thereby making it easier to operate. This machine differs from Ojomo*et al*'s machine in the power source for operation of the machine which is manual as against the use of electric motor respectively.

Nwaokocha and Akinyemi (2008) designed and fabricated a dual purpose fish pellet making machine which could be operated both electrically and manually. The machine used a worm screw to propel the ingredients through the die. A hopper contained the ingredients which were conveyed by the worm screw that compacted and expelled it through the die. The machine capacity was 25 kg/h and its electric and manual efficiencies were 92.6% and 91.4% when run by electric motor and manually respectively. Though Nwaokocha and Akinyemi's design could be powered electrically and manually, its manual operation does not include the use of a chain and sprocket system as present design under consideration.

Similarly, Kaankuka and Osu (2013), developed a revolving die and roller type pelletizing machine to produce fish feed pellets for small scale fish farmers. The components were designed based on strength and rigidity. An electric motor drives the die by a shaft connected to its pulley. The rotation of the die initiates the rotation of the rollers which pick up the feed material and compress it into the die holes to form pellets. The pelletizing machine was tested at two speed levels of 507rpm and761 rpm respectively. Higher pellet output was obtained from the die speed of 761rpm which was attributed to the production of higher heat which resulted in proper gelatinization of carbohydrate in the compounded feed. The gelatinized starch acts as a binding agent and this reduces crumbling during pelleting. Though Kaankuka and Osu's design uses flat die for the formation of the pellet feed, it was assisted with roller which compacts and compress the feed ingredients to pass through the die plate, while the researchers' design uses a spiral conveyor to compact and compress the feed ingredients to pass through the die plate.

Olusegun, Adekunle, Ohijeagbon, Akande and Mohammad (2017) also developed a113.1kg/h fish meal pellet processing machine which produced 4mm diameter pellets, with an average length of 6mm. two 3cm 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 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 7 days of drying in open air was 26.5% wet basis (w.b). 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 pellets formed. The difference between Olusegun *et al*'s design and the present design is that their machine was powered by an electric motor and had a gear reduction system for the operation of the machine and also made use of one diameter (4mm) of a flat die plate for pellet production, whereas our design which is been manually operated makes use of three interchangeable die plates (4mm, 6mm,8mm) and can use more other diameters.

In another study, Muo, Okpe, Okoleokwe and Ogbu (2018), designed and fabricated a fish feed pelleting machine in order to increase the effort of fish farmers to grow fish continuously and feed the nation with diet full of fish. Survey has pointed fish feed as one of the outstanding factors limiting the progress of the farmers as the high cost of feed scare farmers from active fish farming. The locally fabricated electrically powered fish feed pelleting machine, driven by three electric gear motors of 3hp,1.8hp and 0.7hp that drive the screw conveyor at the barrel, the hopper conveyor and the extrusion cutter respectively. The components of the machine were locally sourced and locally fabricated. The machine's pelleting efficiency was calculated at 0.97% and was capable of producing 0.053kg of feed per second. Muo*et al's* design defers from this study based on the power source for operating the machines, which gives added cost to the machine.

Statement of the Problem.

The modern fish mill plants produced by the Chinese and Asians are elegant but very expensive (LIVI, 2014) and the locally manufactured, electrically or fuel operated fish feed machines are said to be expensive, while the manual machines are perceived to require more force for the operation of the machine because it does not have an external feature or system which will increase the mechanical advantage of the machine. Consequently, there is a need to improve the locally developed manual machines that will produce the same pellets efficiently, reduce the force/torque of operating the machine, and be affordable and easier to operate by the farmers. Kaankuka and Osu (2013), noted that when pellets are compressed the loss of nutrients through leaching is minimized unlike the loose powdered feed. The pelletized fish feed will go a long way to maximize profit from fish production and minimize wastage. This will enable the nation to produce more fish to meet the protein, mineral and oil needs necessary for a healthy nation and also conserve foreign currency. Pelleting of feeds, however, would need a pellet mill, a machine used to create a cylindrical pellet from a mixture of dry powdered feedstock, such as maize, soybeans, fish meal and a wet ingredient, such as molasses or steam (Romallosa & Cabarles, 2018). The pellets are made by compacting the mash or meal into small holes in a die, which is usually round, and the pellets are pushed from inside to the pelletizing cylinder out of the die holes.

Therefore, in order to reduce the manual operating torque of the machine but effectively produce pellets efficiently, the researchers have fabricated a manually operated fish feed pelletizer with an incorporated chain and sprocket system to enhance the efficiency of the machine as well as include three detachable interchangeable disc-die plates of different diameter holes to produce different sizes of feed using locally available material. This will aid small scale farmers to have affordable machine and enable them process feeds using their own desired nutrients composition for their fishes. Since the machine is manually operated, it eliminates the need for electricity and fuel which are scarce in the rural areas. It can also be easily moved from place to place, even with use of wheelbarrows.

Purpose of the study

The purpose of this study is to fabricate a low-cost manual fish feed pelletizer with interchangeable die plates. Specifically, the study intends to:

1. Determine the efficiency of the produced fish feed pelletizer and
2. Determine the production rate of the pelletizing machine.

Research Questions

1. What is the efficiency of the produced fish feed pelletizer?
2. What is the production rate of the pelletizing machine?

2.0 Materials and method

2.1 Design considerations

The general consideration in designing this manual operating pelletizing machine is to produce a machine that is easy to operate, that has high efficiency and of low cost. Material selection in terms of availability and suitability, die thickness and diameter of holes are factors in pellet quality and quantity, overall cost, efficiency and output, speed of rotation for each die thickness/hole diameter combination, the ratio of moisture added to a given volume of feed.

2.2 Pelletizing machine description and operation

The machine components consist of Hopper, Shaft, Spiral conveyor, Pellets' outlet, Ball bearing, Industrial bearing, perforated die, Pelletizer cylinder, Hopper throat, Chain, Sprocket, Chain guard, Collection tray, Handle and Frame, (See figure 1).This machine operates on the principle of rotational motion of the shafts. Sprockets and chain are used to transmit power to the three shafts using a Chain and Sprocket System (CSS). The spiral conveyor is attached to the shafts that rotate in same direction, the loading of un-pelletized feed is done manually through the hopper, the un-pelletized feed falls due to force of gravity, the handle is wound rotating the chain and sprocket system through the shaft as well as the spiral conveyor in the pelletizer cylinder where the feed experiences circular orbit in a horizontal plane about the axis. With the help of the shaft and cylinder, the force on the cylinder compresses the feed into solid which is pushed through the dies to produce pellets of uniform sizes and shape and discharges out through the holes of the die. The important components of the pelleting machine are the hopper where the feed meal is fed into the machine and the pelleting chamber in the form of worm auger or screw shaft which is seen to propel the feed. The shaft is operated by chain and sprocket system that is powered manually. The output pellet is produced by compacting and forcing it through a die opening via a mechanical process. These whole components rest on the frame which gives support to the machine.

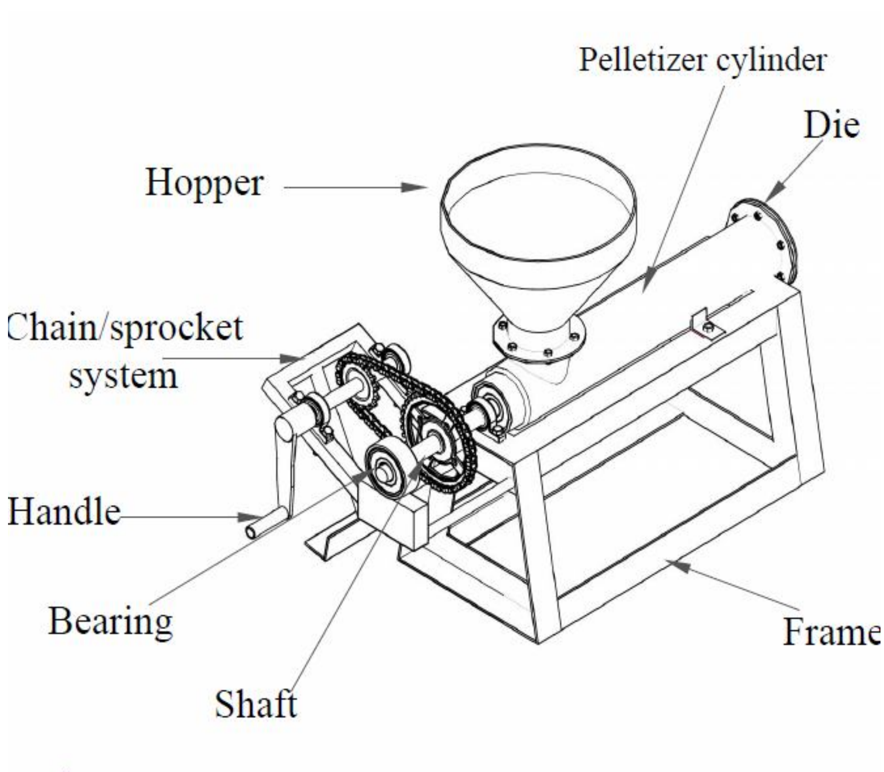

Figure 1: View of the manually operated fish feed pelletizer

2.3 Summary of component design analysis and bill of engineering quantity

The summary of component design analysis is given in Table 1; it covers the machine parts used.

Table 1: Summary of component's design Analysis

Sn	Components designed	Design specifications
1	Hopper	The hopper capacity is 0.031m^3
2	Pelletizing cylinder	The cylinder has a volume capacity of 0.00242m^3, joint to a pellet outlet with a flange of diameter 144mm of galvanize steel pipe.
3	Sprocket and chain	The driver sprocket has 14 teeth while the driven sprocket has 42teeth, having a drive ratio of 3:1. The chain length is 74 pitch units/Chain links and having a center distance of 22.98pitch units.
4	Perforated die	There are 3 interchangeable die of 4mm, 6mm and 8mm diameter with 5mm thickness mild steel.
5	Power source	The machine is manually operated with the use of a wind handle connected to a chain and sprocket system.
6	Spiral conveyor	Length of 365mm and diameter 35mm of mild steel.
7	Shaft	25mm diameter and 360mm length of mild steel.
8	Chain	Motorcycle chain model: 420-1-106L
9	Bearing	The bearing type is single row, deep groove, ball bearing and has the following parameters; bore (35 mm), width (17 mm) and outside diameter (72 mm).

2.4 Evaluation of the Machine

The output of the machine in terms of pelleting efficiency, production rate and broken percentage was tested using a Chain and Sprocket System with three (3) interchangeable die plates having perforation hole diameter of 4 mm, 6 mm and 8 mm at a steady speed.

The feed used for the test was poultry feed (Oracle starter chicken mash), which was milled again to give very fine aggregates. A sample of the feed weighing 2kg was prepared and tested on the machine for each die plate operation.

3.0 Results

3.1 Efficiency of the machine

The efficiency of the machine was tested using a Chain and Sprocket System with three (3) interchangeable die plates having perforation hole diameter of 4 mm, 6 mm and 8 mm.The efficiency of one chain and sprocket system showing the efficiency of the machine is given in Figure 2. The fish feed pelletizer efficiencies are measured against the variation in die plate perforation diameters of 4 mm, 6 mm and 8 mm for the one chain and sprocket manually operated system. For the 4 mm die plate, 2 Kg of wet feed was fed into the machine's hopper and was pelleted. The efficiencies of the machine using a 4 mm die plate having replicates of 1, 2 and 3 were 82%, 87% and 88% under the processing time of 0.104, 0.084 and 0.083 (hour) respectively. The 6 mm die plate as well was tested using 2Kg wet feed mash which was fed into the machine's hopper and was pelleted, efficiencies for replicates of 1, 2, and 3 were 85%, 86% and 87% with processing time of 0.71, 0.067 and 0.066 (hour) respectively. Lastly, for the one chain and sprocket manually operated system the 8 mm die plate having replicates of 1, 2 and 3 for 2Kg wet feed pelleted has efficiencies of 80%, 80% and 87% with processing time of 0.06, 0.06 and 0.05 (hour) respectively. The average pelleting efficiency of a CSS for 4mm, 6mm and 8mm perforated die plate were derived to be 86%, 86% and 84% respectively. The total average Pelleting efficiency of 1CSS was derived to be 85%.

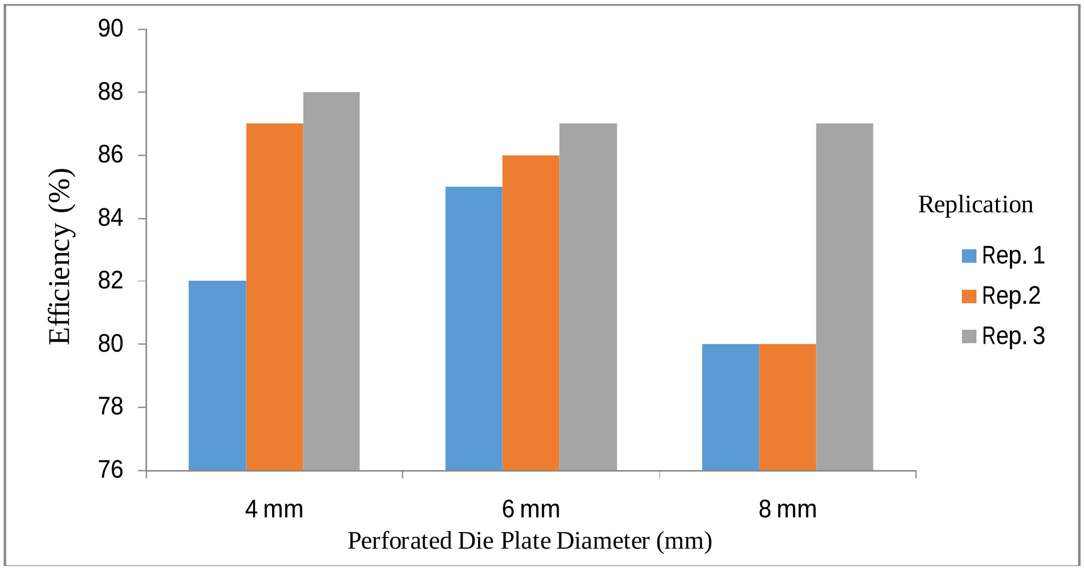

Figure 2: Chain and Sprocket System showing the efficiency of the machine

3.3 Production Rate of the Pelleting Machine

The production rate which was computed using the test carried out using the variation of die plate perforation diameters with one chain and sprocket system was evaluated using 2 Kg of wet formulated feed.The Chain and Sprocket System showing the production rate of the machine is given in Figure 3. The machine production rates were calculated from the data collected during the machine's performance evaluations. The rate of producing pelleted feed was plotted against the various die plate perforation diameters. The 4 mm die plate perforation diameter had the production rates (Kg/hr.) of 10.6, 13.3 and 13.6 under replications of 1, 2 and 3 respectively. The 6 mm die plate perforation diameter production rates (Kg/hr.) were 16.1, 16.9 and 17.1 under replication 1, 2 and 3 respectively. While the 8 mm die plate perforation diameter production rates (Kg/hr.) were 18.8, 18.9 and 22.8 under replication 1, 2 and 3 respectively. Based on the average production rate of CSS for 4mm, 6mm and 8mm perforated die plate were derived to be 12.5kg/hr., 16.7kg/hr. and 20.2kg/hr. respectively. The total average production rate using the CSS was derived to be 16.5Kg/hr., which is an improvement over that reported by Burmamu, Aliyu and Tya, (2015) which was a one disc die design which had a throughput of 9kg/hr.

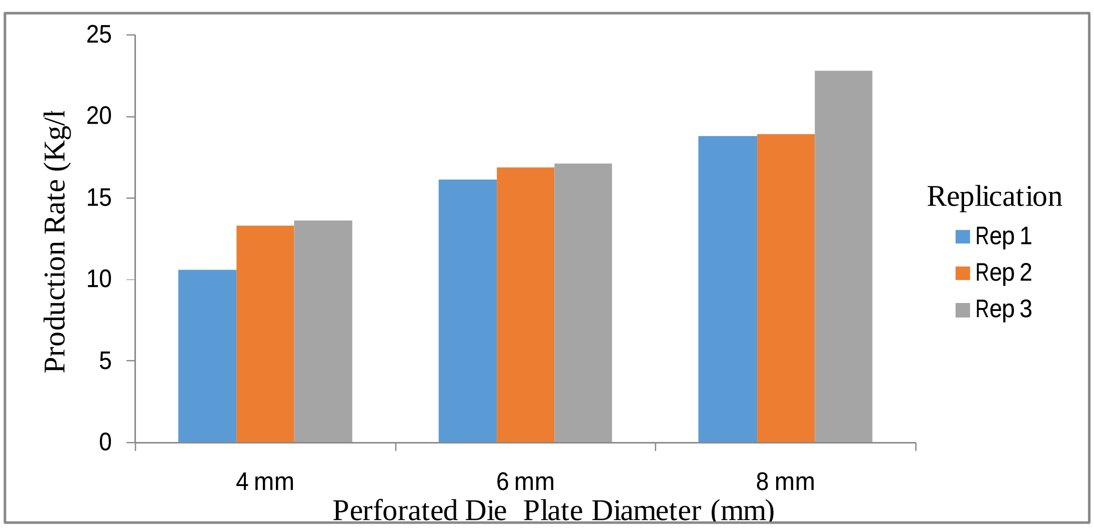

Figure 3: Chain and Sprocket System showing the production rate of the machine.

Discussion of Results

The Chain and Sprocket System manual fish feed pelletizing machine with three interchangeable die plates was produced. This is comparable to that produced by Burmamu, Aliyu and Tya (2015) who also produced a manual fish feed pelletizing machine for use by local farmers. The Chain and Sprocket machine is cheaper than that produced by Burmamu*et al*'sas this one costs just about sixty-five thousand naira (₦65,00) to produce. The Chain and Sprocket System machine also costs less than all the electrical fish feed machines produced by Nwaokocha and Akinyemi (2008), Ojoma, Agbetoye and Olugunagbe (2010) and Muo,Okpe, Okoleokwa and Ogbu (2018).

The efficiency of the fabricated Chain and Sprocket machineis 85% which is slightly lower than the machine produced byOjoma, *et al's* (2010), which used an electric motor and had an efficiency 87.6% which can be attributed to steady electric supply. However, the efficiency of the CSS is lower than that by Burmamu*et al*'s (2015) which was 88.3%, though itself a manual machine.

The Chain and Sprocket fish feed pelletizer produced has a production rate or throughput of 16.5kg/h which is higher than the machine produced by Burmamu*et al's* (2015), which was 9kg/h. This can be attributed to the introduction of the chain and sprocket in the fish feed pelletizing machine produced for this study. The production rate of the machine under study is however lower than the production rates of all the electrically operated fish feed pelletizing machines reviewed. This is also attributed to the steady electrical power supply to these machines.

4.0 Conclusion

A manually operated fish feed pelletizer was fabricated, which consisted of a chain and sprocket system. It had 3 interchangeable die plates which enables the farmers to have different sizes of pellet feeds depending on the sizes of fish to be fed. The fabricated manual operated fish feed pelletizer was tested and the overall performance of the machine was verified. The materials that were in contact with the feed were made of high carbon steel. This machine also enables farmers to formulate and pelletize their locally made feeds for their fishes. It also has provision for additional die plate diameters for other sizes of pellet feed as may be desired by the farmers. Asides the machine being originally designed for fish feeds; it is observed that it can as well be used to make feed pellet for other livestock whose feeds are consumed in pellets. The result generally indicated that the 1CSS had higher pelleting efficiency as well as production rate.

Recommendations

1. Fish farmers should avail themselves of this CSS machine since it is easy to assemble and disassemble and it is also very cheap and therefore very affordable.
2. In view of the fact that electricity is not constant in Nigeria and fuel is expensive and at times very scarce this manually operated a CSS will save fish farmers that trouble and provide ready means for them to produce their own fish feeds with the nutrient formulation they want instead of going to buy from commercial fish feed sellers.
3. Local entrepreneurs are also encourage to produce this machine in large quantities to make them available to fish farmers.

References:

Atoyebi,G. Y. (2007). *Modification and testing of worm fish meal machine.* Department of Mechanical Engineering Project Work, University of Ilorin, Nigeria.

Burmamu, B. R; Aliyu, B.&Tya, T. S. K. (2015). Development of manually operated fish feed pelleting machine. *International Journal of Research in Engineering and Advanced Technology,* 2(6), 23-32.

Kaankuka, T. K. &Osu, D. T. (2013). Development of a revolving die and roller fish feed pelletizer. *International Journal of Engineering Innovations and Research.* 2(1), 105-110.

LIVI Machinery Manufacturing Co. Ltd; (2014). Modern fish feed machinery for all sizes of fish. ZhengzhonLivi. Manufacturing Co. Ltd. https://www.exportersindia.com.zhengz.

Muo, V. I; Okpe, B; Okoleokwe, V.&Ogbu, C. C. (2018). A design and fabrication of fish feed pelleting machine. *International Journal Science Research and Management,* 6(7), 78-84

Nwaokocha, C. N. &Akinyemi O. O. (2008). Development of a dual mode laboratory sized pelleting machine. *Leonardo Journal of Science*, 13(1), 22-29.

Ojomo, A. O; Agbetoye, L. A S. &Olagunagba, F. O. (2010). Performance evaluation of a fish feed pelletizing machine. *Journal of Engineering and Applied Sciences*, 5(9) 88-97.

Olugboji, O. A; Abolarin M. S; Owolewa, M. O. & Ajani, K. C. (2015). Design, construction and testing of poultry feed pelleting machine. *International Journal Of Engineering Trends And Technology,* 22(4), 168-172.

Olusegun, S. D; Adekunle, A. S; Ohijeagbon, I. O; Aknde, K. A. & Mohammad, B. G. (2017). Design, fabrication and evaluation of fish meal pelletizing machine. *Journal of Science and Technology,* 37(1), 51-63.

Omitoyin, B. O. (2007). Introduction to fish farming in Nigeria. Ibadan University Press, University of Ibadan, Nigeria.

Romallosa, A. R. D. &Cabarles, J. C. (2018). Technical evaluation of a roll-type extrusion pellet mill for animal feed production. Journal of Agriculture and Natural Sciences, 5(1). Doi:10.30845/jals.v5nlp2.

Wondra, K. J; Hancock J. D; Behnke, K. C; Hines, R. H. & Stark, C. R. (1995). Effect of particle size and pelleting on growth performance, nutrient digestibility, and stomach morphology in finishing pigs. *Journal of Animal Science,* 73: 757-763