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Assessing the Potential for Biogas and Bio-fertilizer Production from Municipal Abattoir Waste in Debre Markos Town, Amhara Region, Ethiopia

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Abstract

The increasing demand for protein-rich food has resulted in a significant rise in the slaughter industry and the production of abattoir waste in urban areas. This study aims to evaluate the amount of abattoir waste generated and explore its potential for biogas and bio-fertilizer production in Debre Markos municipality. The researchers collected primary and secondary data through field observations and reports from Debre Markos municipality abattoir office, respectively. By applying mathematical models, the study estimated the amount of abattoir waste produced and its feasibility for biogas and bio-fertilizer production. The results showed that the abattoir slaughtered approximately 6,420 cattle annually, generating 249,096 kg of waste per annum. Through anaerobic digestion, this waste could produce around 13,276.82 cubic meters of biogas and 18,308.56 kilograms of bio-fertilizer, with a potential monetary value of $11,924.3 per year. However, at present, the abattoir waste disposal occurs in an open area, which poses environmental, social, and economic effects on nearby residents. Therefore, relocating the abattoir away from residential areas and implementing anaerobic digestion for waste treatment is an essential solution to address these issues and enhance resource reutilization.

Keywords: *Abattoir Waste, Bio-fertilizer, Bio-gas, Mathematical Models*

1. Introduction

Globally, meat consumption is on the rise due to increasing population and income levels. This surge has led to a significant increase in slaughterhouse waste generation. While this waste is biodegradable and organic, it poses a significant environmental and health challenge if not managed properly. Traditionally, studies have focused on converting slaughterhouse waste into animal feed and fertilizers, highlighting its potential for sustainable waste management (Hejnfelt & Angelidaki, 2009).

Slaughterhouse waste consists of various animal by-products, including rumen and blood components, which can harbor harmful pathogens like bacteria, viruses, and parasites. The daily quantity of waste generated varies depending on the type and number of animals slaughtered (Afazeli et al., 2014; Parker et al., 2022).

The global demand for protein-rich food has tripled in recent years, leading to a substantial increase in abattoir waste generation (FAO, 2011). This poses a significant environmental concern, particularly in urban areas where over-dumping of organic waste is prevalent (Ezeoha & Ugwuishiwu, 2011). In developing countries, like many African nations, improper dumping of industrial waste, including abattoir waste, remains a common practice (Chukwu, 2008; Singh et al., 2014).

The improper management of abattoir waste, especially in developing countries, has severe environmental and societal consequences (Akinro et al., 2009). Improper disposal can contribute to environmental degradation, disease transmission, and adverse health effects for communities living near abattoirs (Chukwu, 2008). While abattoir waste is entirely organic and can be composted, recycled, or repurposed, it is often left to decompose, causing unpleasant odors (Fearon et al., 2014).

Despite the negative impacts of improper abattoir waste disposal, research has demonstrated its potential for conversion into valuable products like biogas and bio-fertilizers (Audu et al., 2020; Azadbakht et al., 2021; Sindibu et al., 2018; Tolera & Alemu, 2020). However, in many Ethiopian towns, abattoir waste is still disposed of in open spaces without any treatment, leading to environmental pollution and health risks for nearby residents.

Abattoir waste in Ethiopia receives less attention compared to other industrial wastes. Limited research has been conducted on its management, particularly concerning environmental issues and the production of biogas and bio-fertilizers (Tolera & Alemu, 2020). While some studies have quantified the amount of abattoir waste entering the environment, more research is needed on its potential for biogas and bio-fertilizer production.

The burning of fossil fuels contributes significantly to greenhouse gas emissions, leading to global warming, depletion of non-renewable resources, rising fuel prices, and negative health and environmental impacts. This has motivated researchers to explore alternative, sustainable energy sources (Majeed et al., 2019; Zhang & Qiu, 2018).

Debre Markos town municipality abattoir currently discharges all its waste products into the environment, posing a threat to the surrounding community. Residents have complained about the unpleasant odors caused by improper waste management. However, the quantity of abattoir waste generated and its potential for biogas and bio-fertilizer production remain unexplored.

This study aims to evaluate the rate of abattoir waste generation and its potential for biogas and bio-fertilizer production, providing a sustainable waste management solution for Debre Markos town abattoir in Ethiopia.

2. RESEARCH METHODOLOGY

2.1. Description of the Study Area

The study was carried out at the municipal abattoir in Debre Markos town, which was established in 1979 GC. It has an area of 1000 meters square and is situated in the southeastern part of Debre Markos town. The abattoir's GPS readings in UTM coordinates are 360872 East and 1140859 North. The abattoir is bordered by villages, and the abattoir house is situated in a wetland area. This abattoir is the only legally known slaughterhouse in the town that only offers cattle slaughtering services (Figure 1).

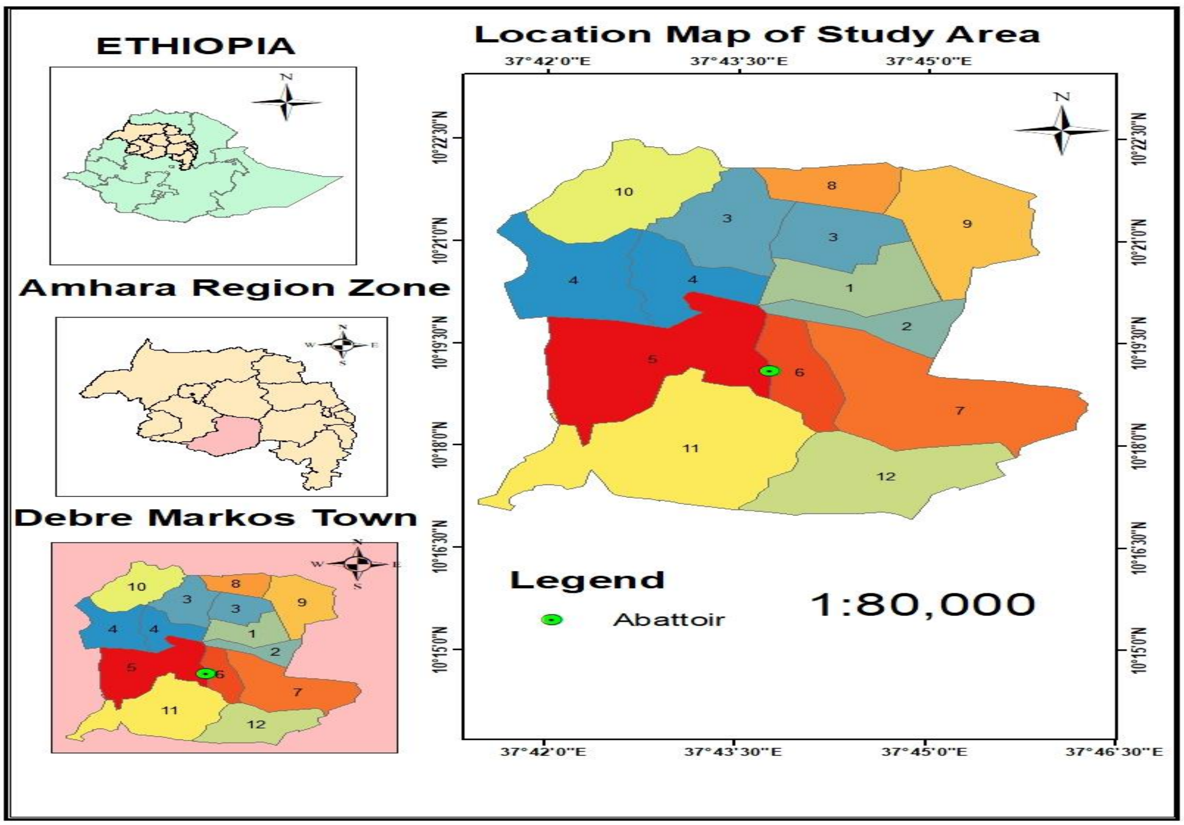

Figure 1. Location map of the study area

2.2. Study Approach

The number of cattle slaughters obtained from the survey was used to determine the volume of waste, biogas, and bio-fertilizer potential. This research was performed following the laws, guidelines, and ethical standards of Ethiopia, where the research was performed (Admasu & Jenberu, 2020).

2.3. Data sources and types

Data was collected through field observations and municipality reports obtained in 2022.

2.4. Method of Estimating Abattoir Waste Generation

According to Twumasi et al. (2016), abattoir waste is divided into two parts: the solid part and the liquid part. Blood, tissue waste, bone waste, and gut content make up the solid portion of the waste, whereas the liquid portion of the slaughterhouse (Twumasi et al., 2016) waste is primarily water used at the lair age to wash the blood and may also contain water used by humans. Based on this study, each slaughtered cattle in the abattoir could produce 88.13 liters of wastewater.

Thus, the amount of wastewater produced per cattle = 88.13 litters. ----------------- Equation (1)

The number of cattle slaughtered during the research period from September 2022 to August 2022, including five days of Pagume, 2022, was obtained from data recorded by Debre Markos municipality abattoir office. This information was used to calculate the amount of major solid elements in abattoir waste. Based on the mathematical compositions developed by (Aniebo et al., 2009; Fearon et al., 2014), the amount of waste composition produced by the slaughtered cattle was estimated in kilograms.

Based on this, one cattle could produce 12.6 kg of blood waste, 8.0 kg of intestine contents waste, 6.4 kg of tissue waste, and 11.8 kg of bone waste; thus, a total weight of 38.8 kg of solid abattoir waste per cattle could be generated (Aniebo et al., 2009; Fearon et al., 2014) -------------------------- Equation (2)

2.5. Method for Biogas and Bio-fertilizer Potential Conversion of Abattoir Waste

2.5.1. Biogas Production from abattoir waste

In this study, the amount of biogas that could be produced from one ton of solid abattoir waste was calculated based on (Ngumah et al., 2013; Rao et al., 2000) conversion coefficients for biodegradable substrates. Based on this method, one ton (1000 kg) of solid abattoir waste could generate 53.3-meter-cube biogas. -------------------- Equation (3)

2.5.1.1. Energy estimation methods

Based on Walker et al. (2009) study, the amount of energy produced from one-meter cube biogas is equal to 22 MJ/m^3. Based on this assumption, 1 Watt is equal to 1 J (joule) per second, and one Watt per hour is equal to 3600 J. Thus, 1 kilowatt hour is equivalent to 3600000J, or 3.6 mega joules. Therefore, 1-meter-cube biogas has a thermal heat value of 22 mega joules, which is equivalent to 6.1 kWh.

Thus, $1m^3$ biogas = 6.1 kWh. ---------------- Equation (4)

The efficiency of biogas to be converted into electricity and heat energy is 35% and 50%, respectively, and there will be 15% losses to the environment from the total waste (Deublein & Steinhauser, 2011).

Thus, 1 m^3 biogas = 2.14 kWh of electricity and 3.1 kWh of heat energy. ----------Equation (5)

2.5.1.2. Equivalence of estimated biogas with other fuels

According to Momodu et al. (2020) study on the energy estimation method, 1 m^3 of biogas is equivalent to 0.45kg of liquefied petroleum gas, 0.6kg of kerosene, 3.5kg of charcoal, 0.4kg of furnace oil, 0.7kg of petrol, and 0.5kg of diesel. --Equation (6)

2.5.1.3. Cost estimation methods from biogas energy

According to Wakjira and Kefale (2022), the electricity tariff amendment study reports that the maximum payment for 1 kWh of electricity or heat equals 0.0462 USD or 2.4810 ETB for residential users.

Therefore, 1 kWh = 2.4810 ETB (0.0462 USD). -- Equation (7)

2.5.2. Bio-fertilizer estimation methods from abattoir waste

According to the Ngumah et al. (2013) study, the coefficients used in estimating bio-fertilizer yields are based on the fraction of the dry mass portion of organic waste that is not converted to biogas. Thus, bio-fertilizer yield can be estimated based on the coefficient fraction of the dry mass and a volatile solid portion of abattoir waste (Deublein & Steinhauser, 2011).

2.5.2.1. Dry Mass (DM) and Volatile Solids (VS)

Dry Mass (DM): It is a solid fresh abattoir waste minus moisture content. DM of abattoir waste is equal to 15% of the abattoir waste generated.

Thus, dry mass = 0.15 x total abattoir waste generated. ------------------------------ Equation (8)

Volatile Solids (VS): It is the theoretically dry mass (DM) of abattoir waste that is converted into gas. Deublein and Steinhauser (2011) Stated that the volatile solids of abattoir waste are equal to 85% of the DM of abattoir waste.

Thus, volatile solids = 0.85 x dry mass of abattoir waste. ------------------------ Equation (9)

Bio-fertilizer yield: the bio-fertilizer yield of abattoir waste was calculated considering DM and VS. So, based on Deublein and Steinhauser (2011) principle, bio-fertilizer yield was estimated as DM minus VS plus forty percent of VS. This is because 60% of VS was converted into gas, and the remaining 40% was left as a residual.

Thus, bio-fertilizer yield = (DM – VS) + (VS x 0.40). ------------------------------- Equation (10)

2.5.2.2. Cost estimation from bio-fertilizer

According to Abebe et al. (2022), the price of chemical fertilizer is 4800 ETB per quintal.

The price of bio-fertilizers is lowered by half as compared to chemical fertilizers. Thus, the price of bio-fertilizer is 2400 ETB per quintal or 24 ETB per kg. Thus, 1 kg of bio-fertilizer = 24 ETB. ----------------- Equation (11)

2.6. Method of Data Analysis

Data were coded, checked for consistency issues, missing values, and amendments if necessary, then cleaned, entered, and analyzed using SPSS (Statistical Package for Social Science) version 26.

3. Results and Discussion

3.1. Trends and rate of abattoir waste generation

From 2014 to 2019, there was an increasing trend in the rate of cattle slaughtering and abattoir waste generation in the abattoir Debre Markos town. However, in 2020 and 2021, there was a decline in cattle slaughtering and abattoir waste generation due to the COVID-19 pandemic outbreak.

In 2022, the number of slaughtered cattle and the amount of abattoir waste generation increased by 139.64% compared to 2021, as indicated in Table 1

Table 1. Trends and rate of abattoir waste generation

Year	Number of cattle slaughtered	Amount of abattoir solid waste generated (kg)	Amount of abattoir wastewater generated (liters)	% increase and decrease in abattoir waste each year
2014	2783	107980.40	245265.79	-
2015	3433	133200.40	302550.29	+23.36%
2016	3554	137895.20	313214.02	+3.53%
2017	3707	143831.60	326697.91	+4.31%
2018	3715	144142.00	327402.95	+0.22%
2019	3884	150699.20	342296.92	+4.55%
2020	2631	102082.80	231870.03	-32.26%
2021	2679	103945.20	236100.27	-1.79%
2022	6420	249096.00	565794.60	+139.64%
Total	32806	1272872.80	2891192.78	

Source: own estimation, 2022

3.2. Abattoir waste generation, biogas, and bio-fertilizer potential

3.2.1. Number of cattle slaughtered in the abattoir

According to the data, the average number of cattle slaughtered daily, weekly, monthly, and annually at the abattoir was 30, 150, 600, and 6,420, respectively. These figures do not include backyard slaughtering in the form of kitchens in the town. The number of cattle slaughtered in each period varies due to the presence of different fasting periods as well as periodic festival events throughout the year. The number of cattle slaughtered each day in the abattoir was lower than Hawassa City abattoir which slaughtered 63 cattle per day (Sindibu et al., 2018). It is also lower than the number of cattle slaughtered in Elfora Kombolcha, Adama, and Mekele abattoirs which slaughtered 275, 200, and 125 cattle per day respectively (Mummed & Webb, 2015) and also lower than Dire Dawa abattoir which slaughtered 66 cattle per day (Tolera & Alemu, 2020).

Moreover, it is also less than the number of cattle that were slaughtered in Nigeria at Suleja abattoir which slaughtered 180 cattle, Minna abattoir slaughtered 60 cattle, Lafia abattoir slaughtered 45 cattle, and Karu abattoir slaughtered 135 cattle per day (Audu et al., 2020). This is because many people prefer farm yard slaughtering without the consent of the abattoir office. But, the number of cattle slaughtered per day in Debre Markos municipality abattoir was greater than Haramaya Town Abattoir and Haramaya University Enterprise Abattoir which slaughtered 10 and 12 cattle per day respectively (Tolera & Alemu, 2020).

The amount of water needed to process one cattle's meat is approximately 88.13 liters, as shown in equation 1. As a result, the amount of wastewater generated for washing meat and cleaning processes was 2,643.90 liters per day, 13,219.50 liters per week, 52,878 liters per month, and 565,794.60 liters per year. This waste is discharged into the environment, as depicted in Figure 2. Besides this, urine and blood generated during the slaughtering operations make up the liquid waste at the abattoir. Due to the high water consumption, a lot of wastewater is produced and it is directly released into the environment without any prior treatment.

During observation of the waste management procedures of the abattoir, liquid waste from the abattoir including blood, urine, wastewater, and dissolved solids was temporarily kept in a septic tanker until it was full. When the septic tanker is full, the waste will overflow and be discharged into the wetland at downstream areas without any treatment.

Figure 2. Liquid abattoir wastewater mixed with blood flowing into tanker.

Source: own-Photo (2022)

Abattoir wastes like manure, intestinal contents, rumen contents, horns, hooves, gallbladders, internal organs, bones, condemned meats, and plastics are left on the abattoir site. Based on field observation, stomach paunches, legs, and heads of cattle were stored there for a long period of time (Figure 3). These wastes are odorous, attract flies, and have caused a bad smell in the area.

Figure 3. Solid abattoir waste (bone and intestinal contents waste) piled up in the abattoir.

Source: own-photo (2022)

3.2.2. Abattoir Waste Generation and Composition

This study showed that Debre Markos municipality abattoir generates 1,164kg of abattoir waste per day, 5,820kg per week, 11,640kg per month, and 249,096kg per year (Table 2). The amount of abattoir waste generation in Debre Markos municipality abattoir is almost smaller than Hawassa city abattoir which generated 2,456.04 kg/day and 885,881.6 kg/year (Sindibu et al., 2018). It is also lower than the annual abattoir waste generation in Suleja, Minna, and Karu abattoirs in Nigeria which generated 8.19, 3.05, and 8.41 tons of abattoir waste respectively (Audu et al., 2020) and Mina abattoir in Nigeria which generated 2,394kg/day and 873,810kg/year of abattoir waste (Ahaneku & Njemanze, 2015). As well as it is also lower than the Temale abattoir in Ghana which generated 2,134kg/day and 778,910kg/year (Frederick et al., 2010). However, it is greater than the annual abattoir waste generation of Harar Town Abattoir, Haramaya Town Abattoir, and Haramaya University Enterprise Abattoir which generated 224,366 kg, 192,253 kg, and 174,193 kg of abattoir waste per year respectively (Tolera & Alemu, 2020)

Table 2. Abattoir waste generation and composition

Time durations	Number of cattle slaughtered	Composition and the total amount of abattoir waste generated (kg)				
		Blood waste	Intestinal contents waste	Bone waste	Tissue waste	Total abattoir waste
Daily	30	378	240	354	192	1164
Weekly	150	1890	1200	1770	960	5820
Monthly	600	7560	4800	7080	3840	23280
Annually	6420	80892	51360	75756	41088	249096

Source: own survey, 2022

According to this study, the amount of blood waste produced was the highest of all types of abattoir waste. Figure 4 shows that blood waste comprised 32% of the total abattoir waste, with a generation rate of 378 kg per day and 80,892 kg per year (Table 2). When compared to other abattoir waste components blood waste is huge. This finding is similar to Aniebo et al. (2009) study that stated blood waste comprised the maximum percentage of abattoir waste.

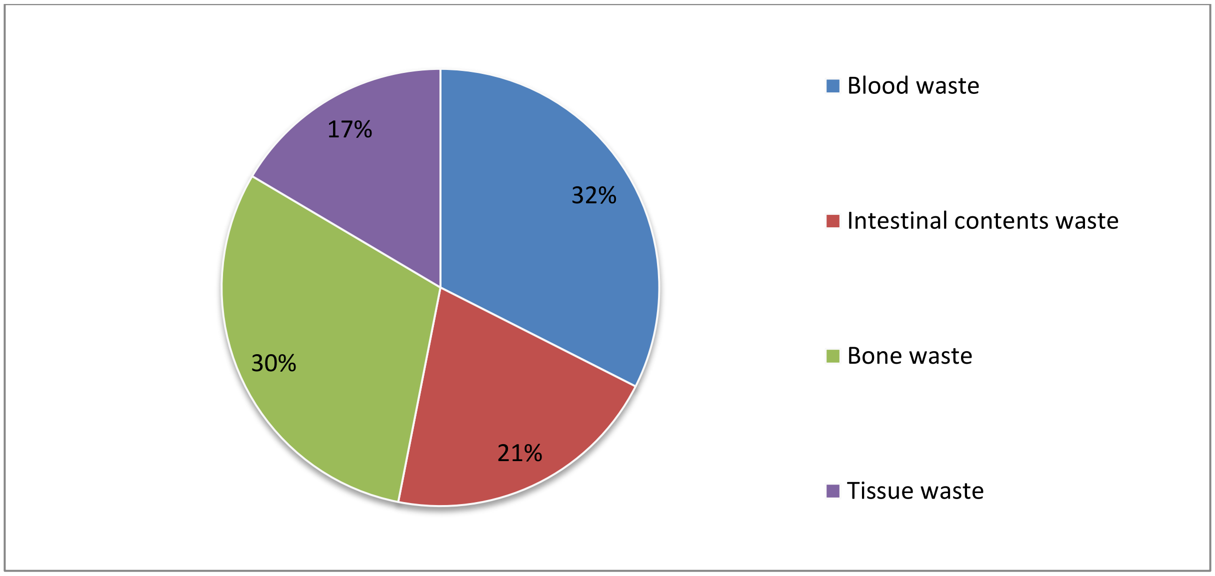

Figure 4. Abattoir waste composition by percentage

3.2.3. Biogas production potential

3.2.3.1. Biogas Estimation from abattoir waste

Biogas production was estimated based on the standard coefficients of Rao et al. (2000) study, which states that 1 tonne of abattoir waste (1000kg) produces a 53.3-meter cube of biogas. Thus, annual biogas production of 13,276.82 m^3 and 62.04 m^3 daily biogas production were estimated from Debre Markos municipality abattoir (Table 3). Biogas production from this abattoir is smaller than a study conducted by Mummed and Webb (2015) study that showed 557m^3, 406m^3, and 253m^3 /day of biogas were produced from Elfora kombucha abattoir, Adama abattoir, and Mekele abattoir respectively. It is also smaller than the biogas produced by the Minna abattoir in Nigeria and Temale abattoir in Ghana produced an average of 45,672.64m3 /year and 40,716.72m3 /year (Frederick et al., 2010) respectively.

Therefore, Debre Markos Municipality abattoir waste has a high potential to produce biogas energy that is utilized for a different purpose which is highly reliable as an alternative energy source. In our country, Ethiopia, 92% of the people use biomass for cooking. This traditional technique adds to Ethiopia's deforestation problem and indoor air pollution (World Bank, 2016). According to Kefalew and Lami (2021) study, 20 up to 60 m^3 per day of biogas is sufficient for small to medium-scale enterprises and a minimum of 0.8 m^3/ day for a family. Thus, Debre Markos town municipality abattoir could generate an average of 36.37m^3 of biogas per day which could be used to run small-scale business enterprises.

Table 3. Biogas production estimation from abattoir waste

Time duration	Abattoir waste (kg)	Abattoir waste (tons)	Biogas yield (m^3)
Daily	1,164	1.164	62.04
Weekly	5,820	5.820	310.21
Monthly	23,280	23.28	1240.82
Annually	249,096	249.096	13,276.82

Source: own calculation, 2022

Energy conversion from Biogas

The total amount of energy that could be produced from one-meter-cube biogas is equal to 6.1 kWh. Thus, 80,988.60 kWh per year of energy could be produced from the abattoir waste (Table 4). Generally, this study indicates that the production of biogas from the abattoir waste was estimated at 62.04 m^3 per day.

Table 4. Amount of energy that could be produced from biogas of abattoir waste.

Time duration	Biogas (m^3)	Energy (kWh)	Estimated energy (kWh)			
			Electricity 35%	Heat 50%	Total 85%	Losses 15%
Daily	62.04	378.44	132.46	189.22	321.68	56.77
Weekly	310.21	1892.28	662.30	946.14	1608.44	283.84
Monthly	1240.82	7569.00	2,649.15	3784.50	6433.65	1135.35
Annually	13276.82	80988.60	28346.01	40494.30	68840.31	12148.29

Source: own survey (2022)

Biogas equivalents of fossil fuels

The amount of biogas that could be produced from abattoir waste can be converted into fossil fuels using the B-sustainability energy coefficient standard (Table 5).

Table 5. Equivalent of biogas potential of abattoir waste to other fossil fuels

Time duration	Biogas m^3	Petrol (0.7kg)	Kerosene (0.6kg)	Diesel (0.5kg)	Charcoal (3.5kg)	LPG (0.45kg)	Furnaces oil (0.4kg)
Daily	62.04	43.43	37.22	31.02	217.14	27.92	24.82
Weekly	310.21	217.15	186.13	155.11	1085.74	139.59	124.08
Monthly	1240.82	868.57	744.49	620.41	4342.87	558.37	496.33
Annually	13276.82	9293.77	7966.09	6638.41	46468.87	5974.57	5310.73

Source: own calculation, 2022

3.2.3.2. Cost estimation of energy produced from biogas

According to Wakjira and Kefale (2022), the electricity tariff amendment study reports the maximum payment for 1kWh of electricity or heat equals 0.0462 USD or 2.4810 ETB for residential users (Table 6). Thus, the cost of 1 kWh is equal to 2.4810 ETB or 0.0462 USD……….... Equation (7).

Table 6. Energy produced and estimated cost

Time duration	Energy in kWh	Energy and its cost	
		ETB (2.4810)	*USD (0.0462)
Daily	378.44	938.91	17.48
Weekly	1892.28	4,694.75	87.42
Monthly	7569.00	18,778.69	349.69
Annually	80988.60	200,932.72	3,741.67

Source: own calculation, 2022 *One Dollar = 53.70 ETB

3.2.4. Bio-fertilizer production potential

To estimate the bio-fertilizer production potential from abattoir waste, Deublein and Steinhauser (2011) stated that coefficient fraction was considered. Based on equations 8 and 9, the dry mass (DM) of abattoir waste is 15 percent of the total fresh abattoir waste, while the volatile solid (VS) is 85 percent of the dry mass. Based on this assumption, bio-fertilizer yield = (DM-VS) + VS * 0.40 (equation 10). Thus, 85.55 kg per day and 18,308.56 kg per year of bio-fertilizer could be produced from the abattoir wastes (Table 7). This can be used for crop production for urban agriculture and urban greenery practices. Bio-fertilizer produced from biogas can bring sustainable crop production with minimum cost (Hua et al., 2020). Anaerobic digestion can generate essential plant nutrients at optimum levels (Veroneze et al., 2019). Besides this bio fertilizer could minimize environmental pollution. Thus, Biofertilizers from the abattoir waste can increase crop yield by 10

3.2.4.1. Estimation of bio-fertilizer production from abattoir waste

percent. In other words, the income generated from Debre Markos municipality abattoir could generate an extra source of income for the town.

Therefore, the production of bio-fertilizers by recycling the abattoir waste is the best way to meet the circular economy and create a healthy and clean environment (Ogbonaya et al., 2011). According to Alexandratos and Bruinsma (2012) study, the total fertilizer use could be increased by 97 million tons, and in 2050 this will reach 263 million tons. By 2050, developing countries would cover more than 70% of global fertilizer production which will increase the cost of fertilizers (Alexandratos & Bruinsma, 2012). Thus, bio fertilizer produced from biogas is environmentally sound and low cost and it can meet the needs of fertilizers to improve agricultural production and productivity at a low cost.

Table 7. Estimation of DM, VS, and bio-fertilizer production potential

Duration of time	Abattoir waste (kg)	DM of abattoir waste(kg)	VS of DM (kg)	Bio-fertilizer Yield(kg)
Daily	1,164	174.60	148.41	85.55
Weekly	5,820	873.00	742.05	427.77
Monthly	23,280	3492.00	2968.20	1711.08
Annually	249,096	37364.40	31759.74	18308.56

Source: own calculation, 2022

3.2.4.2. Cost estimation of bio-fertilizer produced from abattoir waste

According to Abebe et al. (2022), the price of chemical fertilizer is 4800 ETB per quintal. The price of bio-fertilizers is lowered by half as compared to chemical fertilizers. Thus, the price of bio-fertilizer is 2400 ETB per quintal or 24 ETB per kg. Thus, one kg of bio-fertilizer costs 24 ETB. Thus, the benefit was estimated from the abattoir waste of 2,053.30 ETB (38.24 USD) per day and 439,405.34 ETB (8,182.59 USD) per year (Table 8).

Table 8. Bio-fertilizer production from abattoir waste and its benefits

Duration of time	No Cattle slaughtered	Waste generated (Kg)	Bio-fertilizer (Kg)	Cost Estimation from Bio-fertilizer	
				ETB	USD
Daily	30	1,164	85.554	2,053.30	38.24
Weekly	150	5,820	427.77	10,266.48	191.18
Monthly	600	23,280	1711.08	41,065.92	764.73
Annually	6420	249,096	18308.556	439,405.34	8182.59

Source: own calculation, 2022

3.2.5. Cost estimation of biogas and bio-fertilizer produced from abattoir waste

By summing the costs of biogas and bio-fertilizer, 2,992.21 ETB (55.72 USD), 14,961.2 ETB (278.6 USD), 29,922.3 (557.2 USD), and 640,338 ETB (11,924.3 USD) were estimated per day, week, month, and year, respectively (Table 9).

Table 9. Summary of the cost estimated from biogas and bio-fertilizer production

Duration of time	No of Cattle	Abattoir waste (kg)	The estimated cost of Energy Estimated					
			Biogas		Bio-fertilizer		Total	
			ETB	USD	ETB	USD	ETB	USD
Daily	30	1,164	938.91	17.48	2,053.30	38.24	2992.21	55.72
Weekly	150	5,820	4,694.75	87.42	10,266.5	191.18	14961.2	278.6
Monthly	600	23,280	18,778.7	349.69	41,065.9	764.73	29922.3	557.2
Yearly	**6420**	**249,096**	**200,932.7**	**3,741.7**	**439,405.3**	**8182.6**	**640,338**	**11,924.3**

Source: own calculation, 2022

4. Conclusion and Recommendations

Debre Markos municipality abattoir generates a significant amount of waste daily, weekly, monthly, and annually. This waste has a substantial potential for biogas and bio-fertilizer production. The estimated biogas production can generate a significant amount of energy, while the bio-fertilizer production can contribute to agricultural productivity. Overall, the abattoir waste presents a valuable resource for sustainable energy and nutrient recycling.

Based on the findings of the study, the following recommendations are forwarded to relevant stakeholders, like local government, municipalities, and non-governmental organizations.

- The abattoir should ensure a clean environment through proper waste management and disposal by implementing sustainable and environmentally friendly waste management methods.
- In the long-term plan, the abattoir waste should be treated with biogas technology, and economic profits should be gained in the form of energy and bio-fertilizers.
- The abattoir waste, like blood, should be processed and used for poultry and pig feed rather than discharged into the open environment.
- The municipality should control illegal slaughtering without the consent of the relevant office.

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