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REVIEW ARTICLE

Valorization of Chicken Feather Waste in west Java into Bokashi Fertilizer Using Anaerobic Fermentation to Support Circular Agriculture: A Review

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Abstract

The rapid growth of the poultry industry in Indonesia, particularly in West Java, has resulted in significant chicken feather waste, which remains largely unutilized and poses environmental risks due to its high keratin content. This review explores the potential of converting chicken feather waste into bokashi fertilizer through anaerobic fermentation as a sustainable strategy in line with circular agriculture principles. The fermentation process involves pretreatment using keratinase producing microorganisms such as *Bacillus subtilis* or *Pseudomonas aeruginosa*, followed by the application of Effective Microorganisms (EM4) activated with molasses. Under optimal conditions, including a carbon to nitrogen ratio of 25 to 30 to 1, temperature between 30 to 40 degrees Celsius, and humidity around 50 percent, the process can produce high quality organic fertilizer that meets national standards. The resulting bokashi exhibits favorable physical and chemical characteristics, such as high nitrogen content and a balanced nutrient profile. More broadly, this approach offers a low cost, scalable, and environmentally friendly solution for managing livestock waste while enhancing soil fertility and supporting regenerative farming. With further optimization and wider implementation at the community level, chicken feather based bokashi has strong potential to contribute to sustainable agriculture and effective waste management in poultry producing regions.

Keywords: chicken feather, bokashi, anaerobic fermentation, keratinase, circular agriculture

1. Introduction

The problem of organic waste is an increasingly serious environmental issue in Indonesia [1]. The waste management performance achievement report of Kementrian Lingkungan Hidup dan Kehutanan (KLHK) in 2021 noted that the data on waste generation in Indonesia in 2021 reached 30.88 million tons [2]. This increased significantly in 2024 which reached 33.6 million tons per year, with the main composition coming from organic waste which reached around 65% of the total waste [3]. Organic waste that is not managed properly will undergo anaerobic decomposition, which produces methane gas (CH_4) as one of the greenhouse gases that cause global warming [4]. This decomposition process also generates leachate (waste liquid) that can pollute groundwater, as well as increase the risk of disease spread due to disease vectors that have an adverse impact on public health [5]. In addition, waste in the livestock sector, especially in broiler production, receives less attention [6]. This waste consists of manure, feed residue, and chicken feathers, which if not managed properly can increase the burden of environmental pollution and has not been widely utilized as a source of valuable raw materials [7].

Badan Pusat Statistik (BPS) in 2024 noted that chicken production in Indonesia increased by 20.41% from 3.19 million tons in 2021 to 3.84 million tons in 2024 with West Java recorded as the province with the highest chicken production reaching 857,576.78 tons (22.35% of national production) [8]. This high level of production is directly proportional to the volume of livestock waste generated every day, including chicken feathers which are often discarded without processing [9]. Based on the ratio of livestock waste, chicken feathers contribute about 4-5% of live weight, which is equivalent to 153.600-192.000 tons per year in Indonesia and 34,303-42,878 tons per year in West Java [10]. Based on chemical composition analysis, chicken feathers show that this waste contains nitrogen levels of (7.23%), organic carbon (34.30%), phosphorus (0.52%,) and potassium (0.39%) [11]. This makes it potential to be used as a base material for slow-release organic fertilizer [12]. However, chicken feathers are a type of organic waste that is difficult to decompose naturally because they contain keratin, a fibrous protein with a stable structure and resistant to biological degradation processes [13]. This is reinforced by research conducted by Winarsih et al. (2022), which revealed that keratin yields were around 2.88% - 3.8% based on tests using Soxhlet and Maceration extraction methods [14]. These results indicate the need for further processing technology to improve conversion efficiency into slow-release organic fertilizer by overcoming the resistant nature of keratin.

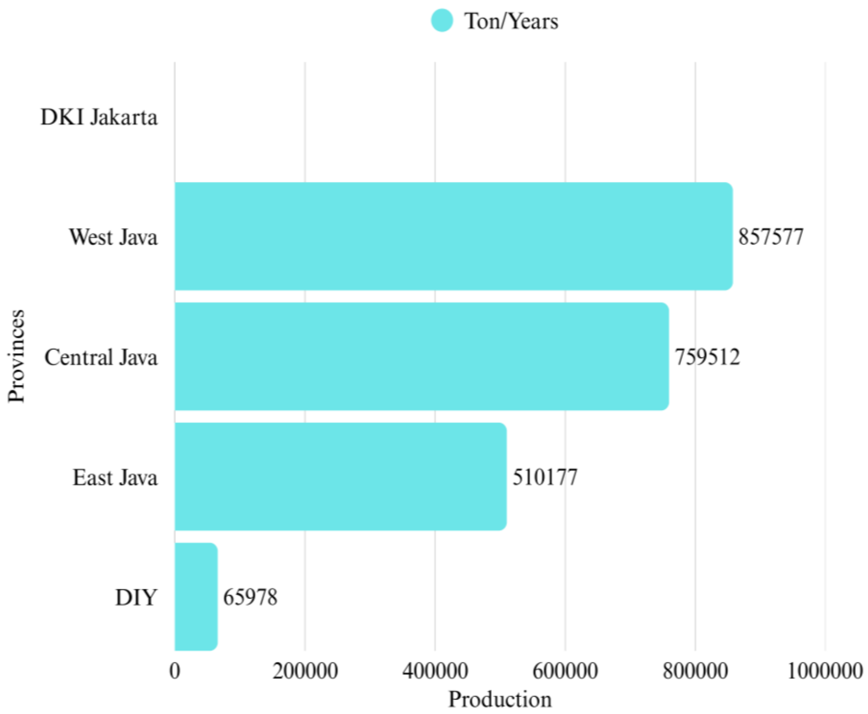

Figure 1. Total Chicken Production in Java [8]

One method that is considered suitable in processing organic waste, especially chicken feathers, is making bokashi fertilizer, which is organic fertilizer processed through anaerobic fermentation using effective microorganisms (EM). EM is a naturally fermented microbial inoculum containing various types of beneficial microorganisms, such as photosynthetic bacteria, lactic acid bacteria, and yeast [15]. These microorganisms play a role in accelerating the decomposition of organic matter to produce nutrient-rich fertilizer [16]. EM is reported to reduce odor, accelerate decomposition rates, and produce fertilizers with high nutrient content so that EM is considered a useful additive in the composting process, especially if the composition of microorganisms is in accordance with the characteristics of the treated waste [17]. The study conducted by Adelia et al. (2019), found that the addition of Bacillus subtilis in chicken feather fermentation was proven to significantly increase keratinase activity to 273.33 Units/ml compared to the control of 3.11 Units/ml, indicating that specific keratinase-producing microbes are more effective in degrading keratin than standard EM consortium [18]. This method is not only cheap and easy to apply, but is also known to be efficient and environmentally friendly, and can be applied to various types of organic waste, including chicken feathers [19].

The utilization of chicken feather waste as a raw material for bokashi fertilizer offers not only an environmental solution but also considerable value-added potential from an economic standpoint. Unprocessed chicken feathers are commonly discarded or sold as wet waste at very low prices; when processed into bokashi fertilizer, however, their market value can increase significantly, reaching approximately IDR 8,000.00 to IDR 10,000.00 per kilogram [20]. This solution is in line with the principles of sustainable agriculture, especially within the framework of circular agriculture. This concept emphasizes the importance of resource efficiency and recycling of waste into valuable agricultural inputs [21]. In addition, this approach also aims to minimize the use of fossil fuels, reduce water and nutrient losses, and encourage the reuse and recycling of agricultural waste without compromising food productivity, through the implementation of regenerative agriculture practices [22]. This strategy not only helps to reduce stockpiles of farm waste, but also contributes to supporting sustainable agricultural practices, especially in chicken production centers such as West Java.

This article is a literature review that examines the potential and challenges in utilizing chicken feather waste in West Java as a base material for bokashi fertilizer through an anaerobic fermentation process using Effective Microorganisms (EM). With a circular agriculture approach, this article presents a scientific review related to the chemical composition of chicken feathers, the effectiveness of the fermentation method, and its contribution to a sustainable agricultural system.

2. Literature Review Methodology

This article was written using a systematic literature review approach, examining scientific literature related to the utilization of chicken feather waste into bokashi fertilizer through anaerobic fermentation [23]. The literature analyzed was selected based on its relevance to the topic, recency (2015–2025), and source reputation (accredited national journals and reputable international journals). The primary focus of this review is on the chemical composition of chicken feathers, the role of keratinase-producing microorganisms, the basic principles of bokashi fermentation, as well as the challenges and opportunities for its implementation in West Java.

2.1. Chemical content of chicken feathers

Chicken feathers contain high protein which reaches 80-85%, this amount is higher than soybean meal protein which only amounts to 42.5% [24]. Chicken feathers consist mainly of a protein named keratin which reaches 90% [25]. In addition, chicken feathers contain 0.19% calcium minerals, 0.04% phosphorus, 0.15% potassium, 0.15% sodium, 1% fat, and 8% water [24][26]. Keratin is an insoluble macromolecule that has high stability with a low decomposition rate and is found in hair, feathers, nails, wool, beaks, and animal horns [27]. This keratin is difficult to decompose naturally due to its resistance to digestive enzymes and other biological processes and it is necessary to break down the keratin to improve the nutrition of the chicken feathers [28]. Chicken feathers also contain high nitrogen [29], so it is suitable for use as a raw material for making plant fertilizers that require nitrogen sources [30].

Tabel 1. Chemical Composition of Chicken Feather

Component	Value (%)	Reference
Keratin	90	[25]
Kalsium	0.19	[24]
Phosphorus	0.04	[24]
Potassium	0.15	[26]
Sodium	0.15	[26]
Lemak	1	[26]
Air	8	[26]
Nitrogen	15-18	[31]

2.2. Basic Principles of Bokashi and Microorganisms

Bokashi is an organic fertilizer produced through a closed anaerobic fermentation process, in which organic materials such as food waste, agricultural waste, or livestock manure are decomposed in conditions without oxygen using microbial inoculum [32]. Unlike aerobic compost which requires aeration and generates high heat, bokashi fermentation takes place in a relatively cool atmosphere, so that important nutrients such as nitrogen and carbon are maintained, with retention rates reaching 93-100% and 64-99% respectively [33]. One of the main factors for the success of bokashi fermentation is the use of Effective Microorganisms (EM), which consists of a consortium of microbes such as lactic acid bacteria (*Lactobacillus spp.*), yeast (*Saccharomyces spp.*), and photosynthetic bacteria (*Rhodopseudomonas spp.*) [34].

Table 2. Functional Comparison of Microbial Groups in Effective Microorganism Technology [35]

Microorganism	Species	Function	Products
Lactic Acid Bacteria (LAB)	*Lactobacillus plantarum, L. casei, Streptococcus lactis*	Fermentation, lactic acid production	Environmental sterilization, suppressing pathogens
Yeasts	*Saccharomyces cerevisiae, Candida utilis*	Synthesis of hormones and enzymes	Stimulating cell division and plant roots
Actinomycetes	*Streptomyces albus, S. griseus*	Antagonism of pathogenic microbes	Production of antibiotics, enzymes, and bioactive substances
Photosynthetic Bacteria	*Rhodopseudomonas palustris, Rhodobacter sphaeroides*	Using light and heat for the synthesis of useful substances	Decomposing harmful gases (H_2S), producing vitamins and antioxidants
Fermenting Fungi	*Aspergillus oryzae, Mucor hiemalis*	Fermentation of organic matter	Producing alcohols, esters, and antimicrobial substances

This combination of microorganisms not only accelerates the decomposition process of organic matter into simple compounds, but also produces organic acids and antimicrobial compounds that are effective in suppressing the growth of pathogens such as E. coli and Salmonella [36]. In addition, microbial activity during fermentation results in a low pH and anoxic environment that reduces foul odors significantly, making this process more environmentally friendly [37]. The fermentation process using Effective Microorganisms (EM) generally takes place quickly, in the range of 7 to 14 days, depending on the type of material and environmental conditions [38]. The final result of bokashi fertilizer with good quality is blackish brown, smells of soil, and has a coarse texture [39].

2.1 Pretreatment and Formulation of Bokashi Substrate

In the initial stage of making bokashi, chicken feathers are cleaned of blood and feces so as not to interfere with the decomposition process by microbes [40]. A study by Pahua-Ramos (2017) showed that thorough cleaning and mixed culture can increase the degradation efficiency by 2-3 times compared to no pre-treatment or with pure culture [41]. The cleaned chicken feathers were then shredded to expand the contact surface with microbes so that the degradation process can run faster [42]. Next, microbial pretreatment using Pseudomonas aeruginosa or Bacillus subtilis is needed because the keratin structure in chicken feathers is highly degradation resistant, where the microbes produce keratinase enzymes that can degrade keratin [43][44]. Research by Verma et al (2020) showed that the use of a co-culture of *Bacillus licheniformis* and *Stenotrophomonas maltophilia* at 37°C and an initial pH of 7.0 resulted in a weight loss of 82% in chicken feathers within two days of fermentation [45]. Chicken feathers that have passed the pretreatment stage are mixed with carbon-rich materials such as rice husks and bran to balance the C/N ratio, as this balance is important for the growth of microorganisms during fermentation [46]. The ideal C/N ratio for fermentation generally ranges from 25:1 to 30:1 so that the decomposition process runs optimally [47]. To increase the success of bokashi fermentation, inoculum in the form of EM4 is mixed with molasses and water using the optimal ratio. Study by Kusuma et al. (2017) used a variation of EM4: molasses of 3: 9 (with the total volume in fermentor water) and succeeded in accelerating the maturity of bokashi fertilizer in 21 days [48]. The study by Kurniawan et al. (2022) showed that the addition of EM-4 at 40% of the solid material gave the best results in the form of a C / N ratio of 18.6, moisture content of 43.08%, P content of 0.74%, K content of 2.17%, and nitrogen content of 2.7% [49].

Table 3. Variation of optimum conditions for the fermentation process of various types bacteria.

Bacteria	**Optimum**		**Reference**
	pH	**Temperature (°C)**	
Ochrobactrum intermedium	9.0	40	[50]
Bacillus licheniformis ALW1	8.0	65	[51]
Bacillus cereus	7.0-9.0	30-45	[45]
Bacillus sp	7.0-8.0	30-37	[45]
Laceyella sacchari YNDH	10.4	70	[52]
Bacillus sp.	11.0	60	[53]
Bacillus clausii	11.0	60	[50]
Bacillus subtilis DP1	10.0	37	[54]
Paenibacillus wooson gensis TKB2	9.0	50	[50]
B. velezensis NCIM 5802	10.0	60	[50]

2.4. Anaerobic Fermentation Process

The anaerobic fermentation process begins after the pretreatment and mixing stages are completed, and takes place in closed conditions without oxygen at optimal temperatures ranging from 30-70 °C [50]. In this process, inoculum in the form of Effective Microorganisms (EM) or Local Microorganisms (MOL) is used to accelerate fermentation, where EM4 generally contains strains such as *Lactobacillus spp, Saccharomyces spp*, and *photosynthetic* bacteria. To optimize microbial growth during fermentation, the EM solution is usually activated first by the addition of molasses at 5%, which acts as a simple carbon source for microorganisms. Fermentation lasts for 10-14 days, depending on the type of material and ambient temperature.

Ripe fermented bokashi fertilizer is characterized by a distinctive smell of fermentation that is not pungent, crumbly and dry texture, and the appearance of white filaments or fungi as an indication that the fermentation process has been completed and the material is protected from decay [55]. The color of mature bokashi is usually blackish brown, and the longer it is stored the color will get darker, indicating the success of the fermentation process [39]. After the fermentation process is complete, bokashi can be used immediately or left open for two weeks to avoid damage due to excess moisture [55].

3. Results and discussion

3.1. Role of Microorganisms and Keratinase Activity in Chicken Feather Fermentation

Keratin is a fibrous protein that is very stable due to the many disulfide bonds, hydrogen bonds, and hydrophobic interactions, making it insoluble in water and common solvents and resistant to protease enzymes such as pepsin and trypsin [56]. Successfully degraded keratin will produce amino acids that can increase soil microbial activity and support plant root growth [57]. Therefore, the use of keratinase-producing microorganisms is an important step in utilizing chicken feather waste as an efficient raw material for bokashi fertilizer. EM4 is widely used in bokashi fermentation. Several studies have shown that microorganisms used for bokashi fermentation, such as those found in EM4, are able to decompose organic matter efficiently while improving soil structure and suppressing the growth of pathogenic microbes. However, standard EM4 formulations do not include keratinase-producing strains that are essential for breaking down stable keratin proteins found in chicken feathers [58].

Chicken feathers can be microbially degraded into biofertilizer using keratin-degrading microorganisms, which offers a cost-effective way to valorize waste rich in keratin [59]. Various microorganisms are known to produce keratinase enzymes, ranging from fungi such as Aspergillus terreus, actinomycetes such as Streptomyces sp., to bacteria of the Bacillus genus, including B. licheniformis, B. pumilus, and B. subtilis [59]. The enzymatic degradation process of keratin takes place in several stages. The first stage is the adsorption of enzymes onto the surface of the keratin substrate through electrostatic and hydrophobic interactions, followed by catalytic action. In general, there are two main mechanisms: sulfitolysis, which is the breaking of disulfide bonds with the help of reducing compounds such as dithiothreitol (DTT) or β-mercaptoethanol, and proteolysis, which is the breaking of polypeptide chains by the proteolytic activity of keratinase enzymes [60].

Several strains of the Bacillus genus have been shown to have a high ability to produce keratinase enzymes to degrade keratinized waste such as chicken feathers. Arokiyaraj et al. (2019) isolated Bacillus cereus from a halophilic environment and optimized its production to reach 292 U/g substrate through Central Composite Design (CCD) and Response Surface Methodology (RSM) approaches, using wheat bran, 1% lactose, and manganese ions [61]. Meanwhile, Nurkhasanah and Suharti (2019) used Bacillus sp. MD24 in solid fermentation (SSF) based on chicken feathers, and obtained a maximum keratinase activity of 527.19 U/mL on the third day of fermentation with 500% moisture content [62]. This comparison shows that the Bacillus genus is very adaptive to variations in fermentation conditions and has high potential to be integrated in the bioconversion strategy of chicken feather waste towards organic fertilizer based on bokashi fermentation.

Table 4. Comparative Study of Keratinase Enzyme Activity

Microorganism	Fermentation Method	Keratinase Activity	Reference
Bacillus cereus	Submerged (CCD-RSM)	292 U/mL	[61]
Bacillus sp. MD24	SSF	527,19 U/mL	[62]
Pseudomonas geniculata H10	Submerged fermentation	36,3 ± 2,7 U/mL	[63]
Bacillus licheniformis BBE11-1	Submerged fermentation	244,5 U/mL	[64]
Streptomyces enissocaesilis AM1	Solid-state aerobic fermentation	0.456 ± 0.038 U/mL	[65]

Based on these five studies, keratinase activity is influenced by the type of microorganism, fermentation method, and environmental conditions such as pH, temperature, and nutrients. Bacillus strains showed high activity under various conditions, while Pseudomonas geniculata was more optimal at low temperature and pH. Coculture systems such as in the study by Peng et al. (2019) also increased the efficiency of keratin degradation through enzymatic synergy. The higher the keratinase activity, the more effective the quill degradation process.

Based on Table 4, keratinase activity varied significantly depending on the fermentation method, type of microorganism, and environmental conditions. Solid-state fermentation (SSF) used by Bacillus sp. MD24 produced the highest activity of 527.19 U/mL, while the lowest activity was found in Streptomyces enissocaesilis with a value of only 0.456 U/mL. The SSF method tends to produce high enzyme activity due to better contact between substrate and microbes and low water requirement, making it suitable for small-scale community-based. However, this method has limitations in terms of consistent control of temperature, humidity and pH, especially in large-scale production.

In contrast, submerged fermentation (SMF), such as in studies involving Bacillus cereus and Bacillus licheniformis, allows for more precise control of process parameters and ease of further processing, although it requires higher water and energy consumption. In terms of microorganisms, the Bacillus genus showed relatively high keratinase activity in both SSF and SmF, making it a prime candidate in the bioconversion of chicken feather waste. In addition, Pseudomonas geniculata does have lower activity, but has the potential to increase degradation efficiency when used in a co-culture system as shown by the study of Peng et al. The combination of selecting superior strains and fermentation methods that are suitable for the availability of resources can increase the effectiveness of the chicken feather fermentation process into high-quality bokashi fertilizer.

3.2. Quality Parameters of Chicken Feather-Based Bokashi Fertilizer

Based on Standar Nasional Indonesia (SNI) 19-7030-2004, the quality of solid organic fertilizer is determined by several important parameters, such as a maximum C/N ratio of 20, neutral to slightly alkaline pH (6.8-7.5), moisture content of 40-60%, and minimum nutrient content of nitrogen (≥ 0.40%), phosphorus (≥ 0.10%), and potassium (≥ 0.20%). These parameters are used as a reference to evaluate the quality of bokashi produced from fermentation of chicken feather waste [66]. The C/N ratio has a significant effect on the composting process, where low ratios can cause nitrogen loss as ammonia, while high ratios slow down decomposition due to lack of nitrogen for microorganisms [67]. In addition, the initial pH of the feedstock is also a key factor, as microorganism activity is at an optimal level in the pH range of 7-8, while too low a pH can slow down the decomposition process [68]. Based on this, various studies have evaluated how chicken feather fermentation affects these parameters in the context of efficient bokashi production.

Several studies have been conducted to evaluate the quality of bokashi fertilizer produced from fermentation of chicken feather waste, especially in terms of C/N ratio, pH, and the content of major nutrients such as nitrogen, phosphorus, and potassium. One recent study by Dewi et al. (2024) reported that fermentation of chicken feathers without any additional ingredients produced a very high total nitrogen content, reaching 11.28%, with a C/N ratio of 7.17 and a neutral pH of 7.36 [69]. Similar results were also reported by Nguyen et al. (2025), who used an oxygen-limited fermentation system to efficiently degrade chicken feathers. The fermentation produced a nutrient-rich liquid with nitrogen (NH_4^+) content of 13,868 mg/L, phosphorus of 2,884.58 mg/L, and a final pH in the neutral range (7.1-7.4), while recording a biodegradation efficiency of up to 81% without detection of heavy metals or harmful pathogens [70]. Table 5 summarizes the results of bokashi quality measurements from several relevant previous studies.

Table 5. Comparison of Quality of Chicken Feather Based Bokashi

Product type	Total Nitrogen	C/N Ratio	Final pH	Reference
Solid Bokashi	11.28%	7.17	7.36	[69]
Liquid Bokashi	3.2%	15	7.2	[70]
Solid Bokashi (vermicompost)	2.2%	25.4	7.5	[71]
Solid Bokashi	7.02%	15.70	7.53	[72]
Solid Bokashi	7.15%	7.14	7.47	[73]
Solid Bokashi	4.00%	5.21	6.75	[74]
Solid Bokashi	1.31–1.44	8.6–13.4	8.11–8.35	[75]

Based on Table 5, it can be seen that most of the fermented chicken feathers produce bokashi with pH in the neutral range (6.75-8.35), which is in accordance with SNI organic fertilizer quality standards. The C/N ratio value obtained is generally <20, indicating the maturity and stability of the compost. The product with the highest nitrogen content was achieved in the unmixed fermentation and oxygen-limited system with 11.28% and 13,868 mg/L, respectively, indicating the high potential of chicken feathers as a source of organic nitrogen. However, several studies have also shown that the use of carbon additives, microbial inoculants, or vermicomposting methods can increase the C/N balance and improve other agronomic parameters. Thus, fermentation strategies tailored to the material conditions and processing methods are key to producing high-quality bokashi from chicken feather waste. The quality parameters of bokashi from chicken feathers show high potential as an environmentally friendly organic fertilizer.

3.3. Challenges and Prospects for Utilizing Chicken Feather Waste

The development of large-scale poultry farming, along with the increase in global consumption of poultry meat (especially chicken), has generated large amounts of feather waste. It is estimated that on a world scale, approximately 8,105 tons of chicken feather waste is generated per year [76]. Since chicken feathers contain 90% keratin which is difficult to decompose, it is not easily graded naturally which leads to the accumulation of chicken feather waste. Indiscriminate disposal of chicken feather waste into the environment causes severe pollution, adverse environmental impacts, and facilitates the emergence of pathogens [77]. Disposal of untreated waste can cause soil pollution and clean water pollution due to the ammonia content that arises from the accumulation of waste [78]. In addition, discarded feathers can cause environmental problems such as nitrate leaching into groundwater, phosphorus runoff into water bodies, and potential increased growth of pathogenic bacteria or viruses in lakes and waterways that will result in health problems [79].

Chicken feather waste has great potential to be utilized in various sectors if managed properly. One of the main utilizations is as a raw material for bioplastics and composites. Keratin, the main protein in chicken feathers, can be extracted and processed into biodegradable bioplastic films with good mechanical properties, thus contributing to the reduction of conventional plastics [80][81]. In addition, chicken feathers can also be mixed with plastic waste to produce eco-friendly building materials such as wood-plastic composites. In the agricultural sector, chicken feathers undergoing hydrolysis can be converted into feather meal, a nitrogen-rich organic fertilizer (12-15%) that is able to release nutrients slowly, which is ideal for sustainable agricultural systems

[82]. This waste can also be used as a biofertilizer through processing using keratinase enzyme-producing microorganisms, producing a biofertilizer that improves soil quality.

In the livestock sector, chicken feathers that have been chemically or enzymatically broken down can be used as high-nutrient animal feed, especially for ruminants and fish, due to their protein content which can reach 85% [83]. Meanwhile, in the field of renewable energy, chicken feathers have potential as a source of bioenergy through anaerobic digestion to produce biogas in the form of methane or hydrogen [84]. In addition, keratin can also be used to produce nanofiber and conductive materials in biomedical applications and energy technology. Finally, chicken feathers also have promising applications in the textile and construction industries, especially as a lightweight and biodegradable nonwoven textile fiber material, and as an environmentally friendly building insulation material [85]. With these diverse potentials, chicken feather waste should not only be considered as waste, but as a renewable resource that can provide economic, environmental, and social value if managed in a sustainable and technology-based manner.

3.4. Economic Feasibility and Scalability Challenges

The production of bokashi fertilizer from chicken feather waste is considered economical, especially when using the solid fermentation (SSF) approach. The study by El Salamony et al. (2024) showed that the SSF method requires less water, energy, and equipment than liquid fermentation (SmF), and is able to produce high amounts of soluble protein from inexpensive substrates such as a combination of chicken feathers and wheat bran [86]. On the other hand, economic simulations by Guo (2025) showed that implementing the bokashi method in educational institutions resulted in a total annual cost of USD 19,170, which is slightly higher than the conventional method of USD 16,505 [87]. However, the bokashi method has the potential for excess fertilizer that can be resold and significantly reduces the carbon footprint. This confirms that cost-effectiveness depends not only on the initial investment value, but also on the efficiency of waste conversion and its potential long-term benefits. Supporting this, a local study by Simbolon et al. (2024) demonstrated that bokashi made from chicken feather waste using local materials such as chicken manure, rice bran, EM4, and palm sugar yielded organic carbon content up to 44.05% and total nitrogen at 4.11% [88]. The use of accessible agricultural residues not only ensures agronomic efficiency, but also strengthens the economic viability of bokashi fertilizer for smallholder farmers in Indonesia.

Although bokashi fertilizer made from chicken feather waste is considered practical at the household or small-scale level [89], its application at a larger scale presents several challenges. These include the need for consistent raw materials, controlled fermentation conditions, and efficient labor use. Additionally, alternative approaches such as subcritical water (SCW) treatment require specialized equipment with high energy input and pressurized systems, which limit their feasibility in rural or smallholder contexts [90]. To achieve broader adoption, efforts are needed to develop simple, scalable technologies and provide institutional support through training and appropriate policy frameworks.

Conclusions

The use of chicken feather waste as raw material for bokashi fertilizer through anaerobic fermentation is a promising approach to support sustainable agriculture and the circular economy, particularly in regions with high poultry production such as West Java. The high keratin content in chicken feathers requires a pretreatment stage using keratinase-producing microorganisms to accelerate the decomposition process. The combination of Effective Microorganisms and molasses has proven capable of producing organic fertilizer with quality parameters that meet national standards. In addition to being technically effective, this approach also offers environmental and economic benefits, such as reducing livestock waste volume, preventing pollution, and increasing the value of organic waste.

Optimizing the implementation of this strategy requires policy support in the form of EM4 distribution subsidies, technical training for small-scale farmers, and the development of standardized fermentation protocols. Some obstacles to implementation in the field include limited fermentation facilities, low public awareness of the economic value of chicken feather waste, and challenges in maintaining the consistency of the final product quality. Synergy between the government, academia, and the community is key to scaling up the implementation and ensuring the sustainability of this program in supporting food security and environmental conservation.

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