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On studying different types of pelletizing system for fish feed

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Abstract
Feeding pellets is advantageous to both aquatic animal and its cultivators which distribute the required nutrients to fishes**.** The form of pellet feed includes proper provision of nutrient to the animals and minimizes the feed wastage. Pelletizer is a mechanical device operated via manually or electrically, which is used to create a pellet by the process of compression as well as molding. The machine operations are: grinding, mixing and extrusion. The differing characteristics are subjected to the pelleting flow processes of heat, moisture, and pressure of feed ingredients. This study addresses the different type of pelletizers. Here, we discuss the revolving type and screw type pelletizers that have potential to produce feeds in the field of fisheries, poultries and so on. The energy transmission of the pelletizer depends on pelleting efficiency, percentage recovery and throughout capacity of the machine. The size of the pellets is based on the cross section of the various types of dies that are discussed.

Keywords: Pellet feed, moisture, pressure, grinding, mixing, extrusion, dies

1. Introduction

Pelleting is considered as a profession, involves imprecise measurement, uncertain results, and indefinable quality of feed. The operation of the pelleting process is known by the characteristics of the feed (moisture, content, fiber, etc.). Pelleted feeds are defined as “Feeds formed by extruding individual ingredients or mixtures by compacting and forcing through die opening by any mechanical process”. Pelletizing is the most frequently used method for producing pellets which increases the efficiency of the utilization of the nutrients. This process increase the bulk density, reduces storage and transportation costs which is easy to handle. Pellet feeds size depends on the size of the cultivated species that have lower densities, which enable them to float on the surface of water for long period. In pelleting processes (known as Agglomeration process) pellets are compressed, and therefore loss of nutrients through leaching is minimized unlike the powdered feed. The pelletizing methods are: (i) wet pelletizing where no compression is done and (ii) dry pelletizing where the pellets are formed by compression. Increase in temperature gradually increases the gelatinization of the starch. Gelatinization occurs by mechanical means such as grinding and pressure. The moisture, temperature and time involved combine to impart an adhesive surface to starch and condition ingredients which, when subsequently dried, improves pellet hardness and water stability.

Sunil *et al*. (2017) [19] designed a pellet machine that provides advantage of producing different size of pellets using different dies. Major problem in machines are unbalancing problem of voltage in multilevel inverter so they suggest a modified switching scheme for balancing the capacitor voltage. It gives the improved performance of the machine [14]. Van Quyen & Nagy (2016) [11] designed a model of the pelletizing behavior of different raw materials based on piston press single pelletizer unit (SPU). The amount of the raw material is less in this process and the parameters could be changed easily [15]. Ambalkar (2018) [2] designed a pellet machine based on the length diameter ratio. The active length (L) / diameter (D) of die hole is one of the factor used to regulate the pellet quality. The pellet feed formation is depend upon (L/D) ratio, peripheral dies speed, number of pellet passing through the die. A higher L/D ratio- production of denser pellets, smaller production, consume higher energy for production. Lower L/D ratio - softer pellets, higher production and it consume lower energy for production.

Keeping in view, the pelletizing machine is proposed to be investigated with the following objectives

1. To modify the existing pelletizing unit for production of aqua pellet feed with enhanced floatability and water stability characteristics.
2. To determine the functional and nutritional parameters of the developed aqua pellet feed.
3. To determine specific energy requirement per ton aqua feed production.
4. To investigate techno-economic feasibility of versatile pelletizing unit and to develop a user friendly software to assess techno-economic viability of multi-feed production plant.

For many years, the processing of pellet feed is achieved by simple and common techniques, which are basically corn, millet, cereal grains and their by-products. They have been classified into hot or cold processes depending on the requirement of the heat. Other classification is based on the process is wet or dry. In ancient time, the pelleting process involved in mixing the feed ingredients and pelleting them without any treatment. The rationale for this approach was to prevent alterations to vitamins and proteins due to the addition of heat to the feed mix. The type subjecting pellet-forming mixtures of animal feed, water and steam by passing the mixtures through a conditioner prior to introduction into the pellet extruders. The addition of steam improved production rates, reduced die wear, and improved pellet quality. Often Pelletizer used for large or small scale production and is applied in farms and industries. The machine pelletizes the material which mixed with suitable media. Considering the need for the farming business they design a cost effective machine capable of converting powdery feed material into pellets. Such machine is expected to of high efficiency in order to minimize the cost of farming and improve the economy through income generation. In Pelletizer machine the flow the material controlled by the rotation of the pelletizing dies and the pellets are produced by the shape of the die. In several occurrence of pelleting has become socially gainful and economically viable. Considering the need for the farming business, in this paper a cost effective machine is designed which is capable of converting powdery feed material into pellets. Such machine is expected for high efficiency in order to minimize the cost of farming and to improve the economy through income generation. In Pelletizer machine the flow the material controlled by the rotation of the pelletizing dies and the pellets are produced by the shape of the die.

2. Materials and Methods

2.1 Components Description

The following parts are involved in Pelletizer machine. The frame, barrel, hopper, screw conveyor, die, pulley and motor. The machine components were made of mild steel. In pelletizing machine various processes are involved like mixing, crushing, rolling, grinding, extruding and chopping.

2.1.1 The frame stand

The frame acted as a support to other components. It has a rigid structure (fig 2.1.1(a)) and designed to withstand dynamic stresses. The dimensions of the frame based on the assembled components of pelletizer (fig-2.1.1(b)). It is made up of non-corrosive material. It has fixed to the ground (machine foundation) to eliminate the vibration created by the equipment or else the bearing support is present at the bottom. The base of the frame which provide the equipment can be stabilized and motion reduced by lowering the equipment. It is commonly used to support various external loads. It was designed to alter the effects of various forces.

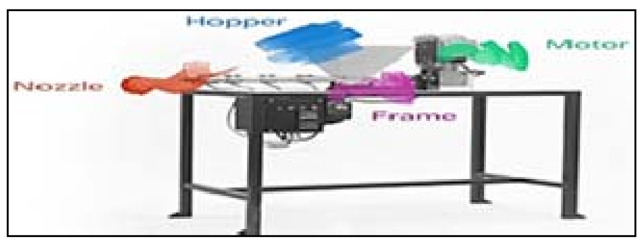

Fig 2.1.1(a): Frame

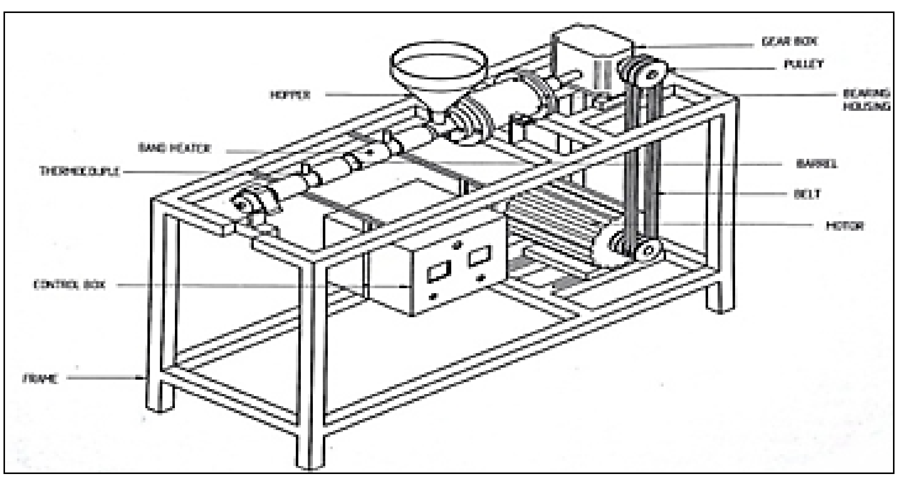

Fig-2.1.1(b): Frame with components

2.1.2 The Barrel

The barrel (cooper) is a hollow cylindrical container and the outer structure of the machine. A flange was joined to the end of the barrel to support the die plate. Barrels have a variety of uses including storage of water and oil. Its surface hardened and have metal contact between the flights and barrel (Fig-2.1.2). The perfect barrel of the screw contains tighter tolerance and proper profiling. The barrels inside diameter should also be checked and visually inspected for damage. The measurements, along with a visual inspection, should provide enough information to determine whether screw or barrel damage has occurred. It can be fabricated from a solid piece of metal.

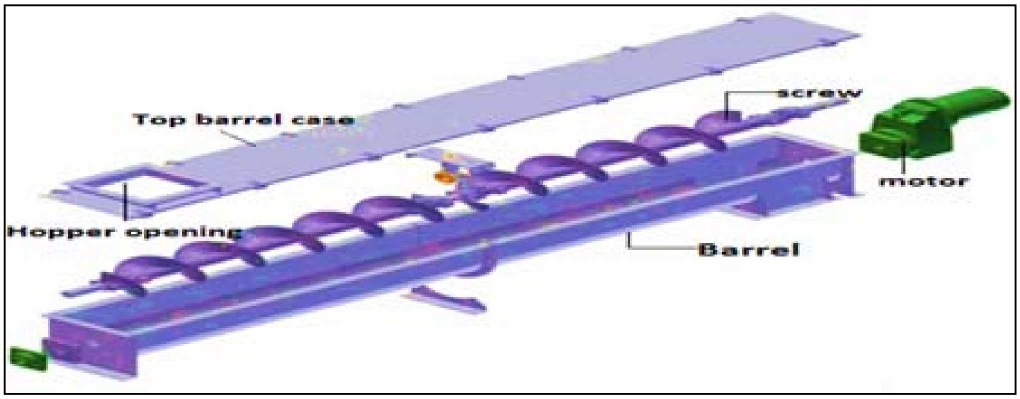

Fig 2.1.2 Barrel

2.1.3 The Hopper
The hopper is a funnel shaped frustum cut out of a square pyramid (Fig -2.1.3). A storage container used to distribute fine ingredients through the use of a receiving chute to maintain control flow, sometimes controlled by external agitation. A storage container used to collect fine ingredients designed to easily distribute materials by utilizing the action of gravity. Hoppers are commonly mounted to allow the groups of wide range of quantity. Most of the hoppers are made of steel.

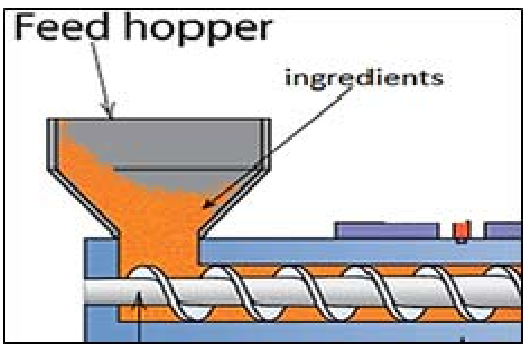

Fig 2.1.3 Hopper

2.1.4 The Die plate
It is required to restrict the flow of feed material and to provide the cylindrical shape of the pellet. A die is a specified tool used in manufacturing industries to chop or shape the material. Pellets made with die ranges from simple feed to complex feed used in advanced technology. The different size dies (Fig-2.1.4) are used to create a different size pellets.

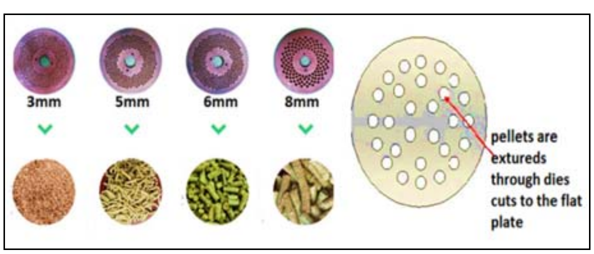

Fig 2.1.4 various type of dies

2.1.5 The Screw conveyor
The screw conveyor was carried on a solid shaft (Fig-2.1.5(a)). It conveys the ingredients along through the die. A screw conveyor is placed inside the barrel and conveys the ingredients by utilizing the friction between barrel and screw. They are used in many bulk handling industries. The flow of the material inclined upward by the operation of screw conveyor. The performance of the screw based on the threads and pitch length of the screw (Fig-2.1.5(b)). When the ingredients reach the spacing or the pitch length of the screw, it lifts horizontally conveying the material towards the die. A variable screw conveyor using the internal friction within a powder or bulk solid to transfer the forward motion of the powder in contact with the spiral to the whole tube contents. The following formula is used to calculate the power requirement of the screw

$$P = [QL(W_0 + \sin\beta)]/3600\eta\ KW$$

Where, P- Power, Q - Energy, W - Work, η - Efficiency

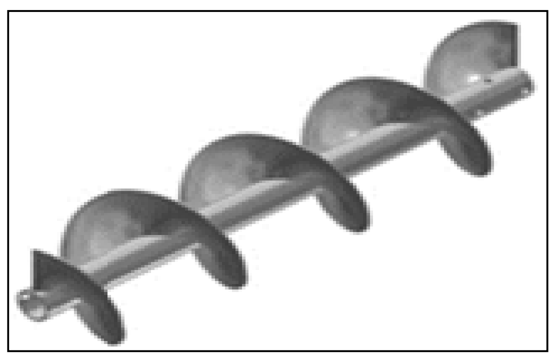

Fig 2.1.5(a): Screw

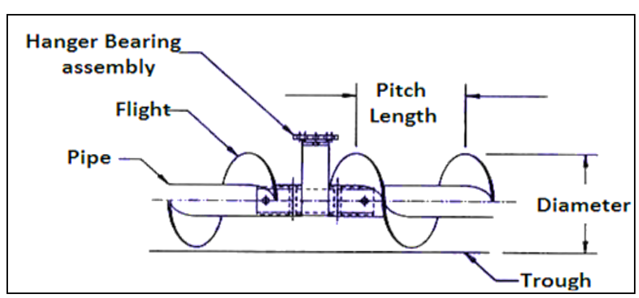

Fig 2.1.5(b): Screw components

2.1.6 The cutter

The cutter is used to cut the extruded product of the required size (Fig-2.1.6(a)). Cutting tool (Fig-2.1.6 (b)) materials must be harder than the material of the work piece, even at high temperatures during the process; the tool must have a specific geometry, with clearance angles designed so that the cutting edge can contact the work piece without the rest of the tool dragging on the work piece surface. The degree of the cutting face is very important, according to the tool width, number of teeth and margin size. Suppose to have a long working life of tool, all of the above must be optimized, including the speeds and feeds.

Fig 2.1.6(a): Operation of the cutter

Fig 2.1.6(b): Cutting tool

3. Classification of pelleting system

The principle behind process of pelletizing (also known as agglomeration) is the opposite of grinding technology: it consists of gathering together or clustering fine solid particles in order to form elements of larger dimensions (spheres, bricks or even cylindrical pellets).Pelleting system can be classified according to their moisture content into two main groups. The classification is given in Fig 3(a).

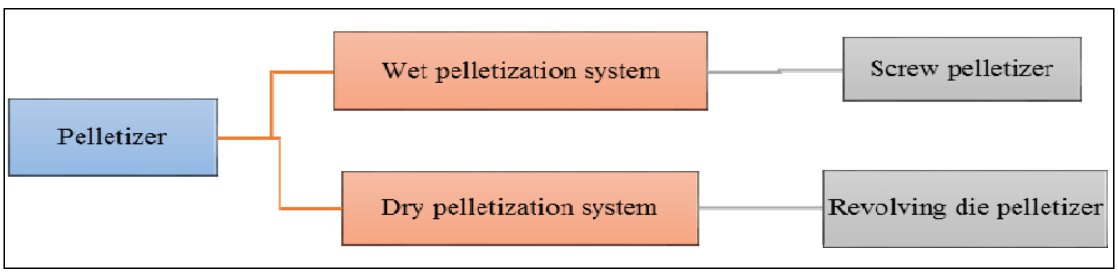

Fig 3(a): Classification of Pelleting System

3.1 Wet pelletizing system

In wet pelletizing system wet powder particles is agitated with steam conditioning and thumbed to form pellets. In this type the compression force is comparatively less. The particles cohesion is obtained through the addition of a binding liquid and the mechanical action of a suitable device. Drying process is necessary to dry the pellets. The type subjecting pellet-forming mixtures of animal feed, water and steam by passing the mixtures through a conditioner prior to introduction into the pellet extruders. The addition of steam improved production rates, reduced die wear, and improved pellet quality.

3.2 Dry pelletizing system

Pellets are formed by compression without steam conditioning, their cohesion being guaranteed through the combined effect of the reduction in particle spacing and the increase in their contact surface. In this system the compression force is too heavy because the raw materials are directly used in solid state. Drying process is not required in this system. The following fig-3(b) describes the processing of fish feed.

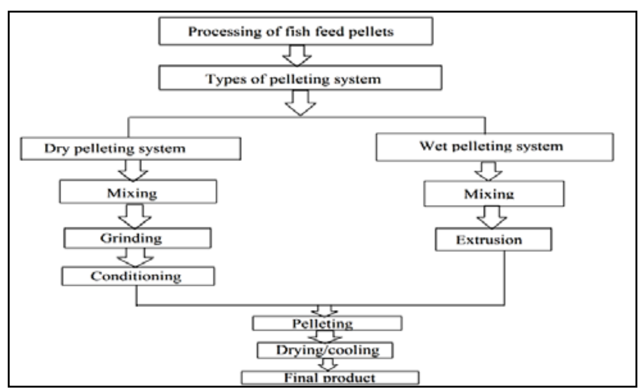

Fig 3(b): Flow chart for pelleting process

4. Design methodology

4.1 Types of pelletizer

The pelletizers are classified into following types,

1) Screw Pelletizer

2) Revolving die and Roller Pelletizer

4.1.1 Screw pelletizer

Single Screw Extrusion (Fig-4.1.1(a)) is one of the process or method used to processing materials of ingredients (raw material food) in wet condition. It is mainly used to improve the quality of the output such as pellets as well as to increase its production by creating pressure and rpm of the screw conveyor. Then it forces or compresses the wet ingredients and the pellets come out like the shape of the die. Single screw extrusion is used within a cylindrical barrel to continuously push the ingredients through the constant profile die (Fig-4.1.1(b)), production rate is typically measured by mass per hour, and is controlled by the screw speed of the machine. The following advantages are present in this type when compared to other machines.

1) This pelletizer comparatively much cheaper than other machines
2) When working, It has less shear

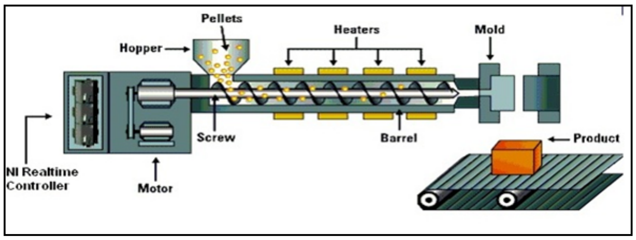

Fig 4.1.1(a): Screw pelletizer

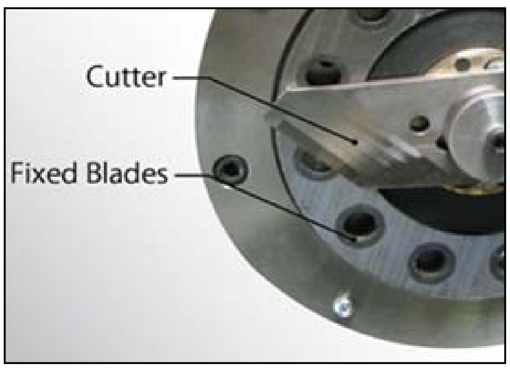

Fig 4.1.1(b): Pelleting zone

4.1.2 Revolving die and roller type pelletizer

In this type die rotation (Fig-4.1.2(a)) initiates the rotation of the rollers which pickup the feed materials and compress it into the die holes to form pellets. This type is used for dry pelletization. When powdered or raw solid ingredients or moist ingredients are used for producing compressed dry pellets by this revolving die Pelletizer (Fig-4.1.2(b)).It was designed and constructed to produce fish feed pellets for small scale fish cultivation unit. The cutting knife is located below the revolving flat die. It is a stationary knife which cuts the emerging strands of feed into pellets as they are discharged through the pelleting chamber to the discharge tray by a tangential force of the rotating die.

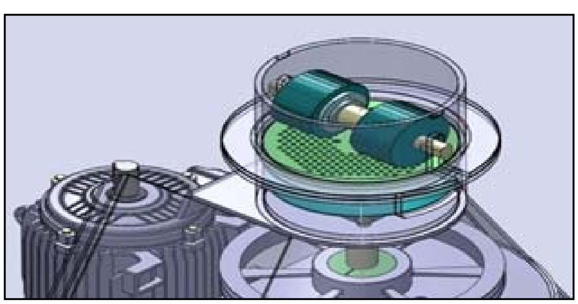

Fig 4.1.2(a): Revolving die

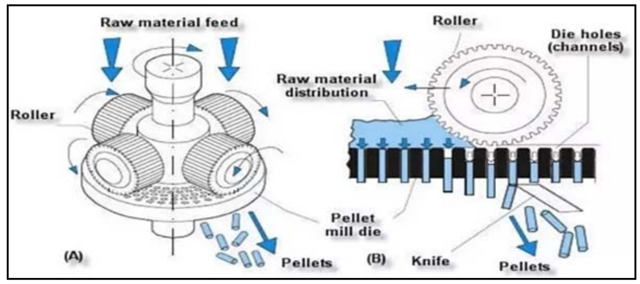

Fig 4.1.2(b): Operating principle of Revolving die & roller

5. Pelleting machine operation parameters

The following formulae are used to find the efficacy of the machine.

Production rate of machine : $R_p = m/t$

Specific energy consumption : $P_s = (P \times t)/m$

Efficiency of pelleting machine: $\eta = W_1/W_2$

Percentage loss due to ingredients not pelletized: $\vartheta = W_a/W_b$

Percentage dryness after day drying: $\kappa = (W_1 - W_3)/W_1$

Notations

R_p	-	production rate (kg/h)
m	-	mass produced(kg)
t	-	time (hr.)
P_s	-	specific energy consumption (kWhkg^{-1})
P	-	power of motor (Kw)
W_1	-	weight of fish meal pellets
W_2	-	weight of ingredients
W_3	-	weight of pellets after 7 days dying
`W_b	-	weight of residual ingredients
W_b	-	weight of ingredients

6. Conclusion and Suggestions

This paper presents a study on the various types of pelletizers which are an incredibly useful tool in the field of aquaculture. The pelletizer is the chance for altering for small adjustment and customization that can yield an extremely high quality product. Here, we discussed the beneficial of pellet feed to reduce the cost and weight of the pelletizer. Also, we suggest that instead of using steel one can use transparent polymer so that the cost and weight of the machine is reduced. The operation of the pelletizers does not require any high technical expertise, so the small-scale fish farmers can conveniently use this machine.

7. Conflict of Interest

The authors have declared that no Conflict of Interest exists.

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