Mass and Energy Balance Analysis of The Animal Feed Industry in Sidenreng Rappang Regency (Case Study: CV Cahaya Mario Feed Mill)

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Abstract. Livestock has an important role in supporting the availability of animal protein in the community. CV. Cahaya Mario as one of the livestock businesses has also established an animal feed factory to meet the internal needs of animal feed. This study aims to analyze the mass and energy balance of the CV Cahaya Mario. This research was carried out in the Kulo sub-district, Sidenreng Rappang Regency from July - September 2022. This research procedure has 2 stages. Mass balance, calculating the mass of incoming and outgoing materials and measuring the content of materials in the form of water content, ash content, protein and fat. Energy balance, in the analysis of internal energy from changes in temperature of materials and external energy from energy sources and mechanical processes. This study shows that the feed process takes place in a continuous flow. From the results of the analysis of the content of feed ingredients, it was found that the content of water content (10%), ash content (19%), fat (2.78%) and dissolved protein (0.08%). Analysis of electrical energy input to the hammer mill is 120.2 Kwh, while the electrical energy to the mixer is 222427.3 Kwh. The size reduction energy for corn in the hammer mill is 801,6 kwh, for soybean meal it is 902,05 kwh. and mixing energy (mixer) of 247.095 kwh. The thermal energy in the corn grinding process is 119.9 KJ, for soybean cake is 18.8 KJ, and for thermal energy in animal feed is 130506.9 KJ.

Keywords: Animal Feed, Mass and Energy Balance, Hammer Mill, Mixer, Size Reduction.

1 Introduction

The increase in corn production as one of the raw materials in the livestock industry is triggered by the increasing demand for eggs and chicken meat in the market. As a raw material for animal feed, corn has the potential to be utilized because it has 70% carbohydrates, 10% protein, and 5% fat [1]. The starch content in corn kernels ranges from 54% - 72% [2]. This content is relatively higher than other food grain commodities. The Livestock business has an important role in supporting the availability of animal protein in the community. The high price of feed corn in recent times had an impact on the increase in feed prices. Meanwhile, the price of live chickens and broiler eggs is falling, causing farmers' businesses to be in a difficult situation.

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Sidenreng Rappang (Sidrap) Regency is one of the largest egg-producing centers in South Sulawesi. The total population of chickens in Sidrap Regency in 2020 reached 4,680,103 tails [3]. Based on the 2006 National Standard regarding the need for feed in the type of chicken and duck cultivation, for laying hens it takes 110 grams per head/day. Fulfillment of poultry feed is currently produced by large companies from outside Sidrap Regency. Seeing this potential, the development of the animal feed industry in the Sidrap Regency area has considerable prospects. CV Cahaya Mario is one of the corn processing factories for animal feed having its address in Mario village, Kulo sub-district, Sidrap Regency. This company was founded in 1993. The company was initially only engaged in laying hens for consumption. To meet the company's internal feed needs and to meet the needs of animal feed in the surrounding area, the CV Cahaya Mario Feed Mill feed factory was developed on December 29, 2021.

In the food processing industry, the concept of mass and energy balance is a controlling parameter in the handling process, especially it can be used to determine the results obtained from a process. The mass of the material passing through the processing operation can be described by its mass balance. Mass balance is used to determine the inflow and outflow of materials in a process. In addition, mass balance is also used to determine the amount/quantity of various materials in each process flow [4].

Energy balance in a system is based on the principle/law of conservation of energy, namely that energy can neither be created nor destroyed. The energy balance will be continuous with the principle of mass balance so that the calculation principle used is similar to the energy balance of mass balance. Energy balance is a condition when the amount of energy in the system is always the same. This energy can be in the form of kinetic energy, potential energy, heat energy, and others. This form of energy can be transformed into other forms of energy. These forms of energy can be in the form of other forms of energy so that the total energy in a system will always be the same [4][5].

In processing corn into animal feed, it is very important to evaluate the mass and energy balance in each stage of the processing process or the whole process. The identification and specification of all materials and equipment related nto the process is included in the calculation process

Baiq Mardayani, et.al (2016) examined the energy and mass balance in the drying chamber, fluidized bed drying device for drying corn. The results of their research concluded that the weight of the material and the moisture content of the material continued to decrease along with the increase in temperature and airflow velocity of the dryer, while for energy balance it was found that the highest drying efficiency value was obtained at 2 m/s air velocity of 11.62% and the lowest efficiency was obtained. slightly at 6 m/s air flow velocity of 4.61%.

A similar study related to the analysis of changes in the physical properties of instant rice from the Ciherang variety (inpari 64), showed that the mass balance of instant rice produced a yield of 42.16% - 59.73% and the energy balance of the instant rice drying process produced input energy of 12.785 kcal while the energy output of 40.0157 kcal so that additional energy (stored energy) is needed from the drying room, namely the heater and dry air from the blower (Tarigan, Elva Gitta Frina Br., 2019)

CV Cahaya Mario feed factory is a new feed industry that uses new technology tools and machines, it is necessary to conduct a study the mass and energy flows that occur in each process of processing corn into animal feed.

2 Material and Method

2.1 Material

The tools used in this research are processing tools and machines, a digital thermometer, a corn moisture meters, and digital scales. The materials used are yellow corn kernels that have been peeled and have gone through a drying process with an initial moisture content of between 14 - 17%, soybean meal, bran, stone flour, palm oil meal and concentrate.

2.2 Method

Mass Balance Analysis. To examine the mass balance in CV Cahaya Mario's animal feed business, direct observations were made in the field. This process is divided into 3 stages:

a. Identify the characteristics of the input and output materials by taking samples 2 times in 3 different types of feed processing. Six (6) samples were tested at the Unhas Food Quality Control and Analysis Chemistry Laboratory to determine the ingredients including water content (oven method), fat content (Soxhlet method), ash content (furnace method), and protein content (lowry method).
b. Characterizing the mechanical processes that occur at each stage of the processing.
c. Calculate the total mass balance for each stage using the Equation 6:

$$M_{in} = M_{out} + \Delta M \tag{1}$$

Information:
M_{in} = total input mass
M_{out} = total output mass
ΔM = mass stored in the system

d. Calculate the mass balance of the parts using the equation [6]

$$(\mathrm{M_c.X_c + M_{sm}.X_{sm} + M_{ct}.X_{ct} + M_p.X_p}) = (\mathrm{M_f.X_f}) \tag{2}$$

Information:
M_c = mass of corn
X_c = water content of corn
M_{sm} = mass of soybean meal
X_{sm} = water content of soybean meal
M_{ct} = mass of concentrate
X_{ct} = water content of concentrate
M_p = mass of premix

X_p = water content of premix
M_{af} = mass of animal feed
X_{af} = water content of animal feed

$$(M_c.X_{fc} + M_{sm}.X_{fsm} + M_{ct}.X_{fct} + M_p.X_{fp}) = (M_{af}.X_{faf}) \quad (3)$$

Information:
M_c = mass of corn
X_{fc} = fat level of corn
M_{sm} = mass of soybean meal
X_{fsm} = fat level of soybean meal
M_{ct}= mass of concentrate
X_{fct}= fat level of concentrate
M_p = mass of premix
X_{fp} = fat level of premix
M_{af}= mass of animal feed
X_{faf} = fat level of animal feed

$$(M_c.X_{ac} + M_{sm}.X_{asm} + M_{ct}.X_{act} + M_p.X_{ap}) = (M_{af}.X_{aaf}) \quad (4)$$

Information:
M_c = mass of corn
X_{ac} = ash content of corn
M_{sm} = mass of soybean meal
X_{asm} = ash content of soybean meal
M_{ct} = mass of concentrate
X_{act} = ash content of concentrate
M_p = mass of premix
X_{ap} = ash content of premix
M_{af} = mass of animal feed
X_{aaf} = ash content of animal feed

$$(M_c.X_{pc} + M_{sm}.X_{psm} + M_{ct}.X_{pct} + M_p.X_{pp}) = (M_{af}.X_{paf}) \quad (5)$$

M_c = mass of corn
X_{pc} = protein content of corn
M_{sm} = mass of soybean meal
X_{psm} = protein content of soybean meal
M_{ct} = mass of concentrate
X_{pct} = protein content of concentrate
M_p = mass of premix
X_{pp} = protein content of premix
M_{af} = mass of animal feed
X_{paf} = protein content of animal feed

Energy Balance Analysis. Several energies are calculated in formulating energy balance:*Calculating the energy input from electricity*

a. Electricity Energy [8]:

$$E_e = Hp \text{ x } t \tag{6}$$

Where: **Ee** is electrical energy (kwh), **Hp** is power (watt), **t** is time or duration (h)

b. Energy consumption in process [9]:

$$E_c = V \text{ x } I \text{ x } \text{Cos } \varphi \text{ x } t \text{ x } \sqrt{3} \tag{7}$$

Where: $\mathbf{E_c}$ is consumed electrical energy, **V** is the line voltage, **I** is the line current, **Cos φ** is the power factor, **t** is grinding time, $\sqrt{3}$ for three-phase electricity

Calculate the energy that occurs in the process:

a. Size reduction energy is calculated using the equation Rittinger Law [10]:

$$E = K_R \left(\frac{1}{d2} - \frac{1}{d1}\right) \tag{11}$$

Where: **E** is energy per unit mass required for the production of a new surface by reduction, $\mathbf{K_R}$ is called Rittinger's constant, $\mathbf{d_1}$ is the average initial feed size, $\mathbf{d_2}$ is the average final product size.

b. The rotary or stirring energy that occurs in the mixer [11]:

$$P = F_D \text{ x } v_{stirrer} \tag{8}$$

$$F_D = \frac{1}{2} \text{ x } C_D \text{ x } \rho \text{ x } v^2 \text{ x } A \tag{9}$$

Where **P** is stirring power (watt), $\mathbf{v_{stirrer}}$ is stirrer power, $\mathbf{F_D}$ is stirring style (N), $\mathbf{C_D}$ is drag coefficient, ρ is density (kg/m^3), v^2 is stirrer speed (m/s), A is the area that hits the material (m^2).

c. Energi thermal bahan dengan menggunakan persamaan [12]:

$$Q = m.cp.\Delta t \tag{10}$$

Where: **Q** is the heat term, **m** is mass (kg), **cp** is coefficient heat, and **ΔT** is the difference in temperatures between the system and the surroundings (°C)

d. Describe the process of mass and energy balance as a whole.

3 Result and Discussion

3.1 Company Description

CV Cahaya Mario was founded in 2004 by Mr. H. Usman Appas. The company is also a development of his grandfather's business which has been running since 1993. Mr. H. Usman Appas is the third generation who later formed CV Cahaya Mario which at that time managed about 2000 laying hens. Along with the development of its business, CV Cahaya Mario Feed Mill currently has around 600 thousand laying hens occupying an area about 20 ha, where the location is in Kulo District, Sidrap Regency. The company currently has 4 cages, of which cage 1 has a capacity of 350 thousand laying hens located in Mario Village. Cage 2 has a capacity of 80 thousand laying hens, cage 3 has a capacity of 70 thousand laying hens and both are placed in the village of Rijang Panua. Cage 4 is placed in the village of Patondong Salo with a capacity of 100 thousand laying hens.

3.2 Mass Balance

The process that occurs in the poultry feed processing business at CV Cahaya Mario Feed Mill is a continuous flow. In a continuous process, some input and output quantities cannot be determined precisely, so certain integers are used as the basis for the example. In this process, it is divided into 3 process stages, where each material entering and leaving is calculated for its mass balance.

Stages 1: Intake. Animal feed processing uses 4 kinds of raw materials, namely corn, soybean meal, concentrate, and premix. The premix is a mixture of bran, stone flour, and palm oil meal. The first intake is shelled corn and soybean meal. The incoming shelled corn mass is 7250 kg and soybean meal 2300 kg. Both are inserted in turns into a sieve drum which serves to sort out dust and dirt contained in the mixture of materials. In this process, there is a reduction in the mass of corn material caused by the presence of sand or gravel impurities contained in the material. Meanwhile, for soybean meal, the incoming mass is the same as the outgoing mass.

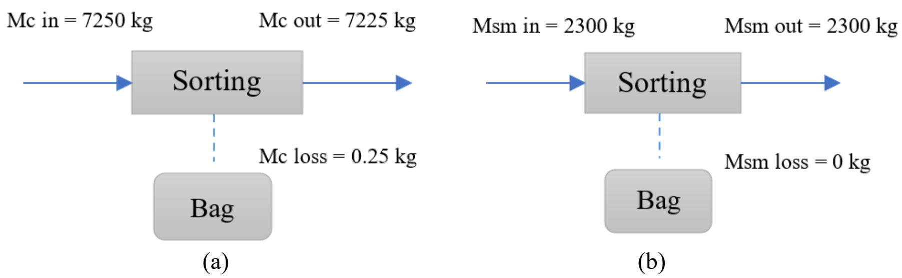

Fig. 1. (a) Sorting diagram of shelled corn on drum sieve, (b) Sorting diagram of shelled soybean meal on drum sieve.

Corn raw materials are then entered into the hammer mill, then ground and ground into smaller particles. Of the total incoming material of 7225 kg, the material that comes out into small particles is 7218 kg. assuming the material left is 0.7 kg. Based on the efficiency of the tool with a driving power of 215 HP with an engine speed of 3000 rpm, the output assumption is 99.9%, where previously there were test results conducted by the NTT Agricultural Technology Study Center (BPTP) regarding the work test of hammer mill type grinding tools. with several types of feed ingredients as test materials, it was found that in shelled corn, the working capacity of the efficiency of the tool with a driving force of 7.5 HP and an engine speed of 1500 rpm was 93.3% [12]. The type of material is one of the factors that affect the workability of the tool other than the skill of the operator, the engine rotation speed (rpm), the size of the tool, and the diameter of the filter hole. There is no review of the literature on the performance of the hammer mill machine for the milling process on soybean meal, so the working capacity of the hammer mill on shelled corn is considered to be the same as the working capacity of 99.9% soybean meal.

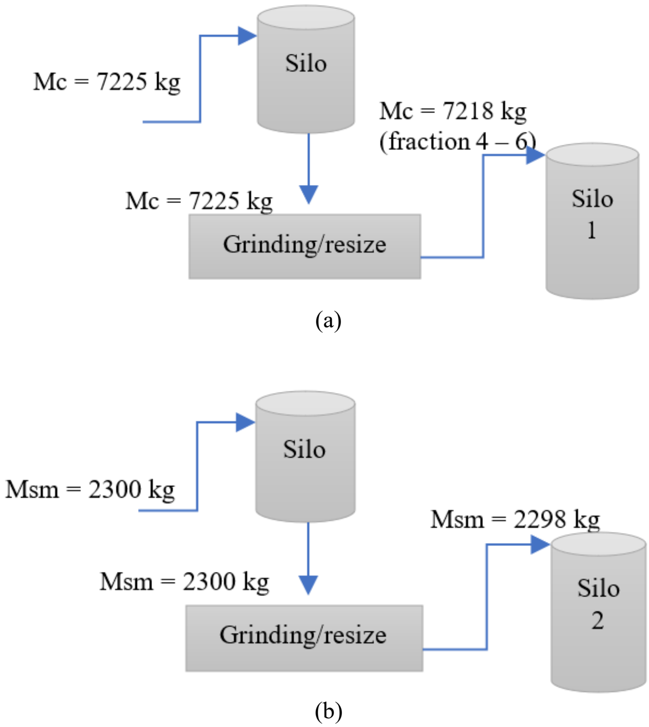

Fig. 2. (a) Corn size reduction in Hammer Mill, (b) Soybean meal size reduction in Hammer Mill.

Stages 2: Weighing and Mixing. The shelled corn and soybean meal which have become small particles are then brought to the silo. Each material occupies 1 silo. The other two materials, concentrate (2300 kg) and premix (3400 kg) are then transported to the silo using a conveyor. There are 4 storage silos in total. After all the silos are filled, weighing will be carried out based on the formulation that has been set. 1 time weighing 1 ton, soybean meal: 150 kg, corn: 475 kg, concentrate: 150 kg, premix 225 kg. The entry setting into the doshing/weighing device is regulated by a valve located at each end of the silo.

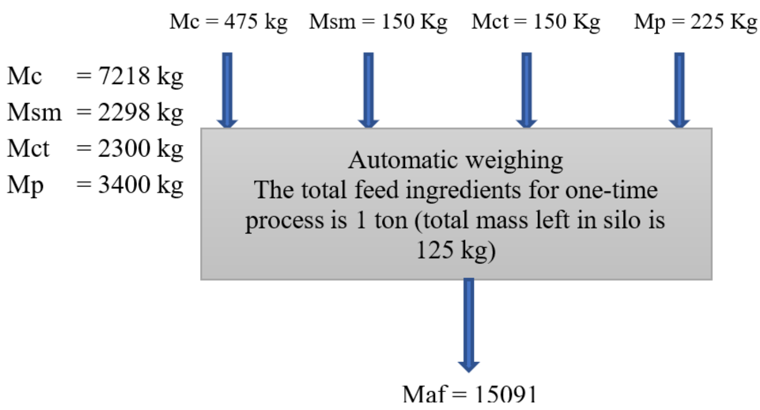

Fig. 3. Weighing diagram of feed raw materials based on formulation.

Of the total feed ingredients of 15216 kg, and with the feed formulation entering the automatic weighing of 15000 kg, there is still some mass of feed ingredients that goes beyond the desired feed formulation. The total mass that should be left in each silo is 216 kg. there is a mass of material that passes outside the formulation due to inaccurate weighing. For more details, it can be seen in Table 1 below where the feed calculation is obtained from the final calculation by the system when all feed processing has been completed. The process sequences are equal to the mass balance values we obtained.

Table 1. Final Recap of The Incoming and Outgoing Material Masses

Material Name	Feed Formula (Kg)	The amount included in the weighing
Soybean Meal	2250	2253
Corn Kernels	7125	7193
Consentrat	2250	2257
Premix	3375	3388
Total	**15000**	**15091**

Source: Process display capture on operator monitor, 2022

Stages 3: Packing. The total mass of feed that enters the packaging is 15091 kg. When packaging is done, the total mass of feed that comes out is 15100 kg. During the process, there is a mass of feed left in the shelter for packing from the previous feed processing of 9 kg. a total of 50 kg sacks produced as much as 302 pieces. The increase in feed mass is caused by the mass of feed left in the previous processing.

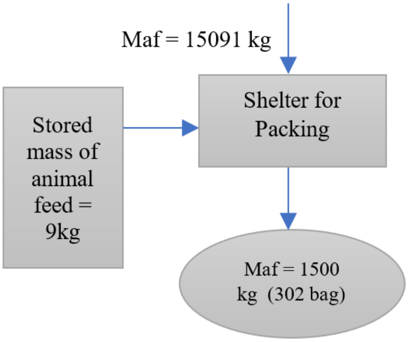

Fig. 4. Packing Diagram.

To measure the content of feed ingredients, 2 random samples were taken in 3 processing times. Based on the results from the Chemical Laboratory for Food Quality Analysis and Control of Unhas, the results of the measurement of the content of feed ingredients were obtained at Table 2.

Table 2. The result of The Measurement of The Content of Processed Animal Feed CV Cahaya Mario.

Sample Code	Parameter			
	Water Content (%)	Ash Content (%)	Fat Content (%)	Dissolved Protein (%)
Animal Feed 1 A	10,30	19,64	2,78	0,08
Animal Feed 1 B	11,92	6,30	3,74	0,10
Animal Feed 2 A	9,91	18,33	3,04	0,11
Animal Feed 2 B	10,24	15,04	4,09	0,08
Animal Feed 3 A	9,73	18,77	2,52	0,10
Animal Feed 3 B	10,26	17,01	3,14	0,12

Source: Analytical chemistry laboratory - Unhas, 2022.

Comparison in the table of laboratory results with the table of requirements for the quality of animal feed according to SNI 01-3928-2006, maximum moisture content of 14%, maximum fat of 7%, and maximum ash content of 8%, it can be said that the quality of feed produced by CV. Cahaya Mario still needs to be improved on the feed formula used to reduce the ash content.

After the processing of chicken feed has been completed, the next step is to calculate the mass balance of the parts. This is done to find out whether the total mass of the incoming ingredients is the same as the mass of the animal feed components.

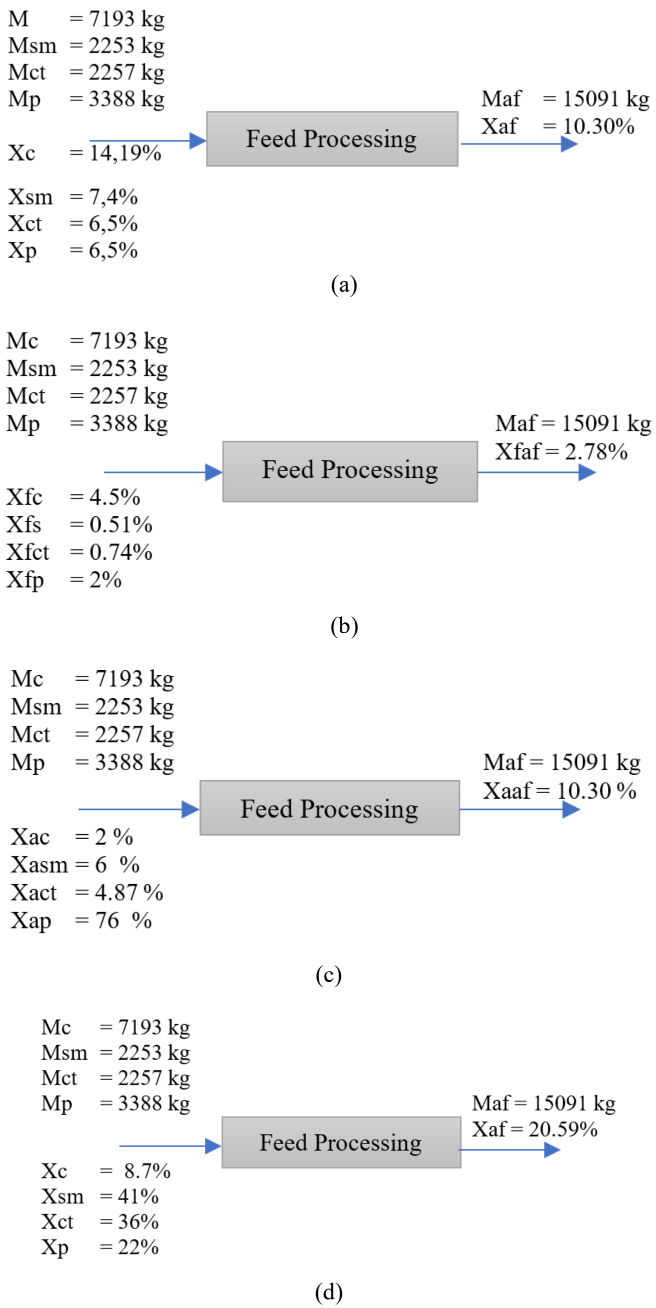

Fig. 5. (a) Water Component Balance, (b) Fat Component Balance, (c) Ash Component Balance, (d) Protein Component Balance.

3.3 Energy Balance Electrical Energy Usage

CV Cahaya Mario Feed Mill animal feed factory uses electrical energy to run the processing process. The lack of availability of generators as additional energy has not been deemed possible because production has not been carried out continuously. The choice of using electricity is more profitable in terms of costs and the environment because electrical energy does not cause noise and odor. For tools that use large amounts of electrical energy, such as hammer mills (215 HP) and mixers (40 HP), the electricity required is 190,153 watts. Where 1 HP is equivalent to 745.7 Watts. The average time required for the hammer mill to grind 9 tons of feed ingredients is 45 minutes, of which 30 minutes for 7 tons of corn and 15 minutes for 2 tons of soybean meal. As for the mixer, mixing 15 tons of ingredients takes 45 minutes. The electrical energy required and the effectiveness of energy by the two machines can be seen in Table 3.

Table 3. Electrical Energy Usage and Effectiveness of Energy at Hammer Mill and Ribbon Mixer.

Process	Electrical Energy Usage (kwh)	Effectiveness of Energy Utilization (KJ/Kg)
Corn kernel size reduction and grinding process in hammer mill	8016.275	1274,27
Soybean Meal size reduction and grinding process in hammer mill	40081.37	22,05
Mixing feed ingredients on a ribbon mixer	222427.396	778,23

3.4 Energy Feed Processing

For energy the size reduction process in the hammer mill for corn and soybean meal raw materials, the Rittenger's Law equation is used. Corn kernels with a size of 11 mm where the desired level of fineness is 2.4 mm (based on the standard size of grain and leaf material as animal feed) with a sieve diameter of 8 mm, while soybean meal with an average initial diameter of 5 mm is ground again into 0.2 mm [14], while the sieve diameter for soybean meal is 3 mm. with a hammer mill power of 215 HP. (1 Hp = 745.7 watts). The electrical energy required to shrink the corn kernels for 30 minutes is 801.628 kwh. While in the process of reducing the size of soybean meal, the electrical energy needed to reduce the size of soybeans for 15 minutes is 902.055 kwh.

Mechanical Energy in this case the rotary energy that occurs in the mixer. The drag coefficients for the box-shaped mixer are 2.05 [13], where the total mass of the dough is 15091 kg. The rotary energy required to stir the total feed dough 15091 kg for 45 minutes is 247.095 kwh. Thermal energy occurs due to an increase in temperature caused by the grinding process or size reduction for feed ingredients and the process of mixing feed in the mixer. Overall, the energy that occurs in the process can be seen in Table 4 below:

Table 4. Size Reduction, Rotary and Thermal Energy in Animal Feed Processing.

Process	Size Reduction Energy (kwh)	Rotary Energy (kwh)	Thermal Energy (KJ)
Corn kernel size reduction and grinding process in hammer mill	801.628	-	119.94
Soybean Meal size reduction and grinding process in hammer mill	902.055	-	18.89
Mixing feed ingredients on a ribbon mixer	-	247.095	130506.97

The process that occurs in the processing of animal feed is a closed process. so all the existing energy is not lost in the surrounding.

3.5 Layout Process Mass and Energy Balance

Based on the calculation and analysis of mass and energy balance in CV Cahaya Mario animal feed processing, the following is Fig.6 is the overall mass and energy balance layout process that occurs.

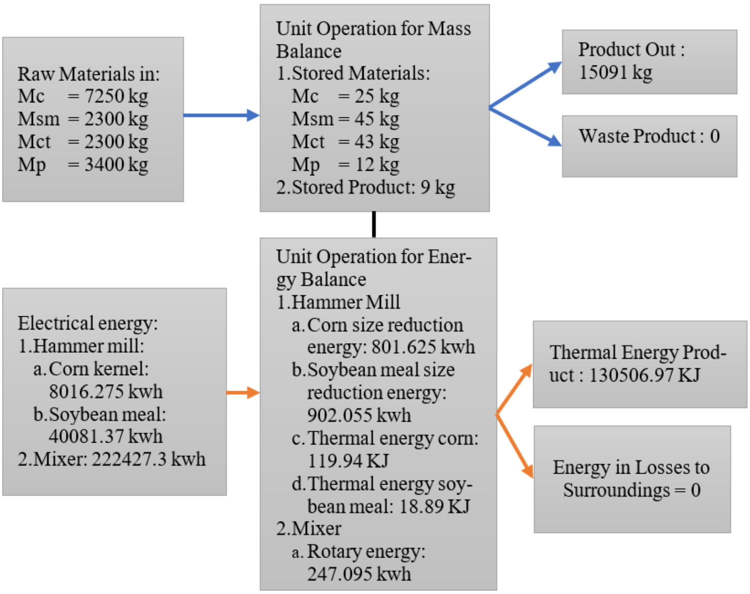

Fig. 6. Diagram of Mass and Energy Balance in Animal Feed Processing CV Cahaya Mario Feed Mill.

4 Conclusion

Based on the results of data analysis and discussion, some can be put forward some the following conclusions:

1. The mass of the material and the mass of the incoming and outgoing parts in the feed processing process are almost the same. This proves that the efficiency of tools and machines is 99.9%
2. The content of animal feed ingredients still needs to be improved in terms of ingredient formulation so that the content of feed ingredients processed by CV Cahaya Mario can meet national standards regarding the quality and quality of animal feed.
3. The largest energy use is found in the hammer mill machine. where in this tool and machine, there are 2 processing grinding and size reduction with two different material's, corn kernel and soybean. Thermal energy for the heat energy produced is 130506.97 KJ with total mass animal feed is 15091 kg.

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