Vol. 07, No. 1 (2020)

A Plant Design of Poultry Feeds Production Derived from Fermented Vegetable Waste of Libertad South Public Market

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Keywords

Vegetable Waste, Fermented Feed, Poultry Feeds, Plant Design, Chemical Engineering, Bacolod City (Philippines)

ABSTRACT

The lack of proper waste management in the city has led to the accumulation of waste and the loss of potential resources. In a day, 16 tons of waste are collected from the Libertad South Public Market. In line with this, the researchers aimed to use vegetable waste generated in the Libertad South Public Market and propose a processing plant to produce fermented poultry feed. Data from the city and the researchers' sampling determined that the waste collected was mostly organics. In preparation for the material balances, energy balances, and plant design, Chemical Engineering principles and multiple related pieces of literature in traditional and digital forms were applied and consulted. The process of producing fermented poultry feeds primarily began with segregating vegetables from undesired or rejected items, followed by the pre-treatment, which includes washing, rinsing, and size reduction of the vegetables. After pre-treatment, vegetable waste was fermented for 24 hours. The fermented feed was then subjected to various physical processes, including drying, pelletizing, and screening. This study presents an alternative way of handling waste while using waste to produce poultry feeds, which could help with the waste problem in the city and various communities.

INTRODUCTION

The advent of technological and human progress comes with increased waste generation. These wastes are dealt with differently in developing countries where waste management is practiced poorly; thus, dealing with these wastes poses a challenge (World Bank, 2019). By 2020, municipal solid waste generation is expected to grow from the current generation of 2.01 billion tons (Kaza et al., 2018). Despite implementing the Republic Act 9003 in the Philippines, the proper management of solids remains deficient (Congress of the Philippines, 2000). People still do not practice segregation; they mix their garbage into one pile and wait for the trash collectors to gather it.

A person is estimated to generate around half a kilogram (kg) of waste daily (Kaza et al., 2018). In

Bacolod City, the LGU has attempted to impose projects that entail proper waste segregation, but these efforts were unsuccessful. With the city, like most in the country, practicing open dumping as a means of waste disposal, most of the waste collected is accumulated and left to rot (Palalon, 2019; Senate Economic Planning Office, 2017). Discoveries have been made to turn these wastes into something valuable by using them as unconventional feedstuff to solve these problems and add value to this insignificant waste (Boushy et al., 1985; García et al., 2005).

The rise in the Philippines' population entails increased demand for food supplies such as poultry and livestock (Sison, 2014; Boushy et al., 1985). Recent data showed a rise in the number of broiler chickens produced in the country. During this year, the supply and demand for poultry increased, especially in areas where universities and colleges are clustered as classes started in cities including Bacolod, Talisay, and Bago (Nicavera, 2019). One of the problems faced by the feed industry brought upon by the increase of poultry production in the country is the shortage of feed ingredients. This shortage leads to feed producers importing the ingredients (Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development [PCAARRD], 2021). Also, 25 percent of the animal feeds made in the country are for poultry (Corpuz, 2016).

In a study by Mirwandono et al. (2018), most waste generated by traditional markets is from discarded vegetables and fruits, which can be processed into something valuable. Studies revealed that vegetable wastes still contain a considerable amount of nutrients, including metabolizable energy, crude protein, and moisture, which are essential in the production of poultry feeds (Sagar et al., 2018; Singh et al., 2012). With the aid of fermentation, it was observed that the nutritional value of these wastes increased to levels that qualify as raw material for poultry feed (Mirwandono et al., 2018; Yang et al., 2006). Results from experiments showed that, with the help of fermentation, broiler chickens were protected from pathogens inside their gastrointestinal tract (Huang et al., 2015; Sugiharto & Ranjitkar, 2019). Subsequently, most feed manufacturing plants use conventional feedstuffs like corn and soybean meal; their prices and supply depend on external factors. Thus, exploring the potential of these unconventional feedstuffs could lower the production and retail cost of poultry feeds (Boushy et al., 1985).

The worsening waste problem brought upon by improper segregation and limited treatment facilities has become an issue in urbanized cities. This study is anchored on an alternative waste management plant that could aid the government's waste management efforts. The researchers propose designing a plant for poultry feed production that uses vegetable waste collected from Libertad Market as the raw material. Specifically, this study aims to determine the annual loading of vegetable wastes (in metric tons) from Libertad Market as the basis for raw material input, perform a lab-scale experiment on the production of poultry feeds from vegetable wastes of Libertad Public Market to determine the composition of vegetable waste and experimental yield of the product, examine the quality of feeds produced based on the basic parameters (crude protein, crude fat, moisture, pH), compare produced feeds with one of the leading poultry feed brand (Pilmico Feeds) based on the parameters stated in the third specific objective, design a process flow diagram of the poultry feed production plant, perform material and energy balances involved in the overall process of poultry feeds production derived from fermented vegetable waste, design necessary equipment in the production of poultry feeds as to sizing, configuration, and selection of materials, determine the production cost for the production of poultry feeds derived from fermented vegetable waste, design the safety, instrumentation, and process control for the production of poultry feeds derived from fermented vegetable waste; and prepare a waste management plan on solid waste, wastewater, and air pollution. Establishing a poultry feed processing plant will help solve solid waste problems and benefit local poultry farmers (Region 6 Profile, n.d.).

METHODOLOGY

The researchers gathered data about waste from the Libertad South Public Market from various articles and relevant journals. A Waste Management Division personnel of the Bacolod City Department of Public Services was interviewed. The manufacturing process of poultry feeds derived from fermented vegetable waste started with collecting raw waste from the Libertad South public market. The collected raw waste then underwent segregation, weighing, cutting, washing, rinsing, and milling until it reached the fermentation process. The vegetable waste underwent fermentation using Lactobacillus spp. for 24 hours. The fermented vegetable waste was mixed with additional nutrients before being dried, pelletized, screened, cooled, and packed. The laboratory design was adapted from Daharbha et al. (2015) and with personal correspondence with Relles (2019).

As for the laboratory design, 2 kg of raw vegetable waste was obtained from the Libertad South Public Market. From the collected vegetable waste, 1.5 kg was segregated. The segregated waste was then cut into smaller pieces before it underwent the washing process. The cut vegetable wastes were washed in 9.6 liters (L) of 0.1 percent sodium bicarbonate solution for 10 minutes. After which, the soaked waste was rinsed with 4.8 L of water. The washed vegetable waste was then milled in a blender. The cultivation of Lactobacillus spp. was done with the help of Negros Prawn Producer's Cooperative (NPPC). The culture was inoculated in phosphate broth for transportation purposes. The NPPC prepared one liter of broth. According to Relles (2019) laboratory design, the milled vegetable waste was mixed with 600 milliliters (mL) of culture media for fermentation. An air-tight plastic container served as a makeshift reactor.

The substrate concentration was monitored during the fermentation stage at 0 hours (hr), 18 hr, 20 hr, and 24 hr. The Phenol-sulfuric method was utilized to determine the substrate concentration. It was seen that the substrate concentration declined as the researchers expected, which coincided with the study by Bhuvaneshwari and Velmurugan (2011). But at the 24-hr reading, the substrate concentration suddenly increased. Certain factors may be the answer to this abnormality, such as an error in the laboratory experiment, incorrect reading in the device, or contaminated samples. After fermentation, the samples were sent to the Provincial Veterinary Feed and Meat Laboratory for quality testing of pH, percent crude protein, percent crude fat, and percent moisture. Additional nutrients, such as rice bran,, were added to make up for the insufficient percent crude fat. However, the researchers did not add rice bran. After fermentation, some samples were dried in the tray dryer for 15 minutes to obtain a moisture content of 18 percent, which was the needed moisture for pelletizing. The dried poultry feed mixture was pelletized to a length of 5 millimeters (mm) with a diameter of 7 mm (Cha et al., 2018)., screened, and cooled. The researchers did not perform pelletizing, screening, and cooling.

The data for the annual mass loading of raw materials (waste from Libertad South Public Market) were retrieved from the Bacolod City Department of Public Services.

As for the composition of vegetable waste, characterization was done by the researchers. ASTM D 5231 – 92, or Standard Test Method for Determination of the Composition of Unprocessed Municipal Solid

Waste, was employed (ASTM Committee D-34 on Waste Management & ASTM Subcommittee D340106, 2008).

The quality of the feeds produced must follow the Philippine Standards guidelines. The poultry feeds were sent to the Provincial Feed and Meat Laboratory for quality testing.

As for the comparison of the produced feeds versus commercial Pilmico Feeds, the criteria were based on the percent crude fat, percent crude protein, percent moisture, and pH. According to the Bago City Veterinary Office (2019), and Provincial Feed and Meat Laboratory, the nutritional facts of Pilmico poultry feed for Broilers are the following: crude protein, >15 percent; crude fat, >3 percent; moisture, <13 percent. These standards also align with the Philippine Standards for Poultry Feed Broiler Finishers.

The process in the production of poultry feeds from fermented vegetable waste involves segregation, weighing, shredding, washing, rinsing, milling, fermentation, mixing, drying, pelletizing, screening, cooling, and packaging. The process flow of this study was based on the studies of Bakshi et al. (2016), Mahgoub et al. (2018), de Silva (1998), Sugiura et al. (2009), Wadhwa & Bakshi (2013) while taking into account the Philippines Recommends Series No. 64-A (Philippine Council for Agriculture and Resources Research and Development, 1987).

As for the material balance procedures, the material balances in the equipment were based on the overall flowchart constituting the entering and leaving streams. The Law of Conservation of Mass was observed when calculating material balances (Felder & Rousseau, 2005). Material balance for single equipment was utilized for segregation, weighing, cutting, washing, rinsing, milling, mixing, drying, cooling, and packaging. A recycling system material balance was applied to pelletizing and screening. As for the fermentation process, reactive system material balances were utilized.

For the energy balances, the study's main areas that utilized energy were fermenting, drying, and cooling. The energy balances in the equipment involved heating and cooling; thus, energy conservation was utilized in determining the heat loss and heat gain (Geankoplis, 2003).

Various Chemical Engineering design books and heuristics were utilized in designing the equipment. The researchers designed the essential equipment involved in producing fermented feed from vegetable waste.

The plant area and spacing of the process areas utilized were based on the size and capacity of the installed equipment. For safety, a Hazard and Operability study (HAZOP) was adopted as the safety analysis technique (Almasi, 2017).

RESULTS, DISCUSSION, AND IMPLICATIONS

In a day, about 16 tons of waste are generated by Libertad Market, disposed of at the open dumpsite of Bacolod City. Out of these tons of garbage, 80 percent comprises vegetable and fruit wastes (R. Palalon, personal communication, 2019). However, only vegetable wastes are used to produce poultry feed. Specifically, the poultry feeds produced are specified to be used by meat-type chickens called broiler chickens.

In the laboratory experiment, 2 kg of waste was collected, and approximately 1.5 kg of vegetable waste was obtained. A sampling experiment was done to characterize the vegetable wastes. The sampling method was based on ASTM D 5231 – 92 or the Standard Test Method for Determination of the Composition of Unprocessed Municipal Solid Wastes. The number of samples needed for the characterization was 45, with a 90 percent confidence level interval to be completed within five sampling days, meaning that nine samples were done daily. From the sampling, the most occurring vegetable wastes were from cabbages, pechays, water spinach, okra, carrots, lemongrass, and tugabang. These vegetable wastes were used for the laboratory scale in the percentages (18%) cabbage, (8%) pechay, (22%) water spinach, (1%) okra, (16%) carrots, (2%) lemongrass, and (33%) tugabang. In the laboratory experiment, vegetable wastes were cut and shredded using knives. The cut wastes were washed with 9.6 L of 0.1% sodium bicarbonate solution, rinsed with 4.8 L of water, and milled using a blender. They were then fermented with 600 mL of Lactobacillus spp., cultured with the assistance and help of NPPC, and dried with hot air at a temperature of 65°C. Samples were then sent to the Provincial Veterinary Office Feed and Meat Laboratory. Results showed that the vegetable wastes did not contain enough fat. Hence, there is a need to add rice bran, which is a great source of fats (Bhosale & Vijayalakshmi, 2015).

It was mentioned that 16 tons of vegetable waste are collected daily, but to allow the plant to operate even at low garbage collection, an input of 15 tons of waste was assumed. With this amount of input waste daily, 11,784 kg of poultry feed is to be produced daily. The plant is to operate daily, seven days a week, and 350 days a year.

The equipment used for the whole process was designed for pre-purchasing and fabrication. An automatic segregator separates the desired materials, which are the vegetable wastes, from the unwanted materials. A weigher is used to determine the amount of vegetable waste to be fed and to ensure the accuracy of the feed raw material. They are then shredded to reduce the size of the vegetable waste. The shredded vegetable wastes are then washed with 0.1% sodium bicarbonate solution to remove the pesticides and other possible contaminants which may reduce the quality of the final product and may interfere with some of the further processes in the plant (HarinathaReddy & Devi, 2014; Vemuri, 2018). Water is used to rinse the sodium bicarbonate solution from the vegetable wastes. A hammer mill is used to further reduce the size of the vegetable waste to 15,000 micrometers (Cha et al., 2018). The raw materials are then fermented in a fermenter with a diameter of 3.61 meters and a height of 2.41 meters, a helical coil with a diameter of 8 centimeters, and an impeller with 0.80 meters in diameter and height above the fermenter vessel floor. The temperature in the fermentation is maintained at 37°C and a pressure of 176.17 kPa.

After a 24-hour fermentation, the vegetable wastes are mixed with rice bran to reach the standard fat content for broiler poultry feeds. Rice bran is to be added since it was stated in the laboratory results during the researchers' laboratory experiment that the fermented vegetable wastes lack fat nutrients, and rice bran is a great source of fat nutrients. The mixture is then dried in a direct-contact, counter-flow rotary dryer with an air inlet temperature of 65°C, reducing the moisture content of the fermented vegetable waste to 18 percent. The fermented vegetable wastes are then sent to the pelletizer. The pellets leave the pelletizer at a high temperature of 80°C. They are then passed to the cooler to reduce the temperature to just a little above the ambient temperature with a moisture content of 13 percent. The pellet feeds are then packaged.

As for the energy balances, only three pieces of equipment were considered –energy balance in the fermentation, cooler, and dryer processes. In the fermenter, a total of 334,122.7656 kJ per hour of energy is lost by the reaction. This is also equal to the energy absorbed by the cooling fluid inside the helical coil installed inside the fermenter. In the computation of the energy balance in the fermenter, an enthalpy change of -29.1 calories per millimole of glucose is used (Forrest et al., 1961). In the dryer, an inlet stream for wet material and dry air of 1,009.48 kg solid per hour and 45,338.85 kg dry air per hour, respectively, an air inlet temperature of 338 Kelvin, and an outlet temperature of 323 Kelvin with a humidity of 0.0283 and 0.0395 kg H_2O per kg dry air, respectively, were used. The rotary dryer has a change in enthalpy of 592.5472 kJ per hour. In the cooler, the inlet temperature of the poultry feeds from the pelletizer is 80˚C. This is to be cooled to a temperature of five degrees higher than the ambient temperature of 28˚C. The outlet temperature of the poultry feeds is 33˚C. With the material's specific capacity of 2 kJ per kg-˚C (Bortone, n.d.), the total energy used in the cooler per hour is 48,972.12 kJ.

The design of the storage tanks is as follows: the water tank is designed to have a height and a diameter of 9.8 meters and 6.53 meters, respectively, with a volume capacity of 327.6 m3; the 0.1% sodium bicarbonate solution tank is designed to have a height and diameter of 12.33 meters and 8.22 meters, respectively, and a volume capacity of 655.2 m3; the rice bran storage tank is designed to have height and diameter of 9.45 meters and 6.30 meters, respectively; and the design for culture storage tanks are the height of 0.9 meters, the diameter of 0.6 meters, and a volume 0.2432 m3. The designs are all based on handbooks and other literature sources.

The plant layout of the poultry feeds industrial plant has a total land area of 1,073.6 square meters. The plant layout consists of the storage room, parking lot, material loading area, administration building, clinic, human resource building, wastewater treatment facility, quality control room, manufacturing area, and a future expansion lot. The total area of the manufacturing area is 218.79 square meters.

The whole poultry feed industrial plant was designed most economically, with the equipment acquired and fabricated according to the desired capacity and design of the plant. The total capital investment of the plant is Php 57,518,807.23, with a total annual product cost of Php 222,857,941.90. The poultry feeds plant needs a total of 90 employees, which consists of the general manager, plant operations manager, department heads, department supervisors, technicians, operators, utilities, department secretaries, an accountant, bookkeepers, security officers, analysts, and an auditor, accounting to a total of Php 22,783,339 of labor cost. The broiler poultry feeds will be sold for Php 28 per kilo, which is cheaper than the usual poultry feed product cost.

To reduce the risks and hazards within the industrial plant and ensure the product's quality, proper safety instrumentation and process controls such as ratio, temperatures, and pH controls are installed with HAZOP plans.

The piping and instrumentation diagram was designed in such a way that it can transfer the material from one piece of equipment to another. Belt conveyors, screw conveyors, and bucket elevators were designed to accommodate the solid material, whereas the carbon steel pipe of schedule 40 was used for transferring liquids. The total conveyor, pump, and blower power requirements were solved based on the transferred material. The total conveyor power requirement was computed as 51.7266 horsepower. The actual work needed by the pump, considering the friction losses in the pipes, was also computed.

Environmental management plans (EMPs) were considered to ensure that the whole process's environmental impact is minimal or none. These EMPs were designed to protect the environment and keep the workers and the people around the plant safe from hazardous materials that may come from the plant. These plans range from personal to institutional safety management plans. Personal protective equipment, or PPE, is provided for each employee to ensure they are safe from the potential hazards caused by the equipment and the wastes produced by the industrial plant. Unpleasant smells stemming from the waste can cause discomfort for workers and the surrounding community. Therefore, misting and exhaust systems will be installed inside the facility. To reduce the plant's liquid waste, which comes from the washing, rinsing, and fermentation processes, screens are used to separate the solid materials, which will be further used in the succeeding processes, from the liquid wastes, which will be disposed to the environment. The liquid wastes from the washing and rinsing departments are to be disposed of based on the parameters provided by DAO 2016-08. The effluent from both processes contains 0.1% sodium bicarbonate solution. According to the Division of Research Safety, the solution may be flushed directly to the sanitary sewer since it is classified as non-hazardous liquid chemical waste. The effluent from the fermentation process will be treated by autoclaving at a temperature of 121˚C for fifteen minutes before discharging to the sewer. This should be done to ensure that the microorganisms used in the fermentation are sterilized. As for the dryer and cooler, the exhausted air from the equipment will pass through filter bags to ensure that the particulates are filtered, and pure air is exhausted.

CONCLUSION AND RECOMMENDATIONS

In conclusion, vegetable wastes are great sources of raw material for the production of broiler poultry feeds, considering that they contain the necessary nutrients that broiler chickens need. However, since the fat content of the vegetable wastes was not enough, there was a need to add rice bran as a great fat source. The vegetable wastes were fermented with Lactobacillus spp. to enhance the nutrient content of the vegetable wastes. The fermentation was done for 24 hours with a maintaining temperature of 37˚C.

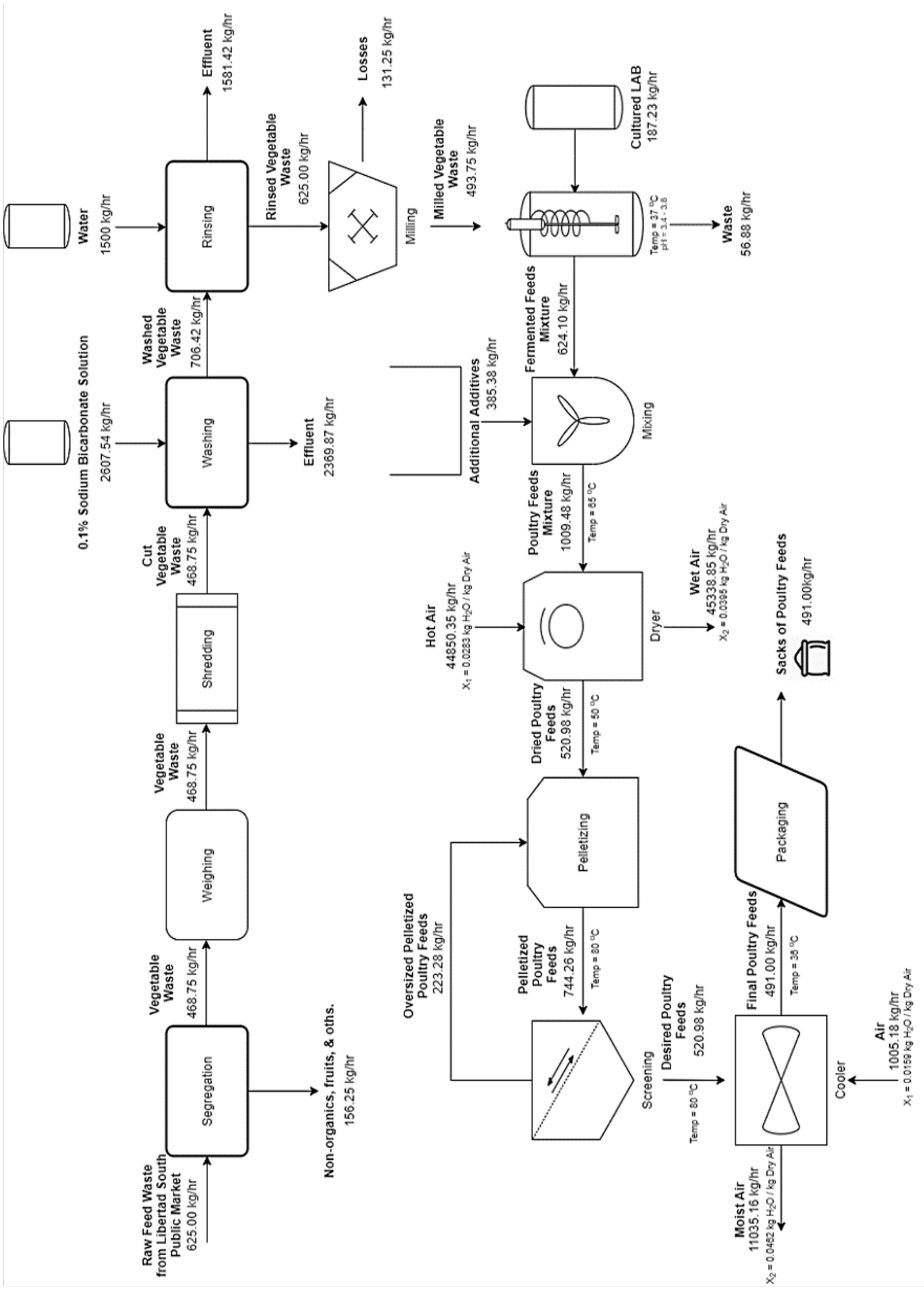
As a summary of the material balances, an input of 625 kg per hour of raw material is utilized, 491 kg per hour of products are produced, and a material balance with complete streams is illustrated.

Energy balance summarizes that a total of 334,122.7656 kJ per hour is consumed in the fermentation process with 48,972.12 kJ per hour consumed in the cooling process and a total of 592.5472 kJ per hour change of enthalpy in the drying process.

The whole plant was designed to be economically efficient without sacrificing the quality of the products produced. It was ensured that, with the plant's capacity and other factors considered, the plant could still obtain profit. The equipment used is acquired and fabricated according to the desired capacity and design of the plant. The broiler poultry feed is sold cheaper, which may become significant and helpful to farmers and poultry owners. Using vegetable wastes as raw materials would help lessen waste in the environment. With the plant's annual capacity of 5,421.89 tons and annual revenue and profit of Php 151,812,920 and Php 19,585,234.80, respectively, the plant can have a payback period of 3.45 years with a return of investment of 28.97%.

As a recommendation from the researchers, future researchers should further examine and test the capabilities of, not only vegetable wastes but also other organic waste materials as potential raw materials for the production of broiler poultry feeds. Future researchers should also explore more on the fermented poultry feeds, especially in enhancing their nutrient contents.

Figure 1
Overall Flow Chart



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