Modification of Feeding Mechanism and Performance Evaluation of Poultry Feed Pelleting Machine

Elsabet Tigistu Takiso

A Thesis Submitted to the Department of Mechanical Systems and Vehicle Engineering

School of Mechanical, Chemical and Materials Engineering

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in Agricultural Machinery Engineering

Office of Graduate Studies

Adama Science and Technology University

July, 2021

Adama, Ethiopia

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DECLARATION

I hereby declare that this MSc thesis entitled "Modification of Feeding Mechanism and Performance Evaluation of Poultry Feed Pelleting Machine" is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

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RECOMMENDATION

I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled "Modification of Feeding Mechanism and Performance Evaluation of Poultry Feed Pelleting Machine" prepared under my guidance by Elsabet Tigistu submitted in partial fulfillment of the requirements for the degree of Mater's of Science in Agricultural Machinery Engineering. Therefore, I recommend the submission of revised version of the thesis to the department following the applicable procedures.

____________________	____________________	____________________
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APPROVAL SHEET

I, the advisors of the thesis entitled “Modification of Feeding Mechanism and Performance Evaluation of Poultry Feed Pelleting Machine” and developed by Elsabet Tigistu; hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

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We, the undersigned, members of the Board of Examiners of the thesis by Elsabet Tigistu have read and evaluated the thesis entitled “Modification of Feeding Mechanism and Performance Evaluation of Poultry Feed Pelleting Machine” and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Agricultural Machinery Engineering.

Chairperson	Signature	Date
Internal Examiner	Signature	Date
Prof. (Dr) Kishor Kolhe		26/07/2021
External Examiner	Signature	Date

Final approval and acceptance of the thesis is contingent upon submission of its final copy to the Office of Postgraduate Studies (OPGS) through the Department Graduate Council (DGC) and School Graduate Committee (SGC).

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School Dean	Signature	Date
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ACKNOWLEDGMENTS

First and foremost, I would like to praise and thank the almighty God for granting countless blessing, knowledge, and opportunity on my thesis.

My deepest gratitude was extending my advisor Dr.Ing.Simie Tola, for his assistance and guidance in reviewing, commenting on, and providing constructive advice throughout my research. Thank you for all of your help and encouragement over the years. I would like to acknowledge all my instructors.

I would like to thank all Agricultural Engineering Research staff members at Melkassa Agricultural Research Center, especially Mr. Laike Kebede and Mr. Dereje Alemu for their invaluable guidance, whose encouragement, guidance and support. My special appreciation goes to Mr. Tilahun Teka, who supported me during the fabrication of the prototype machine.

It gives me huge pleasure to acknowledge Adama Science and Technology University for providing me financial support in the form of a scholarship and offering me to pursue my postgraduate studies in Agricultural Machinery Engineering and for funded my research by grant number ASTU/SM-R/102/19.

Lastly, and most importantly, I would like to thank my parents, and my friends who loved me, supported me; and, who brought more happiness and love to my life. Without their love, support and encouragement, I would not have made this achievement. To them I dedicate this thesis.

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LIST OF ACRONYMS

AIRIC	Agricultural Implement Research and Improvement Center
ANOVA	Analysis of Variance
AOAC	Association of official Analytical Chemists
AoR	Angle of repose
ASABE	American Society of Agricultural and Biological Engineering
ASME	American Society of Mechanical Engineering
CV	Coefficient of Variation
CoF	Coefficient of friction
CSA	Central Statistical Agency
FAO	Food and Agriculture Organization
FR	Feed rate
GIS	Geographic Information System
HTST	High-temperature short-time
MARC	Melkassa Agricultural Research Center
Masl	Meters above sea level
Mb	Bending Moment
MC	Moisture content
Mt	Torsional Moment
rpm	Revolution per minute
PE	Pelleting efficiency
SS	Sum of squares
STDEV	Standard deviations
TpC	Throughput capacity

ABSTRACT

Ethiopia has the highest chicken population in Africa, and about 60% of the total chicken population of East Africa. Poultry production is mainly affected by animal feed because from production cost 60-70% cost is spent on the animal feed. To improve feed quality, increase chicken ingestion, growth, and reduce feed wastage pelleting feed has no alternative. In Melkassa Agricultural Research center there are food extruder machines which have high horsepower, low capacity and lack of feeding and cutting mechanisms. Feeding manually it is hard to find same product quality and optimum machine capacity. To eliminate this problem the modification of feeding mechanism and addition of cutting system was required. The pelleting machine consists of hopper, screw feeder, screw extruder, die plate, cutter and power transmission units (belts and pulleys). The physical properties (moisture content and bulk density) and frictional properties (angle of repose and coefficient of friction) of feed ingredients (maize grit, wheat bran and noug cake) was determined. The split plot experimental design was used; feed rate was the main plot and moisture content subplot. The experiment design was laid as 3x3 with three replications and had a total of 27 test runs (3x3x3=27). To the poultry feed formulation the feed mixed in the ratio of 50:35:15 for maize grit, wheat bran and noug cake respectively. The machine was tested with mixed feed to evaluate its performance in three fed rates (hoppers get opened 25, 50, and 75%) and three moisture content (15, 20, and 25%). Machine throughput capacity, pelleting efficiency increases both in increasing feed rate and moisture content. The optimum machine capacity 35.6 kg/h, pellet efficiency 90.8%, and 91.3% was found on fed rate (hopper gets opened 75%) and 25% moisture content. The improved extrusion machine increased the productivity of the machine, throughput capacity increased and the pelleting task became simple due to addition of the feeding and the cutting system. Thus it can be concluded that the prototype machine produced a quality pellet which is suggested by FAO. Therefore small-scale poultry producers can use this machine to reduce feed wastage, improve feed quality and increase their chicken productivity.

Key words: pellet, extrusion, poultry, screw, die, and cutter.

CHAPTER ONE

1. INTRODUCTION

1.1. Background

The poultry industry is considered as one of the most active meat-producing industries requiring frequent increases in production to satisfy the worldwide demand for poultry meat. The largest broiler chicken producers by country are the United States, China and Brazil with the United States and Brazil contributing to two-thirds of poultry meat exports globally (Abdanan, et al.,2015). In the poultry industry it is well recognized that feed represents the most significant cost of broiler production. Most production costs estimates range from 60-70% as being feed costs. Certainly, the major portion of feed costs is for the ingredients used. However, the cost of feed processing represents a significant portion of feed costs and likely gives the greatest opportunity for influencing broiler performance beyond nutritional adequacy.

In Ethiopia, the term poultry is almost synonymous with chicken. Other poultry species such as guinea fowl, geese, turkeys, and ducks are not common in the country. Poultry production offers considerable opportunities in terms of generating employment opportunities, improving family nutrition, empowering women (especially in rural areas), and ultimately ensuring household food security. Extensive scavenging poultry production is often the domain of poor women. Reasons include that it requires little initial investment and that it does not usually conflict with women's other household duties (FAO, 2019).

In Africa, Ethiopia is the highest in chicken population (Tadelle et al., 2003), and about 60% of the total chicken population of East Africa, which includes local, exotic, and hybrid chicken breeds. Report on the population of Ethiopian chickens estimated to be about 56.53 Million (CSA, 2017). Poultry Production Systems in Ethiopia is an appropriate and locally available resource in livestock populations. Small-scale producers dominate Ethiopian poultry production systems, and poultry production can be categorized as a village (sometimes also called traditional or backward), semi-intensive, and modern (or intensive) production systems (Tadelle et al., 2003).

Since the major production cost incurred in the intensive chicken production system is feed and feed-related costs. Accordingly, there should be an appropriate use of the feed as it determines the profitability and sustainability of the operation (Yenesew et al., 2015). However, feed processing has the potential to improve broiler performance. Consequently, a major emerging area for research in is the preparation of feeding earlier ingestion to increase the value of the feed (Peisker et al., 2006), and ensuring feed palatable, easy to consume and digest by the birds and minimizing feed wastage is desirable (Abdanan et al.,2015).

In Ethiopia Most of the poultry companies have their own feed mills. The feeds produced by most of these companies are intended primarily for consumption within their own farms and only the surplus is sold to other producers. However, not all intensive poultry producers own feed mills. Producers operating at and around 1000 birds purchase compound feeds from larger poultry producers and other companies specialized in feed mill operations. Compound feeds are available mostly in the form of mash. Pellets are not common. Feeding systems are rarely automated, including in large-scale intensive farms operating over 10000 birds (Nigussie , 2019).

Chickens are kept for both eggs and meat production purposes. Local chickens in Ethiopia play a vital role in many poor rural households, they provide scarce animal protein in the form of meat and eggs (Bangu, 2016). Poultry production in Ethiopia is characterized by low output, mainly due to different feed system factors. Production is almost wholly dependent on the scavenging feed resources available within the local environment in small-scale scavenging family poultry systems, such as household waste and food leftovers, field crops, worms, and insects.

One of the processing factors that add the value of the feed is pelletization of feed. Pelleting feeds usually result in an increased density and intake of the ration, and also improves growth and feed efficiency (Yenesew et al., 2015). Researchers and nutritionists continually explore options to reduce chicken production costs. Particle size reduction and pelleting have been shown to improve feed conversion and reduce feed cost in both swine and poultry. Chicken fed pelleted feed have higher body weight and improved feed conversion relative to those fed mash feed. Pelleted feed also has the benefits of decreased feed ingredient separation, decreased feed wastage, improves starch gelatinization, and improved palatability (Chewning et al., 2012). While chickens are feeding, which are fed in troughs, hoppers, or tube feeders, scratch grains are often scattered on the ground. Besides, as feed constitutes 60-70 % of the total cost of production, any attempt to reduce the feed cost may lead to a significant reduction in the total cost of production.

In Ethiopia utmost compound feeds are available mostly in the form of mash, and pellets are not common. Feeding systems are rarely automated, including in large-scale intensive farms operating over 10000 birds (Nigussie, 2019). Those pellet feed producers are using the machine which exports from abroad. The prohibitive costs of imported pelleting machines make them unaffordable to the local producers.

The availability of feed processing equipment that improves feed quality and consequently bird performance also receives more attention. This paper is focused on poultry feed pelleting machines, one of the firsts which have the greatest influence on broiler performance and feed quality.

1.2. Statement of the problem

In Melkassa Agricultural Research Center AIRIC there are food extruder machines, which are imported from abroad. This machine has high horse-power (10 hp), low output capacity with an average capacity of 11-16 kg/h, lack of feeding system (ingredient fed to the machine manually), and the output product is in the form of straight ropes (rod) because there is no cutting mechanism. Through feeding manually it is hard to find a stable and consistent feeding, this causes the machine to operate below its optimum capacity. As Rokey (2000) suggested extrusion rate of the extruder is typically controlled by a feeder screw or other metering devices. Thus, manual feeding affects the output capacity and output product appearances. It also makes the operation very tedious and uninteresting. The cutting mechanism retains the final products with uniform size.

To solve the problems mentioned above, it is essential to improve machines to increase the quality of the pellets, reduce the workforce, make the operation simple, and increase capacity. The development was made in adding feeding, cutting systems and by modifying the die plate.

1.3. Objectives

1.3.1. General objectives

The general objective of this study is to modify the feeding mechanism and performance evaluation of poultry feed pelleting machine.

1.3.2. Specific objectives

- To determine physical and frictional properties of feed ingredients.
- To design and fabricate screw feeder, die plate, and cutter.
- To test and evaluate performance of the machine in terms of machine throughput capacity, pelleting efficiency.

1.4. Significance of the study

The modification on the poultry feed pelleting machine eliminate the drawbacks in the existing pelleting machine include the tediousness and time consuming involved in operating manually feeding feed and cutting to obtain the desired length pellets. The development increased productivity, showed how to effectively use the available power, give a better way of feeding for poultry birds, and it creates an attractive working environment for poultry producers, contributing good insight on the extrusion pelleting machine. Encourage technology transfer in Ethiopia.

1.5. Scope and limitation of the study

The study focused on the objectives of modification of feeding mechanism and performance evaluation of electric motor operated poultry feed pelleting machine. The improved machine parts were designed using CATIA V-5 software, and fabricated using locally available raw materials and then tested using available poultry feed material, performance of the machine evaluated in terms of three feeding rate and three moisture contents, in order to evaluate machine capacity and pelleting efficiency. The data analysis was made using SPSS and Microsoft excel.

This thesis was done on poultry feed pelleting and the parameter tested was machine capacity and pelleting efficiency. However, the machine must be tested by some other parameter using different feed ingredients, die plate, and number of cutting blade.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Poultry production

Poultry production in Ethiopia can be described not only as the production of meat and eggs, but also distribution and retailing of these products. Poultry production systems of Ethiopia are classified into the small-scale intensive, semi-intensive, extensive scavenging and small-extensive scavenging systems. Producers keeping over 1000 broilers or 500 layers are considered in the medium-and large-scale intensive systems. Within such systems, there are large variations among producers in terms of technology use, management level and scale of operation. Although not exhaustive, information is provided on some of the larger companies, with around 10000 birds or more. In the section regarding family poultry production systems small-scale intensive and semi-intensive production systems are treated together. The extensive scavenging and small extensive scavenging systems are also presented together due to the lack of clear statistics identifying these sub systems (Nigussie, 2019).

Poultry feed and nutrition is one of the most critical constraints to poultry production under both the rural small holder and large-scale systems in Ethiopia. The problem is mainly associated with lack of processing facilities, inconsistent availability and distribution and sub-standard quality of processed feeds. Regular availability of good quality feed ingredients and a fully balanced complete feed are essential for efficient poultry production (Alemneh and Getabalew, 2019).

2.1.1. Poultry Feed

Feed is the most important input for poultry production. Poultry feed resources can be described as that of any ingredients, which is eaten by poultry and has nutritional value. The nutritional contribution of an ingredient can be expressed as energy, protein, or micronutrients for birds. However, poultry feed may be described as that containing all the necessary nutrients for the birds to remain healthy and productive. The quantity of each required nutrient varies depending on the species of bird, age, productive state, environmental condition and disease status (Mengesha, 2012).

Figure 2. 1.Chickens feeding on grain, mash, and pellet

2.1.2. Nutrient requirements and feed formulation

Nutrient requirements and feed formulation consists of the calculation of the different amounts of raw materials that are necessary to form a diet that supplies all the nutrients required by an animal (Guerre, 2016). There are different diet source are needed for poultry feed requirements to satisfy nutrient requirements.

Energy Sources; Cereal grains the raw materials most widely used as a source of energy in pig and poultry diets. These compounds also provide proteins, mineral, and vitamins but the main reason for their use is energy. The raw materials used as energy sources are the main component of the diets. are the main contributors, but the types of cereal grains used depend largely on their costs and their local availability for animal diet (Guerre, 2016).

According to Ravindran (2016) maize grit is extensively used as an energy source in poultry feed. In America and Europe, the incorporation rate can reaches 50%–80% of the diets.

Stein and Shurson (2009) recommended cereal by-products (rice bran, maize grit gluten feed, wheat bran feed, confectionary, distillery by-products, and other cereal by-products) are increasingly used in animal feed. Their rate of incorporation can be as high as 10%–15% in some poultry diets.

Protein sources; are the second largest component of poultry diets. As Guerre (2016) recommended protein must available in poultry feed formulation up to 20%.

2.2. Pelleting feed

Pelleting is one of the basic technological operations in animal feed industry. Pelleted feeds have been defined as “agglomerated feeds formed by extruding individual ingredients or mixtures by compacting and forcing through die openings by any mechanical process”. During the process a number of discrete ingredients, which are ground or milled, are mixed and then combined with small amounts/conditioning of liquid before being pressed through a die to form a pellet, which is then cut to size (Dunnett, 2013).

2.2.1. Extrusion pelleting

Food extrusion can be defined as a process of mixing, homogenizing and shaping low moisture food materials and more recently high moisture food materials into intermediate or finished products by forcing them through a specially designed die. The word “extrudate” originates from the Latin word “ex” (out) and “trudere” (to thrust). Food extrusion is a modern high temperature short time (HTST) cooking process with several other unit operations such as conveying, kneading, heating, mixing and forming in a single unit. Extrusion food processing is widely used to restructure starch and food extrusion technology and oil-seeds processing. protein based food materials to manufacture a variety of ready to eat breakfast cereals: paste, bread substitutes and pet foods (Adekola, 2016).

The basic concept of extrusion process is HTST, where the high temperature is a direct result of friction (dry extrusion), or pre-conditioning and steam injection (wet extrusion), or a combination of both. The humidity of treated material in dry extrusion is about 30% while it is up to 80% in wet extrusion. Extrusion is the process in which the material is exposed to high temperatures (up to 200°C) and high pressure, which can range up to 25 MPa (Riaz, 2007). Therefore, this process is classified as heat treatment with high temperatures and short period of its action (Puvača et al 2012). Now, the extruder is considered a HTST bioreactor that transforms a variety of raw ingredients into modified intermediate and finished food and feed products. During extrusion cooking, temperatures can be as high as 200 C, but the residence time is usually 15-20 seconds. For this reason extrusion cooking is called HTST.

Many different materials are formed and shaped through the extrusion process. In the polymer industries, thermoplastics, thermosets, and elastomers are extruded. In the food and feed industries, breads, cereals, feed diets, pasta, snacks, confections, meats, starches, and numerous other items are independent on extrusion. The pharmaceutical and nutraceutica1 industries and metal, clay, ceramics industries use extrusion (Huber, 2000).

2.2.2. Effects of heat treatments on feed ingredients

Effects of heat treatments on nutritionally valuable feed ingredients during extrusion:

Starch: Animals utilize their feed better if a portion of starch in it is previously gelatinized. Starch is stored in the grain in the form of spherical crystals and its molecules are not accessible to enzymes action. During the heat treatment, starch granules absorb water and, depending on the nature and properties of materials, and process conditions (temperature, pressure, length of the process, etc.), the crystalline structure of starch granules is destroyed, which leads to gelatinization . As the degree of gelatinization is higher, the enzymes will dissolve starch more easily (Riaz, 2007).

According to Riaz (2010) and Puvača et al., (2012) pelleting increased the degree of starch gelatinization by 49.6% in feed mixtures for chickens, by 22% in feed mixtures for pigs and by 16% in feed mixtures for young bulls. Presence of water is a necessary condition for the process of gelatinization of starch component, but it also acts as a lubricant and bonding agent increasing the contact surface.

Protein: Extrusion improves protein digestibility via denaturation, which exposes enzyme-access sites. Most proteins such as enzymes and enzyme inhibitors lose activity due to denaturation. The extent of denaturation is typically assessed as change in protein solubility in water or aqueous solutions. These changes are more pronounced under high shear extrusion conditions (Camire, 2000).

The globular proteins from the oilseeds will occur as relatively large particles in the raw materials, but they will also be softened down to the same general size range by the extruder. These proteins hydrate and form viscoelastic dough pieces by agglomeration with the water. In the shearing zone the protein pieces are macerated in the shearing fields between the screws and the other materials. The cereal proteins also form viscoelastic dough which is macerated to small particles (Riaz, 2000).

Figure 2. 2. Pellets

Studies have revealed that feeding assured livestock with pellets have great benefits.

Mbugua et al. (2002) noted that pelleting amaranth diets improved the nutritional value and was beneficial in improving growth of chicks.

Galen et al. (2008) pointed out some other advantages of pelleting feeds, which includes the saves made through decrease food wastage, improvement on feed efficiency, reduced selective feeding, control of undesired micro-organism, increase in bulk density and better handling characteristics. They added that quality addition to the feed include better durability and fewer fines of the pellets, complete pasteurization, increased utilization of feeds, starch gelatinization increment and production of by-pass fat and by-pass protein.

Shah et al. (2018) is stated almost all livestock feeders agree that animals make better gains on pelleted feed than a meal ration. The most logical reasons are that the heat generated in conditioning and pelleting makes the feedstuffs more digestible by breaking down the starches, the pellet simply puts the feed in a concentrated form, and pelleting minimizes waste during the eating process.

Regupathi et al. (2019) also stated that highly compressed pellets facilitate storage and transportation, as large quantity of feeds could be carried economically from one location to the other.

2.3. Pelletizing machine

Pelletizing machine is specialized equipment. It is used for pelletizing of powder materials into pellets. It is original and peculiar with large scale disc-pellet machine and designed on the basis of the large scale disc pellet machine that is used in industries like iron and steel industry, chemical industry, pharmaceutical industry, cement industry, ceramics industry, railway corporations seen in metallurgical workshops and related industries (Kaankuka and Osu, 2013)**.**

Molding of animal feeds inform of capsules, small enough for easy consumption by fishes and poultry is the major function of pelleting machine. Livestock feeds is processed with the aim of maximizing utilization efficiency of the nutrients (Tillman and Waldroup, 1986).

Olugboji et al. (2015) design, construction and testing of poultry feed pellet machine. The machine was a cheap, electrically operated feed pellet machine with locally available materials. Two horse power electric motor was used to drive the machine. The main features of the machine are the hopper, pulley, supporting frame extrusion barrel, bearing housing, the knife cutter. The experimental test was done by mixing various ingredients thoroughly into paste form using water as binder and was then feed into the hopper. The machine was then set to gyration. This extended through the extending holes of the die plate and was cut to desired sizes by the cutting mechanism. The experimental work was carried out by testing the machine and the operation capacity was found to be 5kg/hr.

Orisaleye and Ojolo (2016) were designed and developed a livestock feed pelleting machine and tested to evaluate its performance. The machine consisted of a screw conveyor, die, barrel and hopper. It can be driven by an electric motor or a prime mover. The machine was tested with broiler's mash and at different levels of moisture content using 500, 750 and 1000 cm^3 each of water and starch binder as preconditioners. The best pellets were formed using 750 cm^3 of either starch or water. The average specific energy consumption when 750 cm^3 of starch binder was used was 0.69 kWh/kg while it was 0.93 kWh/kg when water was used as preconditioner. The density of the pellets varied between 0.7 and 1 g/cm^3.

2.4. Type of extrusion pelleting machine

Extruder classified as dry and wet extruder (Nabil, 2000).

2.4.1. Dry extruder

Dry extruders the term ‘dry’ extrusion, as opposed as wet extrusion, refers to the fact that this type of extruder does not require an external source of heat or steam for injection or jacket heating, and all product heating is accomplished by mechanical friction on capitalized on the inherent moisture and/or oil for providing lubrication. Dry extruders can process ingredients which have a wide range of moisture contents, i.e. 10–40%, depending on the premixed formula. Dry extruders have the option of water injection during extrusion. Usually starchy material requires some moisture in order to gelatinize. Recent research has shown that efficiency/throughput of the extruder is almost doubled if the starting material can be preconditioned with steam and water. In dry extrusion, pressure and temperature are at their maximum just before leaving the die. The die design and opening also play very important roles in pressure build-up. The cooking range in a dry extruder can be 82–160ºC (180–320ºF) with very high pressure.

2.4.2. Wet extruder

Wet extruder ‘Wet’ means that steam and water can be injected into the barrel during processing. Typically, the barrels of these machines are also equipped with heating and cooling jackets. They process more tonnage of extruded products than any other extruder design. The products produced range from fully cooked, light density corn snacks, to dense, partially cooked and formed pastas (Rokey, 2000).

2.5. Screw extrusion pelleting machine

Several types of extruders are used for processing food and feed products. Some are single screw, some are twin screw, some have internal steam locks, some have grooved barrels, some have continuous flights, and others have interrupted flights. Some extruders generate their own heat by friction for cooking and other use additional heat sources like steam for cooking purposes. All these extruders work depends upon their application (Riaz, 2010).

Screw extruders are work in single- , or twin-screws rotating in a stationary barrel to convey material for-ward through a specially designed die (James, 2006).

Screw extruders are most likely used now days. On the basis of screw design, two types of extruders are most commonly used: Single-screw extruder and Twin-screw extruder.

2.5.1. Single-Screw extruder

Single screw extruder contains one screw which continuously rotates in barrel of single screw extruder. Single-screw extruders were first used in the 1940s to produce puffed snacks from cereal flours and grits. During transport through the extruder, mechanical energy from the rotation of the screw is converted to heat. A single-screw extruder is a drag flow device, i.e. Material is dragged down the barrel. Single-screw extrusion operation depends upon the pressure requirements of the die, the slip at the barrel wall (controlled by the barrel wall temperature, the presence of barrel wall grooves, or both) and the degree to which the screw is filled (Frame, 1994 and Riaz, 2000).

2.5.2. Twins-screw extruder

Two rotating parallel screw having same length is present in barrel of twin screw extruder. Twin screw extruder entangled than single screw extruders, and yet gives substantially better control and more adaptability. The flow of product will be uniform through barrel as a result of positive pumping of screw flights (Gaikwad, 2019).

2.6. Operation of single screw extruder

2.6.1. Principle of operation single screw extruder

Material is fed continuously into an inlet hopper and transported forward by the rotation of the screw. As it reaches the die, the pressure increases to the level required to propel the extrudate through the die openings. The rotating screw moves material from inlet to discharge as a result of the material slipping on the screw surface. The friction between the material and the screw surface results in heating of the material (Huber, 2000).

2.6.2. Mechanism of flow in single-screw extruder

As the screw rotates inside the barrel, the movement of the material along the screw is dependent on whether or not it adheres to the screw and barrel. The material flow in single-screw extruder discussed below.

Drag flow: to convey the feed material through the barrel of the extruder and to develop pressure at the die. The frictional force between the material and the barrel wall is the only force that can keep the material from turning with the screw.

Cross-channel flow: arise by the rotation of the screw in the barrel. This flow does not contribute to the net movement of material along the barrel but instead recirculates it within the screw flights and hence is responsible for some of the mixing action of the extruder.

Pressure flow: causes movement backwards down the extruder barrel, causing further mixing of the product.

The three flows combine to give the net flow of material out of the die (Rokey, 2000).

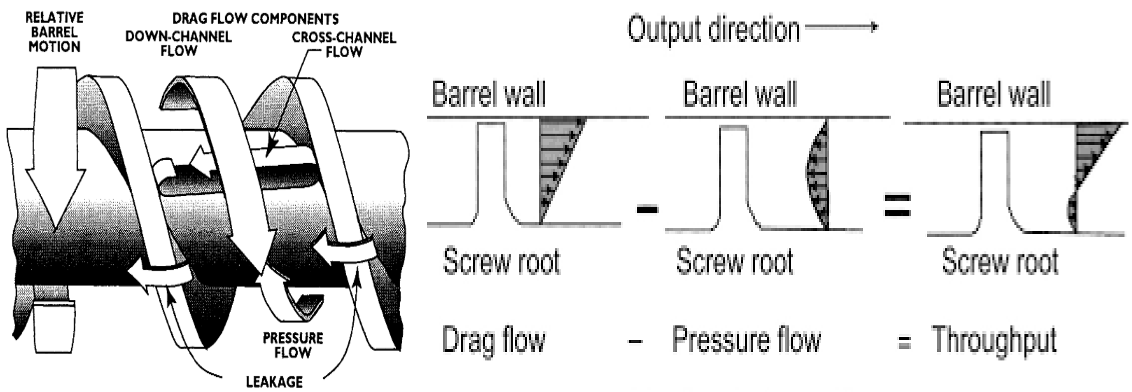

Figure 2. 3. Flow components and velocity profile in single-screw extruder

2.7. Feeding device

Feed conveyance systems are an essential part of an extrusion operation. Consisting and uniform feeding of materials is necessary for the consistence and uniform operation of an extruder. Hoppers or bins are integral part of feeding devices and are used to hold the dry ingredients above the feeders. The feed delivery system must be able to uniformly feed a dry and/or liquid ingredient or blend of ingredients. The extrusion rate of food extruders is typically controlled by a feeder screw or other metering device. The output of the single-screw cooking extruder is, therefore, independent of screw speed. The feeder screw, which delivers dry mix from the extruder bin, must be equipped with a variable speed drive to allow the dry speed to be set to rotational speed necessary to deliver dry feed at the desired extrusion rate (Rokey, 2000).

2.7.1. Feed rate

Feed rate has an overall effect on extrusion. Feed rate affects the residence time, torque load, barrel pressure, and dough temperature (Fang and Hanna, 2010). Generally, an extruder is operated at the maximum feed rate to achieve maximum output. However, starve feeding is sometimes employed to increase the residence time and achieve the desired extrudate characteristics (Stevens and Covas, 2012).

Feeding of raw material into extruder should be constant and non-interrupted for an efficient and uniform functioning of the extrusion process.

2.7.2. Screw feeder/conveyor

Screw feeders are used extensively in the food, plastics, household products, mineral processing and agricultural industries to draw bulk materials from hoppers or bins and transfer them over short distances. They generally provide good through-put control and facilitate a level of environmental protection not possible with belt conveyors. The typical configuration consists of a bin and hopper coupled to a screw casing and a screw within. As the screw rotates material is drawn from the hopper and transported along the casing (Fernandez et al., 2011).

Screw feeders are designed to meter bulk materials and are typically located at the beginning of a process. Capacity or feed rate can be accurately controlled with screw feeders. Screw feeders are available in a variety of sizes, lengths, configurations and materials of construction. A screw feeder is typically mounted directly to a:

- Hopper–Square or rectangular in shape with sloped bottom and limited storage capacity.
- Bin–Square or rectangular in shape with sloped bottom and large storage capacity.
- Silo–Cylindrical in shape with cone or mass-flow bottom and large storage capacity.

The screw feeder has a helicoidal surface fitted on a shaft that rotates inside a fixed tube. The material which comes out of the silo is pushed by the helicoid flight along the base of the tube in the direction of transport (Bortolamasi and Fottner, 2001).

2.8. Evaluation of the existing machine

Before the improvement design was made preliminary work to identify the existing extruder machine behaviors was must be done. The extruder machine consists of a hopper, frame, electric motor, transmission system, extruder camber (screw and barrel), and die. The parts specification was taken by direct measurement and calculation, the result listed below.

Frame: with the dimension of height = 568mm, width = 500 mm, and length = 1000mm.

Electric motor: three phase electric motor three phase 10hp (7.5kw) electric motor with 1440 rpm.

Transmission system: power transmitted via v-belt and pulley to the extruder. Pulley diameters of the electric motor and extruder are D_1 = 75mm, and diameter D_2= 200mm respectively. The belts are v-type, and three v-belts used center distance (C) = 660.

Extruder camber: Screw is a single screw which has constant pitch and screw diameter, and the total length is 600mm, and length of screw with tread/flight 250mm. Specification of screw are listed below figure 2.4. shows screw configuration of the extruder.

- Screw diameter (D) = 60mm,
- Pitch diameter (S) = 20mm,
- Channel depth (H) = 10mm,
- Channel width (W) = 10mm,
- Shaft diameter (d) =32 mm,
- Number of flights (n) = 6.5,
- Flight thickens (t) = 20mm,
- L/D ratio = 6,
- Clearance (barrel to screw) (c) = 6mm,
- Helix angle (φ) = 7^0, found from the following formula.

$$\tan\varphi = \frac{S}{\pi D} \quad \ldots\ldots (2.1)$$

Where: φ = helix angle (^{0}),

S = screw pitch (mm),

π = 3.142,

D = screw diameter (mm).

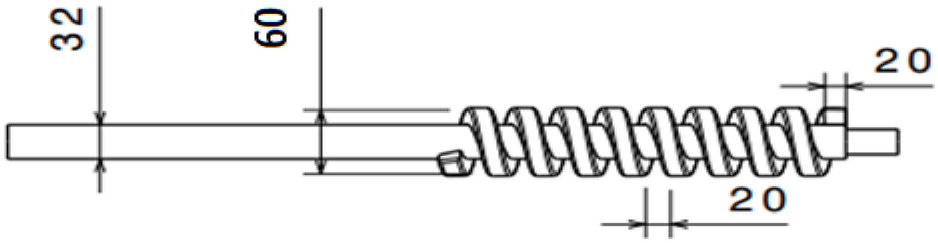

Figure 2. 4. Extruder screw

Barrel: the barrel opens to both ends, to one end the die is attached to it, and on the other end it is attached to the bearing houses, then in the upper side the hopper is connected to it. The barrel is with length = 250mm, outside diameter = 80 mm and thickness = 6mm made of mild steel. The barrel is Smooth (un-grooved).

Die: with two holes with 3mm diameter and it was in a cup form engaged to the barrel.

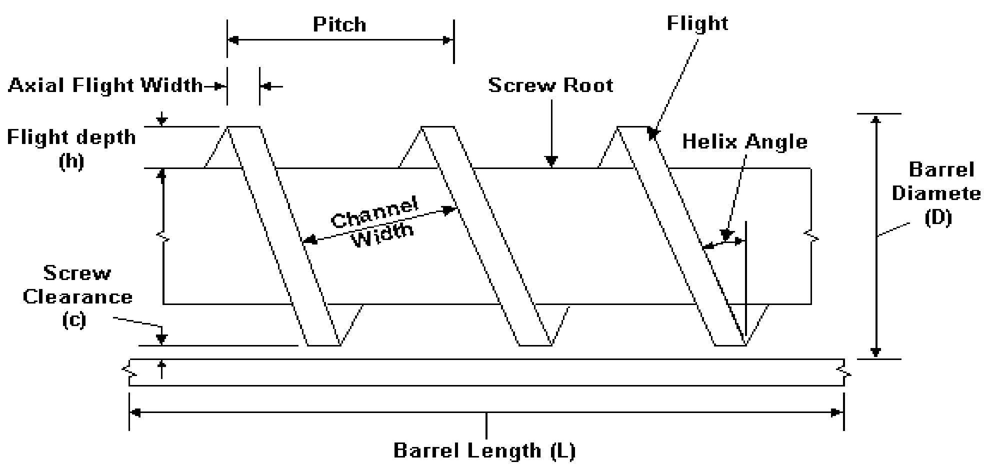

Figure 2. 5.Single screw nomenclature

Determination on existing machine

Belt speed determination**: -** The belt speed of the extruder machine was calculated as V= 5.7 m/s using equation as (3.4) expressed by (Shigley J. E., 2001).

Velocity determination**:** Power was transmitted from the electric motor to the extruder shaft via a V-belt. From diameter of motor and extruder pulley D_1 =75mm, and D_2 =200mm respectively.

The velocity ratio of 1:2.6 was calculated and the speed of the extruder was found N_2= 554 rpm from velocity ratio formula given by (Khurmi and Gupta, 2005).

Angle of contact: Angle of contact (angle of wrap) between the belt and each pulley was determined using the expression given by equation (3.6 and3.7). The determined values for angle of wrap of belt on motor pulley and angle of wrap of belt on extruder pulley 169.2^0 (2.96 rad) and 190.8^0 (3.3 rad) was found.

Tension in the belt**:** The tension in a power transmission belt, maximum tension, and centrifugal tension of the belt was determined as 385 N and 5.7 N. using equations (3.34 -3.36) as suggested by (Gupta and Khurmi, 2005). The determined value of tension in tight side and tension in slunk side 379.3 and38.7 N was found.
Torque and power determination: the torque and power transmitted via the belts to the extruder shaft was found 34.1 Nm and 4Kw from the equations (3.42 and3.43) given (Khurmi and Gupta, 2005).

Determination of the throughput capacity of the extruder

The maximum possible output of the extruder is calculated based on the volumetric flow rate. The calculation are based on maximum output, which is not normally attained because

• The coefficient of friction of the feed with then barrel wall or the screw root is not ideal

• The internal coefficient of friction forcing the resin to flow as a plug is not optimum,

• The extruder generates pressure, and/or

• Bulk density varies.

The volumetric flow rate is given by the following equation.

$$\dot{V} = v_z \, W \, h \quad \text{(2. 2)}$$

$$v_z = \pi \, D \, N \, \text{Cos}\varphi \quad \text{(2. 3)}$$

Where: $\dot{V}$ = volumetric flow rate ($m^3\, min^{-1}$),

v_z= channel velocity,

W= channel width (mm),

h = channel depth (mm),

D= screw diameter (mm),

N= screw speed (rpm)

φ = helix angle (^{0}).

From the volumetric flow rate we can find mass flow rate.

$\dot{M} = V \times \rho_{bulk}$ ………………………………………………………………………… (2. 4)

Where: $\dot{M}$ = mass flow rate (kg min^{-1}),

ρ_{bulk} = bulk density (kg m^{-3}).

The determined volumetric flow rate is attained if the extruder operates without the restriction of the die. We know that the die restrict the flow and creates pressure inside the barrel. Therefore we have to consider the die restriction and different factors which affect the flow rate of the extruder.

Let as assume the effective area of the extruder and the output area /opening area of die, which are calculated as follow.

- Effective area of extruder:

$A_E = \frac{\pi}{4}\left({d_b}^2 - {d_s}^2\right)$ …………………………………………………………………... (2. 5)

Where: A_E = effective area (mm^2),

d_b = internal diameter of barrel (mm),

d_s = diameter of shaft, (mm).

- Die opening area:

$A_d = n\,\frac{\pi}{4}d^2$……………………………………………………………………………… (2. 6)

Where: A_d = total area of die holes (mm^2),

n = number of die hole,

d = diameter of die hole (mm).

The die opening area is 28.3% of the effective area of the extruder. Therefore the output becomes 28.3% times the determined flow rate. Assumed degree of trough filling 45% the actual flow rate of the screw feeder equals the sum of die opening area and degrees of trough filling. Therefore for the screw feeder design the maximum output 42kg/hr.

After evaluation of the existing extruder machine this conclusion was given, the extruding machine is a dry type (no water injection system), high friction and power. The screw speed of 554 rpm was calculated from velocity ratio equation (3.4), which the suggested by Fellows, (2003) typical screw speeds range between 150 and 600 rpm for food extruders. As recommended by Mościcki and van Zuilichem (2011) for food products, L/D ratios of 6 to 15 are required because of biopolymer extruder should be shorter than that of chemical polymer so as to control chemical reactions such as burning of starches and denaturation of proteins the calculated L/D ratio was 6 it is in the recommended range. Due to the smoothness of the barrel the ingredients to be used must be granular for reducing stickiness properties and increasing friction.

Figure 2. 6. The existing extruding machine

2.9. Summary of literature review

From literature review, it was noted that pellet feed is one of the most important processes performed before feed ingestion; it has played an important role in growth of poultry livestock and poultry producers. It improve feed quality, increases feed intake and reduces feed waste this reduces production cost.

As the research indicates to obtain optimum capacity and the desired result the extruder machine must contain feeding and cutting units. These units are desired for continuous feeding and shaping the pellets.

The extruder machine existing in Melkassa Agriculture Research Center was a dry type; single screw extruder used for pelleting food/feed, this machine was without feeding, conditioning, and cutting units. To optimize and advance the extruder machine, the improvement has been made by adding feeding and cutting units, and by modifying pelleting die.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. Study site description

The poultry feed pelleting machine parts of the prototype were fabricated and tested in Melkassa agricultural research center, which is one of the federal research centers located in the Oromia region. The research centers were placed near the town of Awash-Melkassa, Adama Wereda, East Shewa Zone, Oromia Regional State, 117 km east of Addis Ababa and 17 km southeast of Adama city. The geographical location of the area is 8°24’985 N and 39°19’529 E and 1,550 m.a.s.l. altitudes.

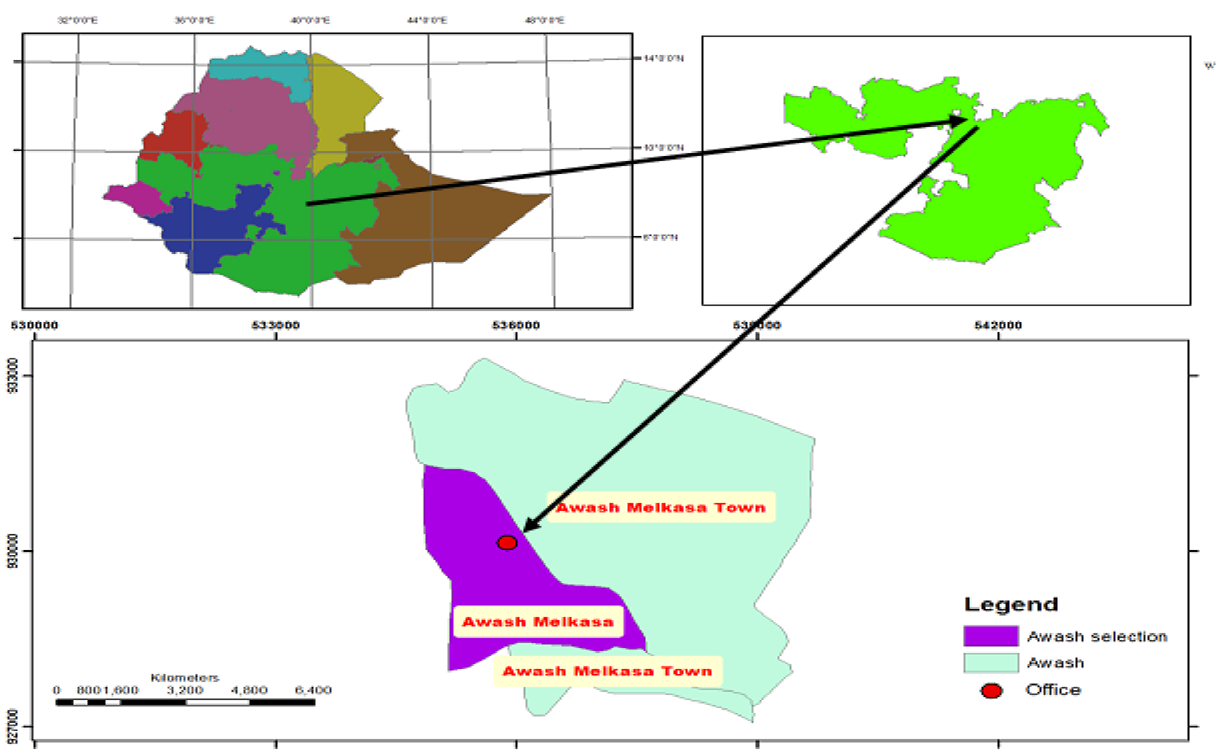

Figure 3. 1. GIS map of Melkassa Agricultural Research Center.

3.2. Material

3.2.1. Experimental Material

The material to investigate engineering properties and to make performance evaluation of the prototype machine, the maize grit, and Niger seed cake (Guizotia Abyssinica)(noug) was found from Melkassa research center. Wheat bran was purchased from the market.

3.2.2. Materials for construction

The materials used for the construction of the machine were sourced locally available and cheap to own. During construction, different materials were selected from the store and related materials were bought from the market to accomplish the requirements. The materials selected from the store and markets were based on durability, strength, endurance, availability, and cost.

The material used for improving extruder machine parts like screw (auger) shaft was made from mild steel and screw flight from sheet metal, and die made from mild steel, the cutter was made from sheet metal, and the frame were constructed from angle iron, safety guard were constructed from flat sheet metal. The shaft for screw feeder was selected from the available store and machined to the optimum required size and the screw flight was welded to it.

Table 3. 1.Machine used for fabrication of extruder machine parts.

No	Machines name	Function
1	Drill machine	Used for making hole
2	Lathe machine	Used for cutting, sanding, knurling, drilling, deformation, facing, and turning.
3	Welding machine	Used to welding metals.
4	Grinding machine	Utilized for grinding a metal work piece into required shapes and sizes.
5	Metal forming machine	Used for bending metals.
6	Press machine	Shaping, blending and pressing metal.
7	Shearing machine	Used cutting curves, angles and various shapes from the work piece.

8	Milling machine	Used for milling, cutting, shaping, carving, contouring, drilling, stamping, and die-sinking.

Table 3. 2. Tools and equipments used for fabrication extruder machine parts.

No	Tools/equipment's name	Function
1	Steel tape	Used to measurement of linear distance
2	Hammer	Used to strike an object
3	Vernier calipers	Used to measure the inner and outer diameter
4	Steel File	Smooth rough edge
5	Screw driver	Used for turning (driving) screws and bolts or other machine elements with a mating drive system
6	Die stock	Used to create uniform threads on different types of screw, bolts and pipes.
7	Architect ruler	A tool used to measure "to scale"
8	Level	Used to show levelness to horizontal or vertical.
9	Speed Square	Used to measure the angular
10	Hand Drill	A small portable drill held and operated by hand used to drill hole.
11	Brace and Bit	A type of hand drill consisting of a bit and a brace to hold and turn it.
12	Vise	Used to secure an object to allow work to be performed on it.
13	Pliers	Hand tool with opposing jaws for gripping, bending and cutting
14	Wrench	Used to fasten a joint comprising a nut and bolt
15	Chisel	Cutting tool with a sharpened edge at the end of a metal blade, used often by driving with a mallet or hammer in dressing, shaping, or working a solid material
16	A tape measure	A flexible ruler used to measure size or distance.

Table 3. 3. Materials and component specifications of extruder machine.

No	Components	Quantity	Material specification
1	Dc engine	1	Ten horsepower electric motor
2	Bearing (block bearing)	2	Made from chromium alloy steel which was attached to the rotating part to transfer rotation
3	Shaft	1	Machined from the mild steel with the diameter of Ø=30mm and length 400mm.
4	Cutter blade	1	Made from mild steel with dimension of 6 *22*2 mm.
5	Screw (auger)	1	Made from mild steel shaft Ø= 52 and length 400mm. and screw flight from 2mm sheet metal. The bended flight welded on the shaft.
6	Barrel	1	Made from galvanized steel with dimension
7	hopper	1	Made from 1mm sheet metal, dimension of 400*220*40 with the shape of a truncated pyramid.
8	Pulley	1	Pulley is made from the aluminum alloy with diameter of Ø = 197.4 mm.
9	Die	1	Made from mild steel, drilled 8 holes with Ø = 4mm and 4 holes with diameter of 6mm for blot to coupling with flange.
10	Belt	1	Made from rubber with a total length of 1440 mm. Selected from store B-53.
11	Frame	1	Made from angle iron with dimension of 40*40*3 and length of 2620 mm.
12	Flange	1	Made from mild steel with Ø = 120mm, thickness of 10mm and drilled 4 holes with Ø = 6 mm.

3.3. Determination of physical properties of poultry feed materials

3.3.1. Bulk density

Bulk density (ρ_B) is the density of a material when packed or stacked in bulk. The bulk density of packed materials depends on the geometry, size, and surface properties of individual particles (Lewis, 1987).

The bulk densities of feed ingredients were determined according to the recommendations of ASABE S269.4 (ASABE Standards, 2003). A container was filled with sample without compacting the contents. The material was leveled with the top of the container and weighed. The mash density was obtained from the ratios of the measured masses of samples in the container to the volume of the container. For each ingredient, three measurements were taken to obtain the averages and standard deviations. Belk density of the samples was estimated as equation (3.1) (Rahman, 2005).

$$\rho_B = \frac{m}{V_B} \qquad (3.\ 1)$$

Where: ρ_B = bulk density (kg m^{-3}),

m = mass of material (kg),

V_B = volume of material (m^3).

3.3.2. Moisture Content

Moisture content was determined by the method of the Association of Official Analytical Chemists 'AOAC' (2000) by the oven-drying method in the laboratory. A clean sample weight was recorded before and after oven-drying. About 10g of each sample were dried in an oven at 105 ^{o} C for 1 hour. Samples were weighed and dried at 105 ºC until constant mass was attained. The moisture content was determined using the equation (3. 2).

$$\%MC_{wb} = \frac{W_1 - W_2}{W_1} 100 \qquad (3.\ 2)$$

Where: W_1 = weight of wet sample (kg),

W_2 = weight of dried sample (kg).

3.4. Determination of frictional properties

The frictional properties such as angle of repose and coefficient of friction are important in designing of hoppers, chutes, pneumatic conveying systems, screw conveyors, forage harvesters, storage bins etc.

3.4.1. Angle of repose

The angle of repose can be defined as the steepest slope of the unconfined material, measured from the horizontal plane on which the material can be heaped without collapsing (A Mehta, 1994). It is one of the widely used physical property of agricultural product in the design and dimensioning of silos, tanks, hoppers and bunkers to determine the capacity and required volume of the stored and transported seeds, wheat bran, rice, flour (Al-Hashemi et al., 2018).

The tilting box method is suitable for cohesion less, fine-grained materials with a grain size less than 10 mm. For determination of this property, a box with open sides at the top and bottom is placed on a horizontal surface. The containers are filled with a sample was raised slightly, and the inclination angle at which the sample began to slide was read by the protractor. The tangent of the angle was recorded as a coefficient of friction. The angle of repose for three feed ingredients obtained from maize grit, wheat bran and Niger seed cake (Guizotia Abyssinica) (Nug) was measured as the tilting angle at which the material begins to slides (Al-Hashemi et al., 2018). As shown in figure 3. 2. angle of repose was determined by the following expression from tilting box method.

$$\alpha = \tan^{-1}\left(\frac{h}{l}\right) \quad \ldots\ldots\ldots\ldots (3.\ 3)$$

Where: α = angle of repose (^{0}),

h = height of box (m),

l = horizontal distance (m).

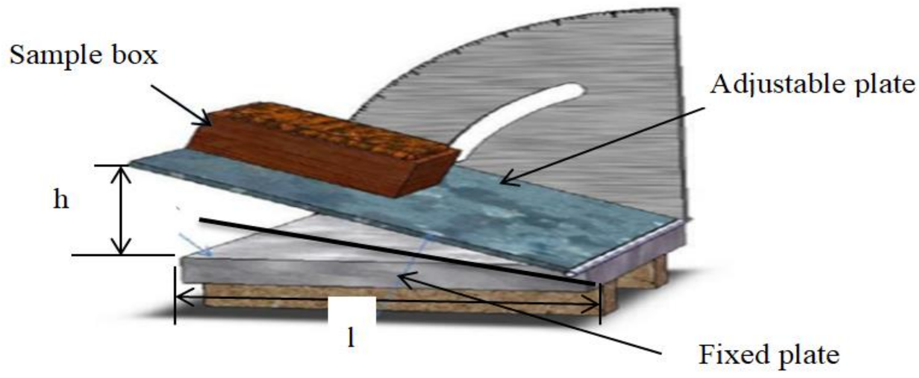

Figure 3. 2. Angle of repose

3.4.2. Static coefficient of friction

The static coefficient of friction of feed samples was calculated from the following equation (Tarighi et al., 2011).

$\mu = \tan\alpha$ ……………………………………………………………………………………......... (3. 4)

Where: μ = Static coefficient of friction,

α = Angle of repose (^{0}).

3.5. Parts and description of extruder

The extruding machine developed has the following major parts: Hopper, Feeding screw/auger, dies plate, flange, cutter, frame, and power transmission system (pulleys, and belts) as shown in Figure (3.3).

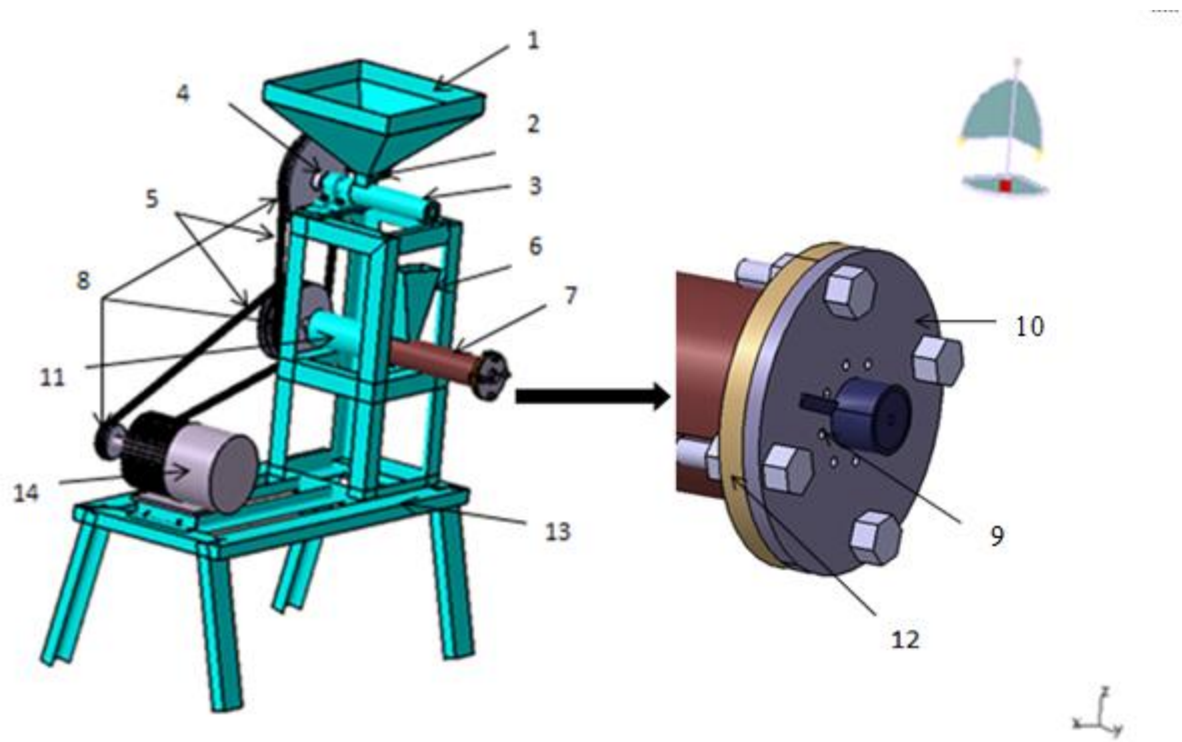

Figure 3. 3. Main components of extruder machine

<u>Parts name</u>

1. Screw feeder hopper	6. Extruder hopper	11. Bearing house
2. Hopper gate	7. Extruder	12. Flange
3. Screw feeder	8. Pulley	13. Frame
4. Block bearing	9. Cutter	14. Motor
5. Belt	10. Die plate	

3.6. Design of extruding machine components

3.6.1. Design of frame

The frame (Figure 3.4) was extended from the existing frame for screw feeder. The frame supports the entire weight of the screw feeder parts. The total weights carried by the frame includes; the weight of screw feeder, the weight of bearings, pulleys and hopper. It was made strong enough to resist the maximum magnitudes of compressive, tensile and impact forces and simultaneously support the other parts of the machine fixed on it. The two design factors considered in the determination of the material required for the frame were weight and strength.

The frame was constructed from a mild steel angle bar of 40mm by 40mm and 3mm thickness, it's used to give the required strength and rigidity from properties of material so that it can withstand all types of load during operation. The overall dimensions of the frame were 300 lengths, 260mm width and 375mm height.

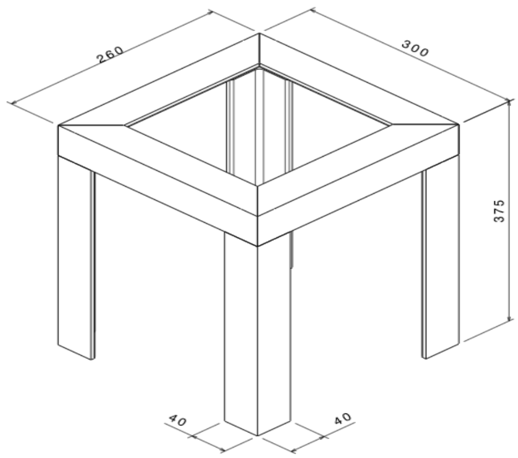

Figure 3. 4. Frame (all dimensions are in mm)

3.6.2. Design of hopper

Hopper was used to store materials temporarily while operation and stored material can be easily delivered to the screw conveyor at a regulated feed rate. The hopper has a shape that facilitates loading, maximum volume utilization and reliable and complete discharge of gravity through its outlet. The shape of the hopper is in the form of square a truncated pyramid with squared hopper on the top, the hopper with an inclination angle the average value of an angle of repose 30^0 of feed material to enable raw materials to be conveyed and stored.

Hopper Storage Capacity: Hopper volume was decided by the duration of time and required mass flow rate of the feedstock to the extruder. The hopper was designed to supply feed material to the feeder continuously for certain minutes, and the hopper should have a maximum holding capacity of 5 kg.

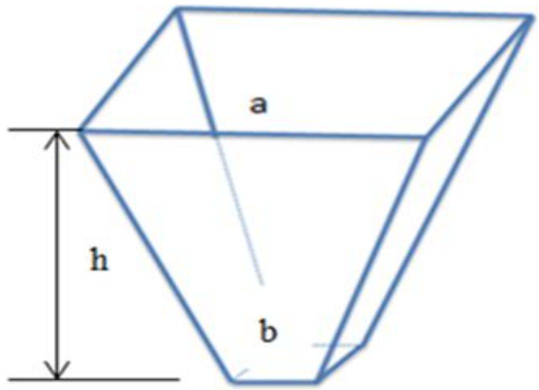

Figure 3. 5. Square frustum pyramid

The volume of the hopper was calculated using following equations used for square frustum/truncated pyramid (3.5-3.8).

$V_1 = {}^{h}/_{3}\,(A_1{}^2 + A_1A_2 + A_2{}^2)$………………………………………………………….. (3. 5)

$V_1 = 0.00146\text{m}^3$

Where: V_1 = volume of truncated pyramid (m^3),

A_1 = bottom area of the frustum (m^2),

A_2 = bottom area of the frustum (m^2),

h = height of hopper.

Bottom area of the frustum was calculated from the eqn.

$A_1 = a^2$ ………………………………..……………..………………..………………… (3. 6)

$A_1 = 0.16\ m^2$

Where: a = bottom side of square (m),

Area of rectangle was calculated from the following eqn.

$A_2 = b^2$…………………………………………….………………………………. (3. 7)

$A_2 = 0.0016\ \text{m}^2$

Where: b = top side of the square (m).

Volume of the square was calculated as following eqn.

$V_2 = b \times w \times h$ ………………………………..………..………………………………. (3. 8)

$V_2 = 0.008 m^3$

$V_T = V_1 + V_2$ ……………………………………………………..…………………………. (3. 9)

$V_T = 0.00946 m^3$

Where: V_2 = volume of rectangle shape (mm^3),

b = length (mm),

w = width (mm),

h = height (mm).

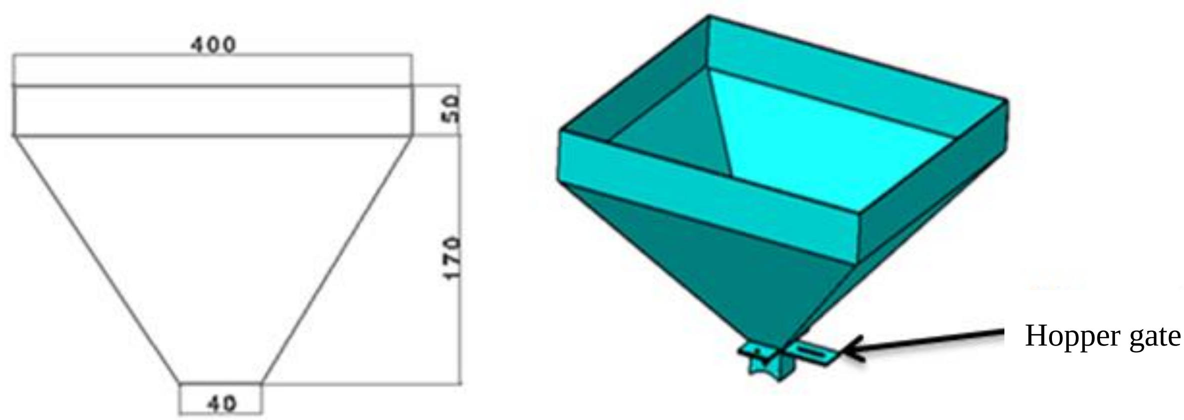

Figure 3. 6. Hopper (all dimensions are in mm)

The volume of hopper was calculated as $9.46 \times 10^{-3} m^3$, which holds 4 kg at once. This gives time for the operator to check the operation. To prevent overfeeding or blockage of the extruder, the hopper was with sliding gates and agitators. The sliding gate is adjusted manually to control feed rate.

3.6.3. Design of screw feeder

The screw feeder (auger) composed of screw and barrel.

Screw design

The diameter of the screw feeder was required for conveying material at maximum rate of 42 kg/h for the capacity of a continuous screw conveyors were calculated from the equation (3. 9) given by (Spivakovsky and Dyachkov 1967). The screw diameter of 48 mm was found to convey the feed material to the extruder.

$$D^2 = \frac{4Q}{60\pi S n \varphi \rho c} \quad \text{.........} \quad (3.10)$$

$D = 48\ mm$

Where; Q = capacity of screw conveyor (kg/hr),

S = screw pitch (mm),

n = speed of conveyor (rpm),

φ = loading efficiency,

ρ = bulk density of the feed material (kg/m^3),

c = loading factor depending on the inclined angle to the horizontal.

The recommended values by (Spivakovsky and Dyachkov, 1967) for slow flowing abrasive material are

S = 0.5D,

φ = 0.125,

c = 1 for horizontal inclination angle (b^0 = 0),
n= 200–490 rpm.

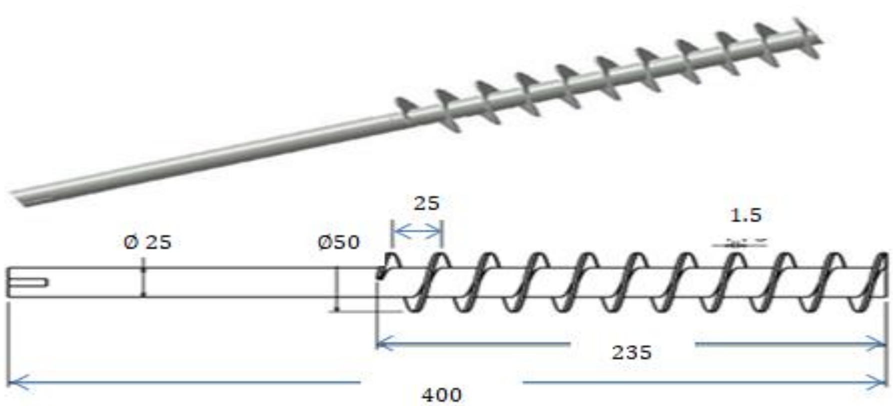

Figure 3. 7. Screw (auger) (all dimensions are in mm)

Barrel design

The cylindrical barrel with a cover plate at both ends, with an opening for put in and to discharge the material were provided at the top and bottom of barrel. Both ends of the barrel were covered with flat plate.

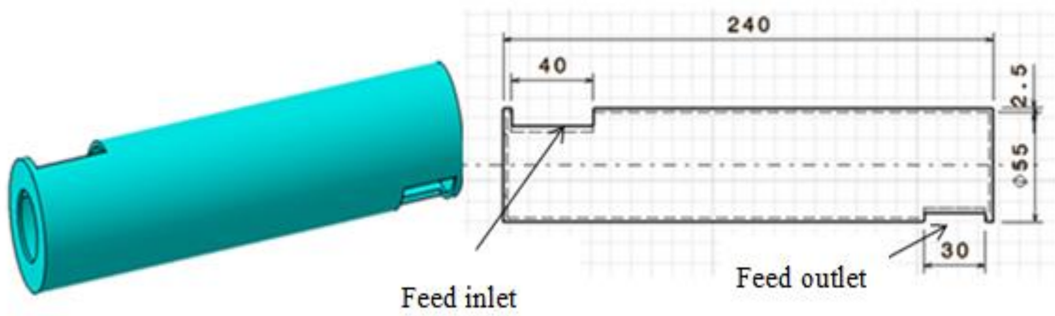

Figure 3. 8. Feeder barrel (all dimensions are in mm)

3.6.4. Design of shaft

A shaft is a rotating machine element which is used to transmit power from one place to another. The power is delivered to the shaft by some tangential force and the resultant torque (or twisting moment) set up within the shaft permits the power to be transferred to various machines linked up to the shaft. In order to transfer the power from one shaft to another, the various members such as pulleys, gears etc., are mounted on it. These members along with the forces exerted upon them cause the shaft to bend. In other words, we may say that a shaft is used for the transmission of torque and bending moment. The various members are mounted on the shaft by means of keys or splines (Khurmi and Gupta. 2005).

The material used for shafts should have the following properties:

- It should have high strength.
- It should have good machinability.
- It should have a low notch sensitivity factor.
- It should have good heat treatment properties.
- It should have high wear resistant properties.

The shaft was designed based on high strength and good machinability when transmitting power under various operating and loading conditions. The mild steel shaft was used for screw feeder. In order to determine the diameter of a screw feeder shaft; all forces acting on the shaft (weight of pulley, weight of maximum feed ingredient, tensions in the belt, tight side and slack side, weight of hopper, weight of barrel and weight of shaft) were considered. The shaft diameter was determined using equation (3.10).

$$d^3 = \frac{16}{\pi\,\tau_{max}}\sqrt{(\mathrm{K_m} \times \mathrm{M})^2 + (\mathrm{K_t} \times \mathrm{T})^2} \quad \text{(3. 11)}$$

$\mathrm{d} = 21.6\ \mathrm{mm}$

Where: d = diameter of shaft (m),

τ_{max} = allowable stress (MPa),

π = constant (3.142),

K_m = Shock and Fatigue factor for bending,

K_t = Shock and Fatigue factor for torsion,

M = maximum bending moment (N-m),

T = Torque acting on the shaft (N-m).

Shear force and bending moment diagrams were determined by considering all forces acting on the shaft and the pull of belt on the shaft. Forces acting at each location of the shaft were computed; the forces are shown in the Figure 3.8.

For a rotating shaft with suddenly applied (minor shock) load, as stated by Khurmi and Gupta (2005) as shown in (appendix table 4) that K_m and K_t range between 1.5 to 2.0 and 1.0 to 1.5, respectively so 2 and 1.5 was taken.

A shaft was supported by two bearings. A 242.6 mm diameter pulley was mounted to the left hand bearings and the belt drives a pulley directly below it with the help of belt having tension T_1 = 379.3N and T_2 = 37.9N, which was placed vertically. The angle of contact for both the pulleys are 173.1 and 186.9^o and μ =0.24.

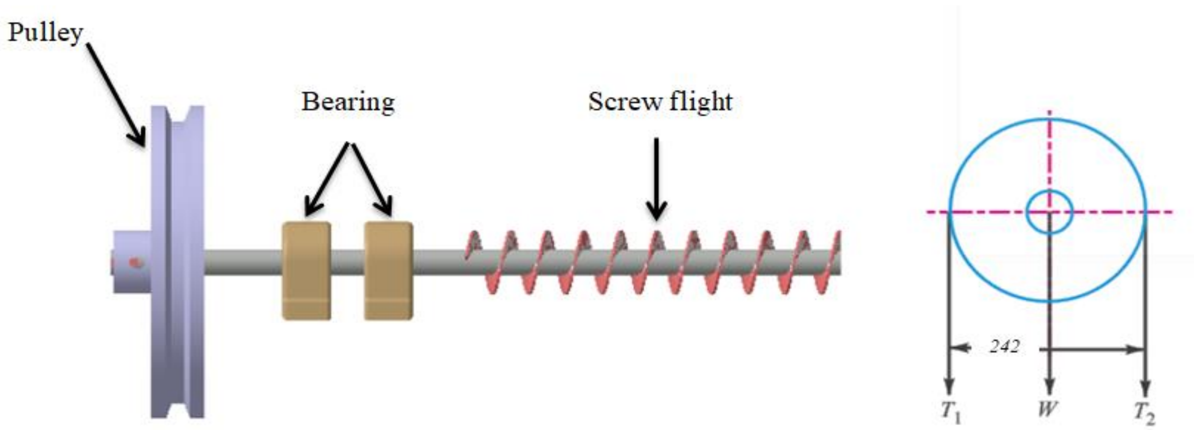

Figure 3. 9. Layout of shaft components (all dimensions are in mm)

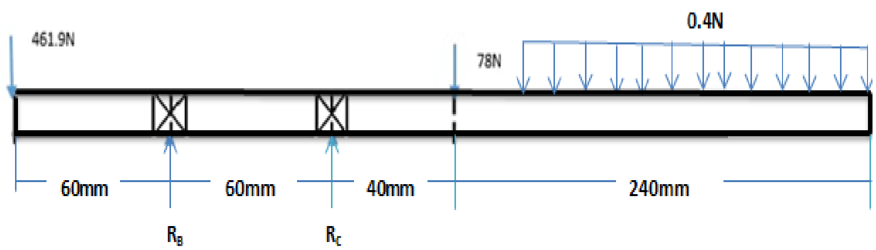

Figure 3. 10. Free body diagram of the shaft

The value of the reaction force was determined by taking the summation of a moment at point B:

$\sum M_B = 0$ ↺ + ve

$R_C \times 0.06 - 461.9 \times 0.0 - 78 \times 0.1 - 0.4 \times 0.22 = 0$

$R_C = 318.3$ N down ward

$\sum F_y = 0$ ↑ +ve

$R_B = 318.3 + 461.9 + 77.98 + 0.4$

$R_B = 859.9$ N

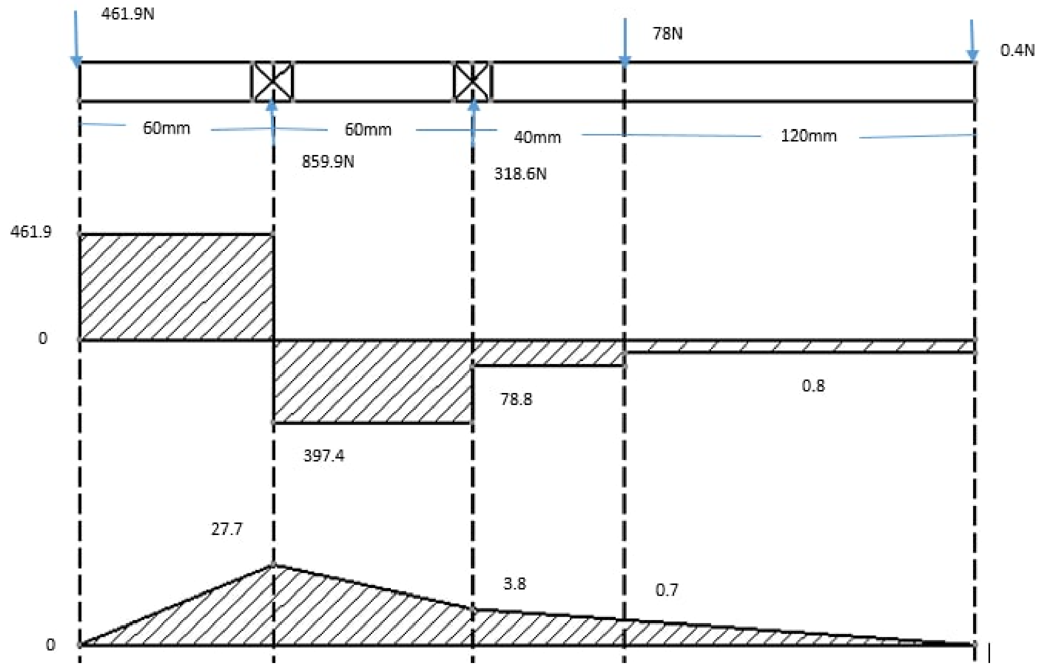

Figure 3. 11. Shear stress and bending moment diagram

The bending moment was selected by taking the maximum bending moment. And the torque of the shaft was estimated using equation (3.11) it was found 255Nm (Khurmi and Gupta, 2005).

$$T = (T_1 - T_2) \times {}^{D}/_{2} \quad \text{………………………………………………..……..………... (3. 12)}$$

Where: T = torque on a shaft (N-m),

T_1 = tight side tension of a belt (N),

T_2 = slack side tension of a belt (N),

D = diameter of the driven pulley (m).

3.6.5. Design of die plate

The die (perforated plate) serves as a restriction device at the end of the barrel which can control barrel fill, pressure, and temperature to some extent (Rokey, 2000). The screw drives and compresses the material toward the perforated plate, and then the material exits in pellet shape. The extruder needed a die which could sustain the high pressure of material conveyed by the feed screw. The die was made using thick mild steel plate. It has a diameter of 120 mm and is removable as shown in figure 3.11. Finally, 8 numbers of holes with a diameter of 4 mm were drilled around the surface of the die plate to make way for the pellets to pass through. The diameter of each drilled hole is 4 mm used as recommended for poultry. It was coupled to the barrel through flange. The die thickness was determined using formula given (Khurmi and Gupta, 2005) in equation (3.12). The die thickness found to be 10 mm.

$$t = KD\sqrt{\frac{P}{S}} \quad \text{……………………………………………………………………} \quad (3.\ 13)$$

Where: t = thickness of the die (mm),

k = coefficient of friction,

D = diameter of the die (mm),

P = compressive pressure of feed through the die holes (MPa),

S = allowable stress (MPa).

Extrusion pressure is pressure exerted by extruder screw-shaft, which was determined using equation (3. 13).

$$P_e = {}^{F}/_{A_w} \quad \text{……………………………………………………………………} \quad (3.\ 14)$$

Where: P_e =extrusion pressure (MPa),

F = resultant force on worm-shaft (N),

A_w = worm-shaft area (m^2).

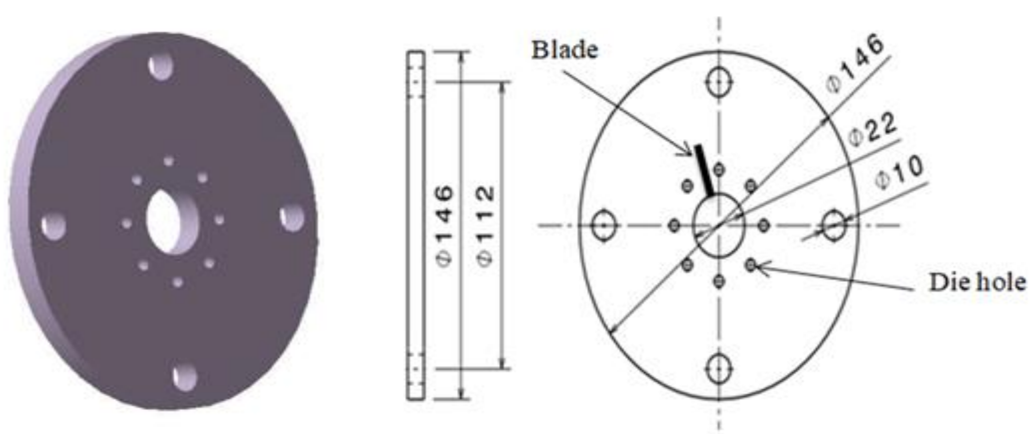

Figure 3. 12. Schematic of die plate (all dimensions are in mm)

3.6.6. Design of flange

Flanged joint is one of the most widely used pipe joints and it may be made with flanges cast integral with the pipes or loose flanges welded or screwed. The flanges are connected by means of bolts. The flanges have been standardized for pressures up to 2 N/mm^2. The flange faces are machined to ensure correct alignment of the pipes/barrel. The joint may be made leak-proof by placing a gasket of soft material, and rubber between the flanges.

The circular flange was used for coupling the extruder barrel to the die plate. The design took place considering that the fluid pressure acts in between the flange and the die which tends to separate them with a pressure existing at the point of leaking. The bolts are required to take up tensile stress in order to keep the flange and the die together.

The effective diameter on which the extruder pressure acts, just at the point of leaking, is the diameter of a circle touching the bolt holes was calculated by equation (3. 17) and force trying to separate the flange and die equation (3.18).

The dimension of the flange was calculated by the equation given by (Khurmi and Gupta).

It is found to be diameter of flange and thickness 122mm and 18mm.

$$D_1 = D_p - d_1 \quad \text{………………………………………………} \quad (3.15)$$

$$D_1 = 122\text{mm}$$

$$F = \frac{\pi}{4}(D_1)^2 p \quad \text{………………………………………………} \quad (3.16)$$

$$F = \frac{\pi}{4}(122\text{mm})^2 \times 1.2\,\text{N/mm}^2$$

$$F = 14\text{KN}$$

Where: D_1 = effective diameter (mm),

d_1 = the diameter of bolt hole (mm),

D_p = the pitch circle diameter (mm),

P = extruder pressure (MPa).

The dimensions of the flange may be fixed as follows:

Number of bolts,

$$n = 0.0275\,D + 1.6 \quad \ldots\ldots (3.17)$$

$$n = 3.8 \approx 4$$

Thickness of flange,

$$t_f = 1.5\,t + 3\,mm \quad \ldots\ldots (3.18)$$

$$t_f = 18mm$$

Outside diameter of flange,

$$D_o = D + 2t + 2B \quad \ldots\ldots (3.19)$$

$$D_0 = 146mm$$

Pitch circle diameter of bolts,

$$D_p = D + 2t + 2d + 12\,mm \quad \ldots\ldots (3.20)$$

$$D_p = 80 + 2 \times 10 + 2 \times 10 + 12$$

$$D_p = 132mm$$

The circumferential pitch of the bolts (P_c) was given by

$$P_c = \frac{\pi D_p}{n} \quad \ldots\ldots (3.21)$$

$$P_c = \frac{\pi \times 112}{4}$$

$$P_c = 88mm$$

Where: D = extruder barrel outside diameter (mm),

d = Nominal diameter of bolts (mm),

B = Width of flange (mm).

In order to make the joint leak-proof, the value of should be between $20\sqrt{d_1}$ to$30\sqrt{d_1}$, Where, d_1 = the diameter of the bolt hole. Since the circumferential pitch obtained (i.e. 88 mm) is within 63 to 94, therefore the design is satisfactory.

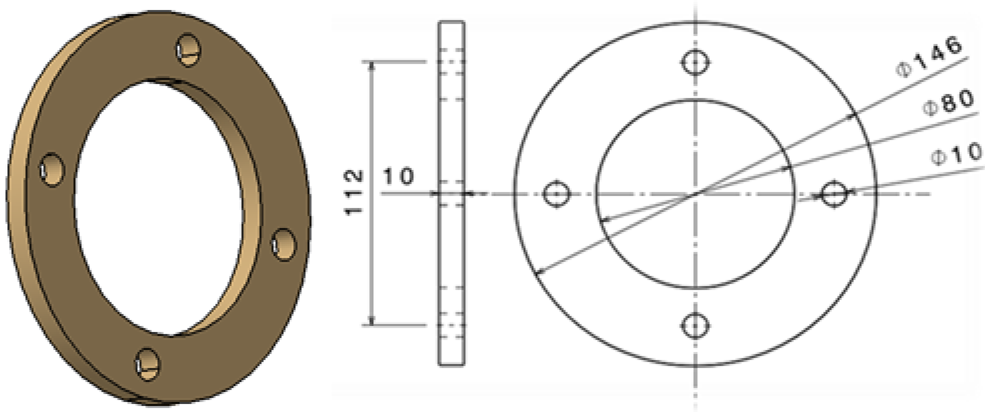

Figure 3. 13. Flange joint (all dimensions are in mm)

3.6.7. Design of cutting blade

The cutting blade is endangered at the end of the die plate perpendicular to the shaft of the extruder, for the purpose of cutting the pellets into a cylinder shape with a required length. The knife cuts the final product into small parts with in a circular movement on the die surface. The knife has a length of 20mm, 5mm width and a force of 2.6 KN. The length of the knife was the whole diameter of the perforated plate. It consists of one sharp blade and the pellet length is controlled by varying number of knifes. The force of cutting was calculated using equation given (Hussein et al., 2015).

$F = (P \times A_1) - (P \times A_2)$ ………..………………………..………………………………. (3. 22)

Where: F = the force of cutting (N),

P = Pressure in the extruder barrel (MPa),

A_1 = Bore area (mm^2),

A_2 = Effective area (mm^2).

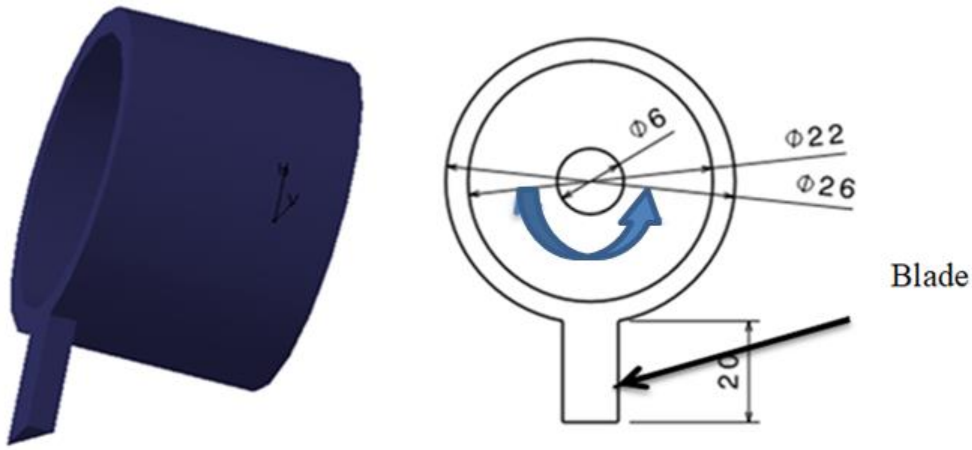

Figure 3. 14. Cutting blade view (all dimensions in mm)

3.6.8. Design of key ways

A key is a piece of metal inserted between the shaft and hub or boss of the pulley to connect these together in order to prevent relative motion between them. It is always inserted parallel to the axis of the shaft. Keys are used as temporary fastenings and are subjected to considerable crushing and shearing stresses. Key ways of width, thickness and length were 7.5, 5, and 47.1mm respectively calculated using equation (3. 23 to 3.25) (Khurmi and Gupta, 2005).

$w = d / 4$ …………………………………………………………………………… (3. 23)

$t = 2w / 3 = d / 6$ … ………………………………………...……………………… (3. 24)

$L = 1.571 \times d$ ……………………………………..………………..…………………... (3. 25)

Where: W = width of key way,

t = thickness of key way,

L = length of key way,

d = Diameter of the shaft or diameter of the hole in the hub.

3.6.9. Selection of bearing

A bearing is a machine element which supports another moving machine element (known as journal). It permits a relative motion between the contact surfaces of the members, while carrying the load. The simplest type of journal bearing is a solid bearing. It's just a block of cast iron with a hole for a running shaft to fit through(Khurmi and Gupta, 2005, Richard and Nisbett, 2011). In addition, a bearing must have a high enough load rating to provide an acceptable combination of life and reliability. The size of bearing used depends on the size of shaft required and by the available space. Bearing size was determined using the maximum resultant force acting on a bearing and the desired maximum lifespan (Khurmi and Gupta, 2005, Richard and Nisbett, 2011).

For machinery application the desired maximum life of a bearing was selected based on the application of bearing. Hence, the desired maximum lifespan of the bearings ranges from 12,000-20,000hr. Therefore the maximum lifespan value of 20,000hr was selected to determine the basic dynamic load rating. Bearing number 205 with bore of 30 mm and width of 18 mm was selected, since the minimum shaft diameter has been determined to be 30 mm.

The rating (or service) life of bearing was calculated by the relationship between the life in revolutions and the life in working hours using equation (3. 25) given by (Khurmi and Gupta, 2005).

$$\mathrm{L} = 60 \times \mathrm{N} \times \mathrm{L}_H \quad \text{(3. 26)}$$

$$\mathrm{L} = 540 \times 10^6$$

Where: L = rating/ service life of bearing,

L_H =the life in working hours,

N = revolution of the shaft (rpm).

The basic dynamic load rating of a bearing was calculated using equation(3. 26) (Khurmi, 2005).

$$\mathrm{C} = \mathrm{W}\left(\frac{\mathrm{L}}{10^6}\right)^{\frac{1}{\mathrm{k}}} \quad \text{(3. 27)}$$

$$\mathrm{C} = 5.7\mathrm{KN}$$

Where: C = basic dynamic load rating,

L = Rating life,

W = Equivalent dynamic load (N),

K = 3 for ball bearing and $10/3$ for roller bearings.

Equivalent dynamic load is calculated using equation.

$$W = (\sqrt{F_X^2 + F_Y^2}) \qquad (3.\ 28)$$

$W = 859.9N$

Where: F_X = maximum resultant force acting on a bearing in a horizontal plane (KN),

F_Y = maximum resultant force acting on a bearing at point B on a vertical plane (KN).

3.7. Power transmission component design and selection

3.7.1. Design and selection of belt

The belts or ropes are used to transmit power from one shaft to another by means of pulleys which rotate at the same speed or at different speeds. The amount of power transmitted depends upon the following factors:

- The velocity of the belt.
- The tension under which the belt is placed on the pulleys.
- The arc of contact between the belt and the smaller pulley.
- The conditions under which the belt is used.

The material used for belts and ropes must be strong, flexible, and durable. It must have a high coefficient of friction. The belts, according to the material used, are classified as follows:

- Leather belts.
- Cotton or fabric belts.
- Rubber belt.
- Balata belts.

Rubber belts are selected because they are simple to get and not expensive. The rubber belts are made of layers of fabric impregnated with rubber composition and have a thin layer of rubber on the faces.

Belt selection

V-Belts are the most common means of driving light loads between short range pulleys. The pulleys have high, steep flanges so that the belt cannot slip off. V-Belts are small in cross-section to reduce friction and heating (Sharma D. N., 2010).

The selection of the belt was made by using the nominal pitch length and center distance, which is determined from Equation (3. 31) and (3. 32), value 1429 mm 375 mm respectively was obtained. From (Appendix Table 2), the nearest standard pitch length is 1440mm. So based on recommended for standard B type V-belts a belt to transmit power from extruder pulley to screw feeder size of B-53 was selected.

Belt length determination

Power was transmitted from the extruder shaft through a V-belt to the screw feeder. Length of belt required to transmit power was determined using open belt equation (3. 28) as given by (Gupta and Khurmi, 2005).

$$\mathrm{L} = 2\mathrm{C} + \frac{\pi(\mathrm{D}_2+\mathrm{D}_1)}{2} + \frac{(\mathrm{D}_2-\mathrm{D}_1)^2}{4\mathrm{C}} \quad \text{……………………………………………………………… (3. 29)}$$

Where: L = belt length (mm),

C = center distance (mm),

D_1 = diameters of driving pulley (mm),

D_2 = diameters of driven pulley (mm).

The center distance calculated by the equation given below (Ojediran et al, 2017).

$$\mathrm{C} \geq D_1 + \frac{D_2}{2} + 50\mathrm{mm} \quad \text{………………………………………………………………………… (3. 30)}$$

Belt speed determination

The belt speed for the screw conveyor drive was calculated using the equation expressed by (Shigley J. E., 2001) and it was determined as $5.7 m.s^{-1}$ using Equation (3. 30).

$$\mathrm{V} = \frac{\pi \mathrm{D}_1 \mathrm{N}_1}{60} \quad \text{………………………………………………………………………………… (3. 31)}$$

$$\mathrm{V} = 5.7\mathrm{m/s}$$

Where: V= belt speed (ms^{-1}),

D_1 = diameter of motor pulley (m),

N_1 = speed of motor (rpm),

π = constant (3.142).

Angle of contact (angle of wrap)

Angle of contact between the belt and each pulley was determined using equations (3.32 and 3. 33). The determined values for contact angle of belt for extruder and screw feeder pulley 173.9^0 (3.25 rad) and 186^0 (3.04 rad) was found.

$$\theta_1 = \pi - 2\sin^{-1}\left(\frac{D_2-D_1}{2C}\right) \quad \text{(3. 32)}$$

$$\theta_2 = \pi + 2\sin^{-1}\left(\frac{D_2-D_1}{2C}\right) \quad \text{(3. 33)}$$

Where: θ_1= angle of wrap of belt on extruder pulley (rad),

θ_2 = angle of wrap of belt on feeder pulley (rad),

$\pi = 180^0$,

D_1 = diameter of extruder pulley (mm),

D_2 = diameter of feeder pulley (mm),

C = center to center distance between small and large pulley (mm).

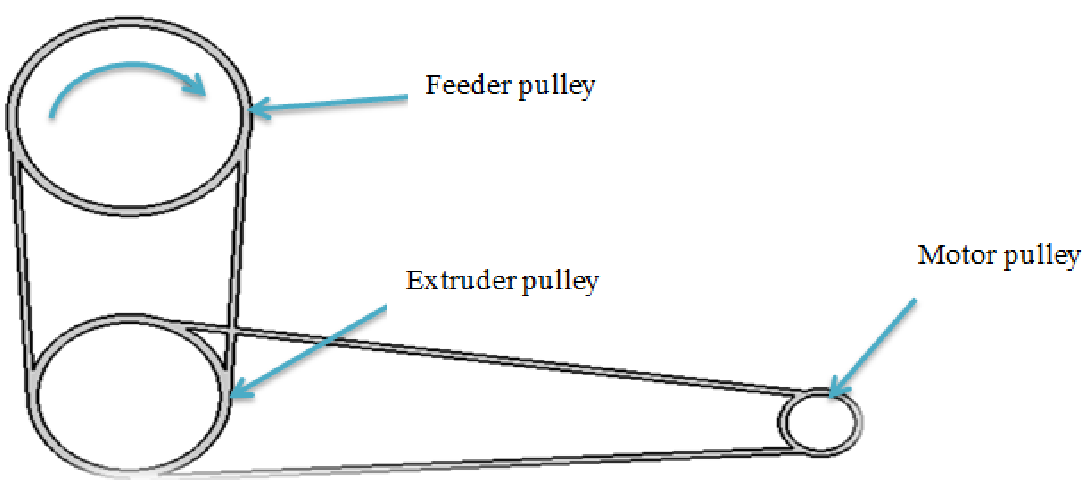

Figure 3. 15. Belt arrangement

The tension in the tight side of a power transmission belt can be calculated using Eqn. (3. 34) as suggested by (Khurmi and Gupta, 2005).

$T_1 = T_{max} - T_C$ ………………………………………………………………………... (3. 34)

The maximum tension in the belt is given as

$T_{max} = \sigma A$ ………………………………………………………………………... (3. 35)

$T_{max} = 385$ N

The centrifugal tension of the belt (Tc) is given by;

$T_C = mv^2$ ………………………………………………………………………….. (3. 36)

$T_C = 5.7$N

The mass of the belt per unit length is calculated as

$m = \rho A$ ………………………………………………………………………...… (3. 37)

$m = 0.176$ Kg/m

Where: T_1= tension in the tight side of the belt (N),

T_c = centrifugal tension of the belt (N),

T_{max} = maximum tension of the belt (N),

σ = Maximum allowable stress of belt (MPa),

T_c = centrifugal tension of the belt (N),

m = mass per unit length of a belt (kgm^{-1}),

v = speed of belt (ms^{-1}) and

ρ = density of belt material (Rubber) ($kg.m^{-3}$).

Cross section area of belt

The cross-sectional area of the belt was calculated by summing area 1, 2 and 3 of the trapezoidal section as shown in the Figure (3.14) and was found to be $1.54x10^{-4}m^2$. From (Appendix Table 1), top width, b = 17 mm, thickness, t = 11 mm and by calculation, the bottom width x = 11 mm. The groove angle of the pulley was taken as 34˚.

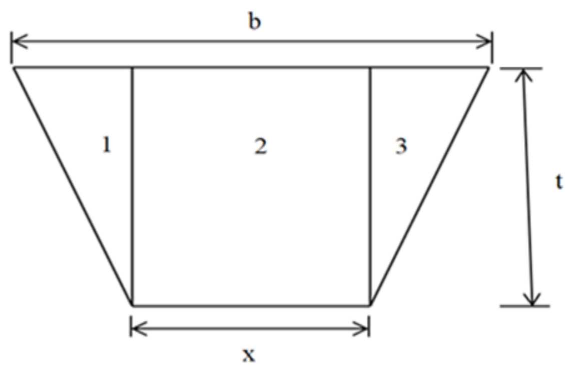

Figure 3. 16. V-belt cross section

V-belt cross section area is calculated from the following equation

$$A = \frac{(b-x)}{2}t + xt \quad \ldots\ldots (3.\ 38)$$

$$A = 1.54 \times 10^{-4} m^2$$

Where: A = belt cross sectional area (mm^2),

b = top width of the belt (mm),

x = bottom width of the belt (mm),

t = thickness of the belt (mm).

Belt tension ratio for v-belt can be calculated using equation given by (Khurmi et al., 2005). The determined value of tension in tight side (T_1) and tension in slunk side (T_2) are 379.3 and 38 Nm was found.

$$2.3 \log \left(\frac{T_1}{T_2}\right) = \mu.\theta\ \mathrm{cosec}\beta \quad \ldots\ldots (3.\ 39)$$

Where: T_1 = tension in tight side (N),

T_2 = tension in slunk side (N),

μ = coefficient of friction between the belt and sides of the groove (0.43),

θ = angle of contact between belt and pulley of driving pulley (rad),

β = groove angle of pulley.

3.7.2. Design of pulley

The pulleys are used to transmit power from one shaft to another by means of flat belts, V-belts or chains. The pulleys must be in perfect alignment in order to allow the belt to travel in a line normal to the pulley faces.

Based on the required speed, the diameter of the feeder pulley was estimated using Equation (3. 40). Figure (3.16) shows the dimension of the pulley.

$N_1 D_1 = N_2 D_2$ ………..…………………………………………………………….…..... (3. 40)

The width of the pulley (face width) B‟ is usually considered to be 25% greater than the width of belt (b) and Equation (3. 41) can be used to estimate the width of pulley (Richard and Nisbett, 2011).

$\mathrm{B} = \mathrm{b} + 0.25\mathrm{b} = 1.25\mathrm{b}$ ………………………………………………………………… (3. 41)

Where: N_1 = angular speed of driven pulley (rpm),

N_2 = angular speed of driving pulley (rpm),

B = width of pulley (mm),

b = width of belt (mm).

According to the strength, weight of pulley, and also the availability of pulley we select aluminum. The diameter of the pulley for the screw conveyor was determined from velocity ratio using equation (3.40) expressed by (R. S. Khurmi and Gupta, 2005). Calculated pulley diameter was D_3 = 242.6 mm shown in figure (3.17).

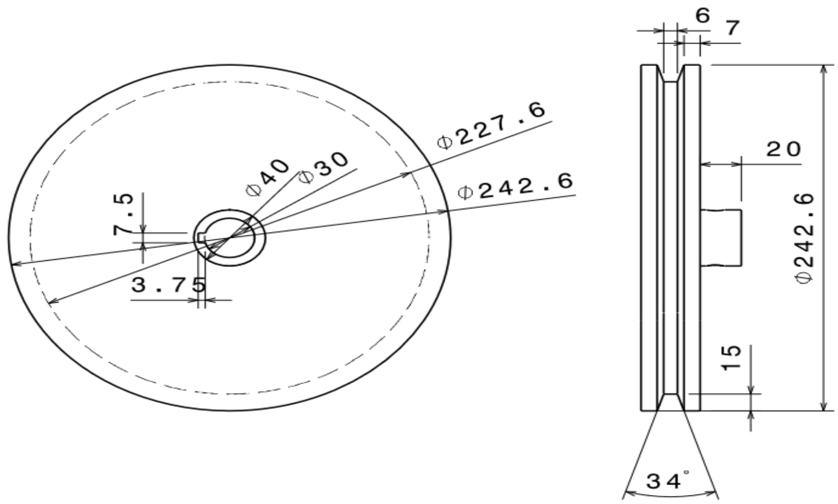

Figure 3. 17. Screw feeder pulley geometry (all dimensions are in mm)

Torque on screw feeder shaft was calculated according to Gupta and Khurmi (2005) using Equation (3. 42).

$T = (T_1 - T_2)\ \frac{D_2}{2}$ …………………………………………………………………………… (3. 42)

$T = 41.4$ Nm

Where: T = torque of a shaft (N.m),

T_1 = tension on the tight side (N),

T_2 = tension on the slack side (N),

D_2 = diameter of the largest driven pulley (m).

The power transmitted by the belt was calculated by using equation (3. 43) given by (Khurmi et al,.2005).

$P = (T_1 - T_2)\, v$ ……………………..…………………….……………………………....... (3. 43)

$P = 1.9$KW

Where: T_1 = Tension in the tight side (N),

T_2 = Tension in the slack side (N),

V= Velocity of the belt (m/s).

3.8. Fabrication of machine

All the machine components were fabricated based on the design specification. The construction was carried out with locally sourced materials to reduce the cost of production. The components design was made using design software (Catia V-5), based on the design specification. The machine fabrication includes the following steps: measuring and cutting parts, welding of members to form individual components of the machine, surface grinding and cleaning of machine parts, assembling machine parts and painting parts.

3.9. Sample preparation

3.9.1. Feed formulation

Poultry feed for this study is formulated due to the recommendation by the research and the availability of feed ingredients for a diet that supplies the main nutrients required by poultry animals. Maize grit, wheat bran, and Niger seed cake (Guizotia Abyssinica) (Nug) were used, with the mixed ratio of 50, 35and 15% respectively.

3.9.2. Desired moisture content determination

For obtaining the desired moisture content of the sample, a calculated amount of water was added using the equation (3. 44) given by Bashar, et al., (2014) and the samples were thoroughly mixed and sealed in plastic bags.

$$Q = \frac{Wi(M_f - M_i)}{(100 - M_f)} \quad \text{(3. 44)}$$

Where: Q = the mass of water added (kg),

W_i = the initial mass of the sample (kg),

M_i = the initial moisture content mass of the sample in % (wet basis),

M_f = the final moisture content of the sample (wet basis).

The feed ingredients were mixed and the required quantities of water was added, and kept for moisture stabilization.

3.10. Preliminary tests

The machine has been tested and preliminary tests and observations have been registered before the final testing and performance assessment of the extruder. Five moisture content and three feeding rates (through opening the hopper gate to three levels) were considered as test parameters. The testing began by switching the engine on and opening the get to the desired level before the feed sample was fed into the machine. Preliminary tests were made using prepared samples before actual test runs.

3.11. Testing and performance evaluation prototype machine

3.11.1. Throughput capacity

Throughput capacity (kg/hr): The throughput is the rate at which the feed sample fed into the machine is being recovered. This is the ratio of the quantity pelleted (in kilograms) to the time taken (in hours) to complete activity. The throughput capacity was obtained using Equation (3. 45) (Okolie et al., 2019).

$$\mathrm{Tpc} = \frac{W_R}{t} \quad \text{.......... (3. 45)}$$

Where: TpC = Pelleting throughput capacity (kg hr^{-1}),

W_R= the recovered weight after pelletizing (Kg),

t = the time taken for complete pelletizing (hr).

3.11.2. Pelletizing efficiency

Pelletizing efficiency % (η); the pelletizing efficiency was obtained using Equation (3. 46). This was used to determine the effectiveness of the machine in producing the pellets. The ratio of the weight of the pellets to the weight of the recovered feed gives the pelletizing efficiency. The weight of the pellets (W_P) was determined by weighing the pellets, which was manually separated from the recovered feed (W_R) according to (Abdel et al., 2011).

$$\eta = \frac{W_P}{W_R} \times 100 \quad \text{.......... (3. 46)}$$

Where: W_P = the weight of the pelletized sample.

W_R = the weight of the recovered feed.

3.12. Experimental design

The experimental design used was a split-plot design. The split-plot design is specifically suited for a two-factor experiment that has more treatments than can be accommodated by a complete block design. In a split-plot design, one of the factors is assigned to the main plot. The assigned factor is called the main-plot factor. Thus, the three levels of feed rate were assigned to the main plot. The main plot was divided into subplots to which the second factor, called the subplot factor, was assigned. Thus, each main plot became a block for the subplot treatments (i.e., the levels of the subplot factor) (Gomez, K.A. and Gomez, 1984). Three levels of moisture content were assigned to the sub plot. The experiment design was laid as 3x3 with three replications and had a total of 27 test runs (3x3x3=27).

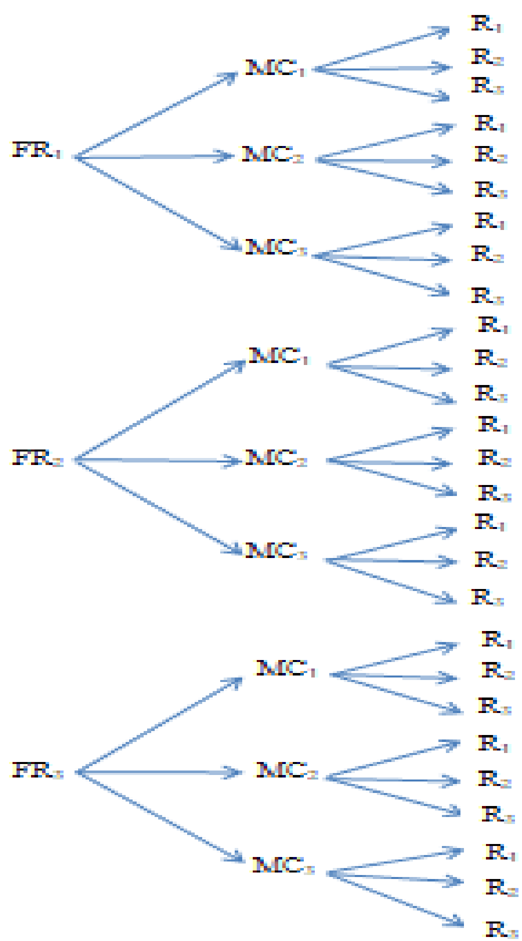

Figure 3. 18. Structure of experimental design.

3.13. Data analysis

Statistical analysis triplicate measurements were conducted to analyze the effects of feeding rates and moisture content on the extruding machine at all evaluation factors of the pelleting machine. Data collected were subjected to analysis of variance (ANOVA) using the statistical procedure as described by Gomez and Gomez (1984). The data were analyzed using SPSS to analyze the mean, standard deviation, and least significant difference test (LSD) ($P < 0.05$). The Regression analysis was made to establish a relationship between the moisture content and the other variables understudy.

CHAPTER FOUR

4. RESULT AND DISCUSSION

The results of physical and frictional properties of feed ingredients, testing and performance evaluation of the prototype of poultry feed pelleting machine were presented and analyzed. The performance of the pelleting machine was assessed in terms of throughput capacity, and pelleting efficiency. The data collected at each test run at different combinations of moisture content, feed rating was subjected to analysis of variance ANOVA to determine the level and extent of the effect of the variables on the machine performance.

4.1. Physical and frictional properties

4.1.1. Physical properties

Physical and frictional properties of feed ingredients was determined at a moisture content of 4.7, 4.2, and 3 % in wet basis for maize grit, wheat bran, and noug cake respectively.

Moisture content

The feed ingredients moisture content was determined using equation 3.2 and its average value obtained were 4.7, 4.2, and 3 % for maize grit, wheat bran, and noug cake respectively on wet basis. The analysis of variance (ANOVA) shown that in table 4.1 the moisture content of wheat bran was significant difference ($p < 0.05$) with in feed ingredients. The analysis of variance (ANOVA) showed that the moisture content maize grit and noug cake were no significant difference ($p > 0.05$) with in feed ingredients.

Table 4. 1. One way ANOVA on moisture content of feed ingredients (with in feed ingredients)

Feed ingredients	Sum of square	df	Mean square	F	P-value
Maize grit	2.26	3	0.753	2.366	0.122
Wheat bran	1.547	3	0.516	3.520	0.048
Noug cake	0.855	3	0.285	2.383	0.120

Bulk density

The feed ingredient bulk density was determined using equation 3.1 the result presented in table 4.2. As table 4.2 the analysis of variance (ANOVA) revealed that the bulk density of all feed ingredients was greatly significant difference ($p < 0.05$).

Table 4. 2. One way ANOVA of bulk density of feed ingredients (with in feed ingredients)

Feed ingredients	Sum of square	Degree of freedom	Mean Squares	F	P-value
Maize grit	14737.21	2	7368.603	57170.2	1.44E-13
Wheat bran	14066.88	2	7033.44	3187.36	8.31E-10
Noug cake	14149.71	2	7074.854	817.6922	4.88E-08

4.1.2. Frictional properties

Frictional properties (angle of repose and coefficient of friction) of feed ingredients used for poultry feed were presented in table 4.3. The angle of repose and coefficient of friction of feed sample was represented in the table according to range (min and max), mean, standard deviation and variance. The mean values of angle of repose were 32.2, 29.3 and 27.4 degrees and the mean coefficient of friction 0.63, 0.56 and 0.51 for each feed ingredients respectively.

Table 4. 3. Angle of repose and coefficient of friction of feed material

Parameter	Feed sample	Range	Mean	StDev	Variance
Angle of repose	Maize grit	31.4 - 32.8	32.2	0.7371	0.543
	Wheat bran	29.5 - 29	29.3	0.251	0.063
	Noug cake	26.3 - 28	27.4	0.952	0.91
Coefficient of friction	Maize grit	0.61 - 0.64	0.63	0.015	0.0003
	Wheat bran	0.55 - 0.57	0.56	0.01	1E-04
	Noug cake	0.49 - 0.53	0.51	0.02	0.00053

4.2. Feed preparation

4.2.1. Feed formulation

Poultry feed was formulated from maize grit, wheat bran, and Niger seed cake (Guizotia Abyssinica) (Noug cake) with the mixed ratio of 50, 35and 15% respectively.

4.2.2. Desired moisture content

The desired moisture content of the sample was obtained by calculating amount of water added using equation (3. 44). For the mass of 1000g mixed feed sample, the amount of water added to obtain desired moisture content was determined. The amount of water added in to the determined moisture content of the mixed samples was presented in table 4.4.

Table 4. 4. Amount of water added to the 1000g mixed samples in grams

Moisture Content (%)	Water added to mixed feed (g)
15	127.3
20	198
25	278.6

4.3. Preliminary tests

The result of preliminary testing of the extruder is presented in table 4.5. Result shows the outcome of the trials on the range of feeding rate and moisture level of mixed feed to be selected for further investigation. As table 4.5 shown when the moisture content was 10 % feed ingredient which comes from the feeder clogged in the extruder. Thus, there was no flow of feed through the die openings, because for dry material it hard to flow in the die hole. Moisture content 30% form pellet, the pellet expands and it adheres to knife, for poultry feed expanded pellet not required.

As table 4.5 shown when the hopper gets opened to 100 % feed ingredient which clogged the die hole and it collected throughout the screw. This is because of flow of feed in the screw feeder doesn’t match to die openings.

Table 4. 5. Result of preliminary test of pelleting machine

Parameter	Value		Observation	Remark
Moisture Content, (%)	10	4	Sample got clogged	Not selected
	15	4	Pellet formed	Selected
	20	4	Pellet formed	Selected
	25	4	Pellet formed	Selected
	30	4	Pellet formed, high expansion, adhere to knife	Not selected
Feed rate (%)	25	4	Pellet formed	Selected
	50	4	Pellet formed	Selected
	75	4	Pellet formed	Selected
	100	4	Sample got clogged	Not selected

For further investigation feed ingredients with 15, 20, and 25% moisture content were selected, which are sample with no expansion, no adhere to knife and good pellet formed for poultry feed. The machine operates safely in 25, 50 and 75% levels of hopper gate opening. While operating no defect was observed on any component parts of the machine.

4.4. Performance evaluation of pelleting machine

Three samples of the feed were prepared at moisture contents of 15, 20, and 25% and feed rating at three levels of hopper get opening (hopper opened at a level of 25, 50 and 75%). Three replicates results were noted at each moisture content level for each feed rating. The throughput capacity (kg/h) and pelletizing efficiency (%) was evaluated using Equation (3. 46), and (3. 47) the result is presented below.

The Analysis of Variance (ANOVA) and Least Significance Test were used to investigate the effect of moisture content and feed rate on the factor of evaluation of the machine. The feed rate of the machine was kept constant while the moisture content varied.

4.4.1. Throughput capacity (kg/hr)

The mean pelleting throughput capacity and analysis of variance are presented in figure 4.1 and Table 4.6, respectively. The ANOVA clearly indicated that the pelleting throughput capacity of the prototype poultry feed extruder was significantly ($P < 0.05$) affected by feed rate and moisture content and the cross effect of the two factors were not significant at ($p > 0.05$).

Table 4. 6. ANOVA on machine throughput capacity (with in subjects effects)

Testament	SS	Df	MS	F	Sig	Partial Eta squared
FR	165.032	2	82.516	128.522	0.000	0.985
MC	192.961	2	96.480	2075.673	0.000	0.999
FR*MC	3.870	4	0.968	2.168	0.163	0.520

The maximum pelleting capacity of 35.6 $Kg.hr^{-1}$ was recorded with the highest feed rate (hopper gets opened 75%) and with 25% moisture content and the lowest pelleting throughput capacity of 23.2 $Kg.hr^{-1}$ occurred at feed rate (hopper get opened 25%) and moisture content 15%. As figure (4.1) shows the pelleting throughput capacity increased with increasing feed rate and moisture content which might be due to higher flow-ability of the feed ingredient and the reduction of residence time. In general, the pelleting throughput capacity directly proportional to feed rate and moisture content.

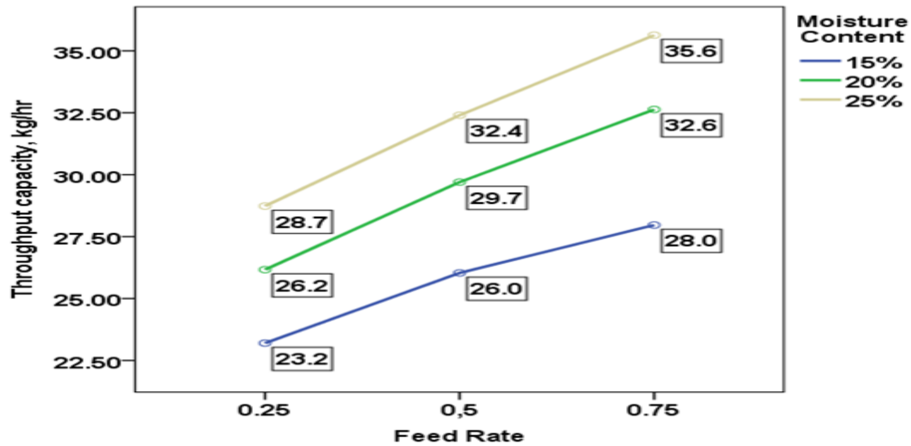

Figure 4. 1. Effect of feed rate and moisture content on the throughput capacity of the machine

4.4.2. Pelleting efficiency

The pelleting efficiency increases with increasing feed rate and moisture content. The statistical analysis ANOVA table 4.7 clearly indicated that the pelleting efficiency of the extruder was significantly ($P < 0.05$) affected by the main effect of feeding rate, moisture content and the cross effect of the two factors. The lower pelleting efficiency obtained in smaller moisture contents which are due to the starch needing moisture to bind, non-pelleted feed the result of low moisture.

Table 4. 7. ANOVA on pelleting efficiency (with in subjects effects)

Testament	SS	Df	MS	F	Sig	Partial Eta squared
FR	344.027	2	172.013	280.711	0.000	0.993
MC	973.140	2	486.570	260.043	0.000	0.992
FR*MC	58.747	4	14.687	10.221	0.003	0.836

The effects of feed rates and moisture content on the pelleting efficiency of the prototype machine are presented in figure 4.2. The highest pelleting efficiency of 91.3 % was obtained at feed rate (hopper gets 75% opened) and moisture content 25% while the lowest pelleting efficiency of 69.3% occurred at feed rate (hopper get opened 25%) and moisture content 15%.

A container was filled with sample without compacting the contents. The material was leveled with the top of the container and weighed. The mash density was obtained from the ratios of the measured masses of samples in the container to the volume of the container.

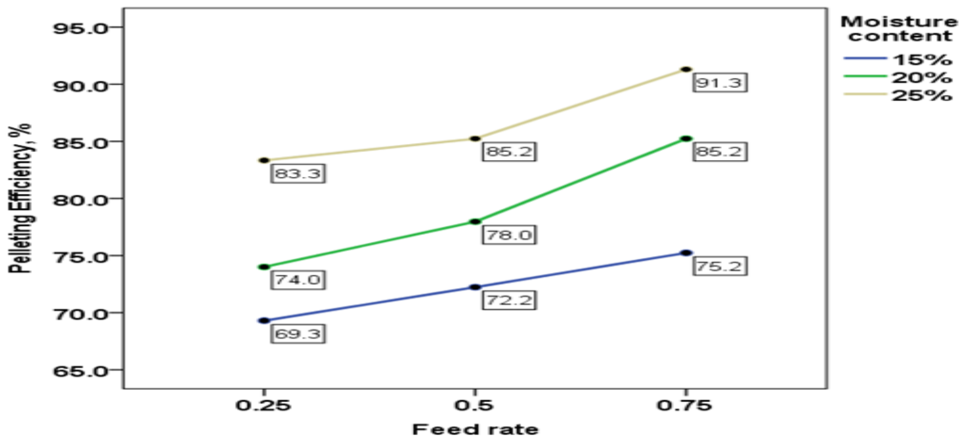

Figure 4. 2. Effect of feed rate and moisture content on pelleting efficiency

4.5. Regression analysis

Regression analysis was used to indicate the effects of independent variables feed rate and moisture content on the machine throughput capacity and pelleting efficiency. A software (Microsoft Excel) was used to develop regression equations that relates the independent variables with the dependent variables it presented in table 4.8.

Table 4. 8. Multiple regressions equations of machine throughput capacity and pelleting efficiency upon feeding rate and moisture content

Regression equations	Coefficient of determination (R^2)
$TpC = 10 + 12.1FR + 65.4MC$	$R^2 = 0.96$
$PE = 41.2 + 15.7FR + 152.6MC$	$R^2 = 0.90$

Where: TpC = throughput capacity, kg/hr; PE = pelleting efficiency (%); FR= feed rate; MC= moisture content (%).

4.6. Comparisons of capacity of existing and improved machine

The comparison of the capacity of the existing and the improved machine was done. As presented in table 4.9 the capacity of the machine was increased after improvement was made. The capacity of the improved machine was higher due to the screw feeder action. As Rokey (2000) suggested the extruder rate is usually controlled by a feeder screw.

Table 4. 9. One way ANOVA on comparing capacity of the existing and the improved machine

Source of Variation	SS	df	MS	F	P-value
Between Groups	718.24	1	718.24	291.3753	0.003414
Within Groups	4.93	2	2.465		
Total	723.17	3			

Pellet size

The pellet size (diameter and length) was measured using Vernier caliper for each moisture content and the result presented in table 4. 10 the value were presented accordingly as range, mean, standard deviation and variance. As shown in table 4.10 mean pellet diameter for moisture content 15, 20 and 25% were 4.2, 4.3 and 4.4 mm respectively. Thus the pellet diameter was almost similar for each moisture content. This result shown as there is no/little expansion of the pellets occurred.

Table 4. 10. Pellet diameter

Feed sample mc,%	Range (min-max)	Mean (mm)	StDev	Variance
15	4 - 4.5	4.2	0.25	0.061667
20	4 - 4.5	4.3	0.25	0.061667
25	4 - 4.5	4.4	0.20	0.041667

The measured length of pellet was presented in table 4.11. As shown in table 4.11 mean pellet length for moisture content 15, 20 and 25% were 10, 8.9 and 9.7 mm respectively. Thus the result indicates that the cutting blade cuts the pellets into close size.

Table 4. 11. Pellet length

Feed sample mc,%	Range (min-max)	Mean	StDev	Variance
15	4 – 14	10	4.58	21
20	6 – 14	8.9	3.08	9.5
25	4 – 16	9.7	4.08	16.6

Figure 4. 3. Poultry feed pellet

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

Design, fabrication and performance evaluation of the poultry feed pelleting machine was done using locally available materials. The design was made by Catia V-5 software, the components were fabricated and the performance of the machine tested in Melkassa Agricultural Research Center. From the above-mentioned findings, it can be concluded that the screw feeder would provide constant feedings to the extruder machine which affects the output pellets to have similar size (diameter), the similarity of pellet diameter indicates that there was a consistent flow of material and the extrudate resident time in the barrel was the same. Pellet size required for poultry feed was attained, pellet with 4.3 mm diameter and average length 10mm. This size is an acceptable standard by (FAO, 1996) proposes that good pellets which are properly formed have their lengths to be about two and a half times their diameters.

The developed machine capacity was increased, the optimum output capacity of the improved machine was 35.6 kg/hr as it is shown in an earlier chapter whereas that of the existing machine optimum capacity was 16 kg/hr this makes the improved machine efficient than the existing pelleting machine. The total manufacturing cost for the developed components was 6513.00 birr as it is showed on appendix table (5-7) its operating cost no change.

Due to the addition of feeder and cutter, the operation becomes simpler and attractive. It reduces the workforce and time spent on cutting the rope like pellets. The improvements made on the existing extruder machine increase the efficiency, quality of pellets.

The small-scale poultry producer can use this machine reduce feed wastage improve feed quality and increase their chicken productivity.

5.2. Recommendations

The following are recommended to further improve the design and operation of the pellet extruder:

- After finishing the work, immediately disassemble the extruder pelleting die, barrel and screw and clean because if the remaining feed cools it sticks the barrel and the screw that cannot start easily and disassemble.
- When the machine works constantly the barrel, screw and die become very hot, therefore a development of the cooling system will be needed.
- The machine should be re-evaluated using different feed ingredients and changing die plate.
- Suggestions on further works to be done to improve the performance of the extruding machine.

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APPENDICES

Table 1. Dimensions of standard v-belts according to IS: 2494 – 1974.

Type of belt	Power ranges in kW	Minimum pitch diameter of pulley (D) mm	Top width (b) mm	Thickness (t) mm	Weight per meter length in N
A	1 – 3.5	75	13	8	1.06
B	2 – 15	125	17	11	1.89
C	7.5 – 75	200	22	14	3.43
D	20 – 150	355	32	19	5.96
E	30 – 350	500	38	23	

Source (Khurmi and Gupta, 2005).

Table 2. Dimensions of standard pitch lengths V-belts according to IS: 2494 – 1974.

Type of belt	Standard pitch length of v belts in mm
A	645, 696, 747, 823, 848, 925, 950, 1001, 1026, 1051, 1102A1128, 1204, 1255, 1331, 1433, 1458, 1509, 1560, 1636, 1661,1687, 1763, 1814, 1941, 2017, 2068, 2093, 2195, 2322, 2474,2703, 2880, 3084, 3287, 3693
B	932, 1008, 1059, 1110, 1212, 1262, 1339, 1415, 1440, 1466,1567, 1694, 1770, 1821, 1948, 2024, 2101, 2202, 2329, 2507,2583, 2710, 2888, 3091, 3294, 3701, 4056, 4158, 4437, 4615,4996, 5377.

Source (Khurmi and Gupta, 2005).

Table 3. Maximum Permissible Working Stresses for Transmission Shafts According to (ASME) code for the design of transmission shafts.

The maximum permissible working stresses in tension or compression may be taken as
(a) 112 MPa for shafts without allowance for keyways.
(b) 84 MPa for shafts with allowance for keyways.
Maximum permissible shear stress may be taken as

(a) 56 MPa for shafts without allowance for key ways.

(b) 42 MPa for shafts with allowance for keyways.

Table 4. The recommended values for Km and Kt.

Nature of load	K_m	K_t
1. Stationary shafts		
(a) Gradually applied load	1.0	1.0
(b) Suddenly applied load	1.5 to 2.0	1.5 to 2.02
2. Rotating shafts		
(a) Gradually applied or steady load	1.5	1.0
(b) Suddenly applied load with minor shocks only	1.5 to 2.0	1.5 to 2.0
(c) Suddenly applied load with heavy shocks	2.0 to 3.0	1.5 to 3.0

Source (Khurmi and Gupta, 2005).

Table 5. Raw material list and cost.

NO	Type of material	Standard size	Price(birr)	unit	Total price (birr)
1	Sheet metal	1.5x1000x2000mm	1400.00	352,000mm^2	246.4
2	Round bar	Ø30 x3000mm	2500.00	500mm	416.6
3	Bearing		800.00	2 pcs.	1600
4	Galvanized circular pipe (hollow)	Ø60x3000mm	1800.00	400 mm	240
5	V – belt	B -53	240	1 pcs.	240
6	Mild steel	10x1250x2500mm	9500	15,400mm^2	73.5
7	Metal bolt and nut	M-10x30	5	4	20
		M-6x30	4	4	16
		M-4x30	3.5	2	7
8	Aluminum pulley	Ø250 mm	800	1 pcs.	800

9	Electrode (pack)	Ø 2.5	130	1pack	130
10	Paint		650	1 Gallon	650
11	Cutoff disc		250	pack 2	250
	Subtotal				4689.5

Table 6. Machine and Labor Costs.

No	Type of machine	Machine cost			Labor cost		
		Working hour	Cost/hr	Cost(birr)	Working hour	Cost/hr	Cost
1	Universal metal cutting	2	65	130	2	25	50
2	Welding machine	12	10	120	12	25	300
3	Grinding machine	6	20	120	6	25	150
4	Bending machine	2	15	30	2	25	50
5	Radial drill machine	2	25	50	2	25	50
6	Lathe machine	10	30	300	10	25	50
7	Power hack saw	5	20	100	5	25	125
				850.00			775.00
Subtotal							1625.00

Table 7. Cost Summary.

No	Types of cost	Sum of cost
1	Raw material cost	4689.5
2	Material wastage(2.5% of 1)	117.2
3	Machine cost	850.0
4	Labor cost	775.0
5	Overhead cost (5% of 3&4)	81.25
Total		6513.00

Table 8. Density of belt materials.

Material of belt	Mass density in Kg/m^3
Leather	1000
Canvass	1220
Rubber	1140
Balata	1110
Single woven belt	1170
Double woven Belt	1250

Source: (Khurmi and Gupta, 2005).

Table 9. Moisture content of feed samples

Feed sample	Mass before oven dry, g	After 1hr oven dry, g	After 1 hr. oven dry, g	After one hr. oven dry, g	Moisture content, Wb (%)
Maize grit	17.8	16.9	17.0	17.0	4.5
	17.7	16.8	16.9	16.9	4.5
	18.6	17.7	17.7	17.7	4.8
	18.9	18.0	18.0	18.0	4.8
	Mean				4.65
Wheat bran	18.0	17.6	17.2	17.2	4.4
	17.8	17.3	17.1	17.1	3.9
	17.3	16.4	16.5	16.5	4.6
	17.9	17.2	17.2	17.2	3.9
	Mean				4.2

Noug cake	17.7	17.2	17.3	17.3	2.3
	17.8	17.3	17.3	17.3	2.8
	18.5	17.7	17.8	17.8	3.8
	17.5	17.1	17.0	17.0	2.9
	Mean				2.95

Table 10. Bulk density of feed ingredients

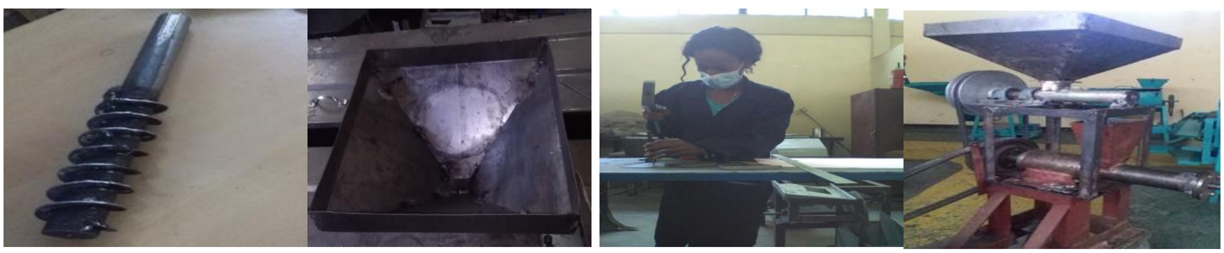
Feed ingredients	Mass of cylinder	Mass of cylinder % sample , g	Mass of sample ,g	Volume, mm^3	density(kg m^3)
Maize	97.3	144.7	47.4	90,477.9	523.8
grit	97	151.5	54.5	90,477.9	602.4
	97	146.4	49.4	90,477.9	545.9
Noug	96.8	141.8	45	90,477.9	497.4
cake	96.8	144.9	48.1	90,477.9	531.6
	96.8	141.7	44.9	90,477.9	496.3
Wheat	96.9	127	30.1	90,477.9	332.7
bran	96.9	127.6	30.7	90,477.9	339.3
	96.8	126.7	29.9	90,477.9	330.5

Table 11. Amount of water added to the samples for 100g of sample in grams.

Moisture Content (%)	Maize grit	Wheat bran	Nug cake
15	12.1	13	14.2
20	19.1	20.1	21.4
25	27	28.1	29.5

ANNEXES

Measuring angle of repose, moisture contents and bulk density of feed samples.



Fabrication of prototype.

Preparation of feed ingredient and formed pellet.

Photos with technician.