Livestock waste and its role in the composting process: A review

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Abstract. Livestock waste, especially manure, is one source of pollution that needs attention. Increasing the number of the livestock industry will encourage increased livestock waste. An increase in livestock population will be directly proportional to waste production. Various efforts have been made to reduce the production of such waste. Along with technological advances, efforts to reduce livestock waste have been carried out such as biogas production, compost processing and bioenergy production. In Indonesia, composting is a simple technology that has developed. The use of a mixture of animal manure with materials from agricultural waste has been widely developed. The combination of these two ingredients will produce a better quality compost product. The application of microorganisms as decomposers has been widely developed in the process of composting livestock waste. Structurally, decomposers will increase and accelerate the process of degradation of compost raw material components. The effectiveness of microorganisms is influenced by the environment. The description in this paper aims to evaluate the role of waste from animal manure as a raw material in the composting process.

1. Introduction
Composting is an aerobic conversion process that runs in a controlled manner from an organic mass into a product suitable for soil requirements. This article aims to evaluate in general the role associated with livestock waste as raw material in the composting process. The combination of animal manure with organic material from plants will improve the quality of compost. Lignocellulose content in plants is one of the material that is quite interesting to study. This is because lignocellulose has an important role and influences the quality of compost [1]. The increasing livestock industry will encourage increased animal waste production. Improper handling can cause threats to the environment. Black Soldier Fly Larvae (BSFL) is one type of fly that has the potential and can effectively change manure into high-quality fertilizer. A study revealed the process of transforming organic matter from animal manure into compost. The results showed that the use of BSFL can reduce organic matter by 20.31-22.18% and the accumulation of volatile fatty acids (VFA) by 25.58-80.08% compared to controls. Composting using BSFL reduces nitrogen by 6.08-14.37%. The application of BSFL significantly increased total phosphorus (TP), total Kjeldahl nitrogen (TKN), and total nutrients respectively 42.30-64.16%, 45.41-88.17%, and 26.51-33, 34%. The results of this study indicate that the use of BSFL can improve product quality and the level of compost maturity. Therefore, the use of
BSFL can be recommended as a transformation agent with high efficiency to convert organic fertilizer into more stable compost. This is appropriate for developing countries, where adopting this process is relatively simple, inexpensive and difficult to manipulate [2].

The dairy farming industry is one of the industries that produce large amounts of milk. However, this industry has the potential to have a negative impact on the environment. Stool production from livestock with poor care, causes pollution to water, soil and air regionally. However, the indirect impacts will endanger human health [3]. At present, a technology has been introduced in the form of biogas production, composting, pyrolysis, bio-oil production and processing of organic fertilizers carried out to utilize large amounts of animal waste [4]. Anaerobic digestion process is a solution of good environmental improvement in Indonesia by reducing emissions, pollutants that produce environmentally friendly energy [5]. However, gas emissions resulting from the anaerobic digestion process have produced something that has great potential to produce global warming, photochemical oxidation, acidification, eutrophication, and toxicity to humans [6]. The composting process can produce organic fertilizer that can be used on agricultural land. However, to reduce cellulose levels in cow dung takes too much time [7, 8].

2. Potential of livestock waste

The composting process is one of the most effective and suitable methods for treating livestock waste. This method has been widely applied in Indonesia [9]. Statistics show that every year, in China, more than 17 metric tons of organic fertilizer have been produced by applying the composting method [10]. Various environmental problems that can arise from the composting process. Among them are the production of ammonia gas (NH₃), nitrous oxide (N₂O) and methane (CH₄) [11]. Various studies have been carried out by researchers to produce compost that is more economical, environmentally friendly. The composting process uses aerobic biochemical reactions. This is greatly influenced by air circulation, especially oxygen which can affect the process of carbon and nitrogen formation [12, 13]. In the past, static composting methods have been widely used. Over time the static method has gradually been replaced by the rotate or aeration method. This is done to speed up the composting process [14].

The aerobic composting process from dairy cow manure to be reused as a base in a cow pen is an efficient and environmentally friendly technology. The composting process is classified as a mesophilic and thermophilic process without cooling and maturation. The results showed that the dominant bacteria were the genera *Clostridium* and *Flavobacterium*. Quantitative PCR shows that there are four common types of pathogenic bacteria, namely *Salmonella*, *Shigella*, *Staphylococcus aureus*, and *Escherichia coli*. However, this type of bacteria was not found after the composting process. These results give an indication that pathogenic bacteria can be deactivated by the composting process using dairy cow manure. Compost products that meet the standards will not be dangerous and hygienic so that they can be used again as a base on cow pens [15]. Since the launch of economic reforms in China, the use of manure (pigs) has increased rapidly. Based on 2014 data, 551 million tons (dry weight) of animal manure was reported [16]. The impact of uncontrolled manure disposal processes causes pollution [17]. In an effort to reduce the level of animal manure pollution, the adoption of technology has been carried out by processing it into compost. This compost is then used in agriculture [18]. The use of bulking agents is widely considered to increase the effectiveness of the composting process. This material is mainly used for cattle dung which has a high density and moisture content but a low (C/N) ratio [19]. Compared to manure, straw has the opposite characteristics (low density, low water content, high C/N). Based on this, to get the best results, the mixing or combination of cattle dung with straw is carried out [20]. However, the lignocellulosic component is not easily degraded. The lignocellulose component is the most limiting factor that influences the composting process. Lignocellulose complexes such as straw have a strong chemical bond between lignin and hemicellulose. This bond forms a defense system that is relatively resistant to microbial degradation. One strategy used is to increase the surface area of cellulose which can be
degraded by microbes. The process of degradation by microbes aims to accelerate the composting process, especially in the use of raw materials for animal manure and straw [21].

The application of microbes was reported to be very effective in increasing the rate of degradation of compost raw materials [22]. This type of bacterial extracellular peroxidase is most often chosen and used to degrade lignocellulose [23]. As one example is the type of microbial Bacillus sp. This bacterium is a type of cellulose and lignin degrading bacteria [24] and Trichoderma sp. as a hemicellulose degradator [25]. Several studies have shown that the application of microorganisms in the composting process able to accelerate and increase lignocellulose degradation [26]. The results of other studies show that there is no significant difference between the composting process using inoculants and without inoculants (control) [1]. This can be explained that there has been competition between microorganisms contained in compost with microorganisms that are inoculated [27]. In addition, it was also explained that during the composting process, an increase in temperature occurred. The process of increasing the temperature until it reaches the tolerance limit can suppress the inoculant growth. This causes the inoculant unable to work effectively [28]. Animal manure is the main site of antibiotic resistant bacteria (ARB) and antibiotic resistance genes (ARGs). A study conducted in a rural industry in China that investigated the characteristics of ARBs and ARGs in fresh fertilizer and compost. The study results showed that the proportion of ARB and ARGs in chicken, pig and cow manure was significantly greater in compost fertilizer, and chicken and pig manure had a higher proportion of ARB and the amount of ARG was higher than in cow manure [29].

3. Composting process

Mature compost can reduce the heating rate, thermophilic phase, peak temperature, and solid degradation rate. The addition of mature compost can increase the content of cellulase, peroxidase, arilsulfatase, and urease during the mesophilic phase, and increase the content of urease. However, it can decrease cellulase, peroxidase, protease, and arilsulfatase during the cooling phase. Mature compost can increase bacterial diversity during the mesophilic and thermophilic phases, however it can reduce fungal diversity. Mature compost significantly increases the uniformity of the bacterial community and affects the structure of the bacterial and fungal community [30].

Figure 1. Convection currents and factors that influence the aeration process on a static compost heap [1]

Figure 1 provides an illustration related to the existence of air movements that are dominant in compost by static methods. The decomposition process that occurs in the pile will increase the temperature, which causes the convection of hot air to the top, and fresh air (oxygen) is obtained from the sides. As seen, some air can also enter the pile due to wind and diffusion. Evaluation of three types of composting systems is a different choice in overcoming weaknesses in static methods. One of the disadvantages is uneven air circulation in all parts. The composting process is one of the practical
technologies to reduce biomass solid waste (BSW) production. This process is an important process to support the production of organic fertilizer [31-33]. Based on this process, the impact that occurs is the release of gases such as: CO₂, ammonia (NH₃), methane (CH₄) and nitric oxide (N₂O) [34-36]. The impact of gas production causes the composting process to run slowly [37-38]. A research has been conducted to determine the characteristics of nitrogen and carbon produced from 4 types of composting process. The treatments consist of static treatment (ST), turning treatment (TT), forced aeration treatment (FAT), and forced aeration with acidification treatment (FAAT). The results showed that the process of degradation of organic matter increased at TT and FAT. This process accelerates composting efficiency. The process of nitrogen loss through ammonia evaporation increased by 14.0%. The process of evaporation of ammonia gas can be significantly reduced to reach 17.0%. Compared to FAT, FAAT increases nitric oxide production and decreases methane emissions. In general, the lowest global warming potential value (52.8kg CO₂eq/t) was found in FAAT. Therefore, based on environmental considerations, fertilizer and toxicity, the FAAT composting method is the best method [39].

4. The role of microorganisms in the composting process
The use of inoculants has been carried out in the process of making a mixture of straw and manure compost. The addition of inoculants is done to accelerate the composting process. A study has applied inoculants to straw raw materials prior to the composting process and during the composting process. Without the use of inoculants, they are used as controls. The results showed that the use of inoculants before composting and when composting increased the maturity index of C/N compost, dissolved organic and inorganic materials increased the total nutritional content of the final product by 4–13% compared to controls. Giving inoculants to the straw before the composting process affects the structure of the straw and increases the degradation of lignocellulose before composting. This is indicated by the decrease in cellulose content in straw by 8-18% and hemicellulose by 20-23% [40].

Figure 2. Comparison of the compost temperature change curve using a static method with the aeration method [1]

Figure 2 shows the compost temperature changes that can be expected in the static and aeration composting methods. Conventionally, the process will involve several populations of bacteria and fungi that develop in different temperature ranges, namely psychophilic (13°C), mesophilic (21-48 °C), and thermophilic (45-68°C). The temperature will be formed during the composting process. However, bacteria will soon work on materials that are easily oxidized. Metabolic processes occur that will cause temperatures to rise. Mesophilic bacteria are known to be effective for breaking down biomaterials
while thermophilic conditions are important in terms of detoxification and seed-breaking systems. The rapid development of the economy in China is driving an increase in the standard of living of people in China. This causes increased pollution. Biomass solid waste (BSW) is a major source of pollutants in rural areas in China. BSW includes food waste, household waste, animal waste, green waste, human waste and various kinds of residues from straw plants. This waste is directly disposed of in areas of rivers and ponds. This results in eutrophication of water resources, dirty gas release and transmission of pathogens [41].

![Figure 3](image1.png)

Figure 3. Curve changes in temperature and pH of the compost using static methods [1]

Figure 3 shows a decrease in initial pH due to the synthesis of organic acids by bacteria. The hydrolysis of acetic acid groups in hemicellulose is the expected source of acetic acid. However, the acid will soon be used by the microbial community which causes the pH to rise. Ammonia production becomes significant during the active composting phase, causing a constant pH. However, in general it remains in the alkaline pH range. Eutrophication is a dangerous type of pollution caused by BSW which is dumped in rivers. Eutrophication can cause damage to algae and produce toxins. Microcystins come from the hepatotoxin family which is produced mainly by several species of cyanobacteria such as *Microcystis*, *Anabaena* and *Oscillatoria* [42]. This poison can cause damage to the liver and can cause cancer [43, 44].

![Figure 4](image2.png)

Figure 4. The nitrogen cycle that occurs in the composting process environment [45]
Figure 4 shows the main chemical processes involved with nitrogen fixation. One of the main challenges in the composting process is how to minimize the loss of nitrogen gas. Nitrogen will be stored in the tissues of living and dead organisms. Organic matter eventually suffers from an enzymatic process. This process will produce ammonium (NH$_4^+$). This process is known as ammonification or mineralization. Under sufficient base conditions, ammonium ions will be converted to ammonia gas, which will escape into the atmosphere. Humid and cold conditions in the outer layer will support the ammonia retention. Under aerobic conditions, most ammonium can be formed and will be converted to nitrite by the bacterium Nitrosomonas [46-48]. Organic fertilizer is not only produced from solid waste, but can also be produced from liquid waste such as urine. One of them is urine from rabbits [49]. Bali cattle as livestock germplasm in Indonesia, not only produce by-products waste products. However, this animal also produces by-products in the form of bones and skin that can be used as a source of collagen. Collagen has been used in various ways to meet the needs of the food and non-food industries [50-52]. Collagen is used as a mixture in reinforcing feed on Balinese cows to produce quality meat [53-55].

5. Conclusion
The composting process on livestock waste involving microorganism activities is an important solution in reducing waste production. Application of technology related to the process of degradation of material components is very important to know. Aerated composting technology has several advantages over static. Microorganism activity has a high ability to degrade material components. Therefore, the use of microorganisms should be considered in producing compost from livestock waste.

Acknowledgements
The author is pleased to express his gratitude especially to the Minister of Research Technology and Higher Education of the Republic of Indonesia, the Rector of Hasanuddin University and the Dean of the Faculty of Animal Science of Hasanuddin University for the facilities provided in various traces of libraries that have supported this paper.

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