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Research Article

# Optimization of Indigenous Microorganism (IMO) Concentration in Chicken Feathers on the Physicochemical Properties of Feather Meal

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**ABSTRACT**

This study aimed to evaluate the effect of adding indigenous microorganisms (IMO) derived from chicken feathers on the physicochemical properties of chicken feather flour, namely, color, microscopic structure, and crude fiber content. An experimental method with a completely randomized design (CRD) with five treatments and four replications was used in this study. The treatments were the addition of IMO chicken feathers at levels A (0%), B (1.5%), C (3%), D (4.5%), and E (6%) to fermentation feather meal. The parameters observed were color (L*, a*, b*), microscopic structure, and crude fiber content. The results showed that increasing IMO concentration significantly decreased lightness (L*), crude fiber content, and increased yellowness (b*) but did not significantly affect redness (a*). Microscopic observations revealed keratin structure degradation at higher IMO concentrations. The optimal concentration was 4.5%, resulting in balanced physicochemical properties of feather flour. These findings demonstrate the potential of IMO application for the sustainable utilization of chicken feather waste as a protein-rich feather meal.

**Keywords**: crude fiber reduction, feather meal fermentation, indigenous microorganisms, physicochemical, poultry waste valorization

## INTRODUCTION

Raising awareness of the importance of environmental conservation can help create a healthy and sustainable environment for future generations. However, many people still lack a clear understanding of the importance of environmental protection. Environmental pollution, including waste-related pollution, is a truly global problem. Waste typically originates from the livestock industry. The livestock industry, particularly broiler chicken farming, produces waste in the form of chicken feathers, which are often overlooked. Therefore, serious, efficient, and effective management is needed to address its impacts.

Chicken feather waste is a continuous problem that increases annually. This is because the number of chickens slaughtered annually increases, increasing the number of feathers produced. According to the Central Statistics Agency (BPS), in 2023, the total production of broiler chickens in Indonesia was 3,997,652.70 tons, an increase from 3,765,573.09 tons in 2022 (BPS, 2024). West Sumatra ranks 15th in Indonesia in broiler chicken production (BPS, 2024). By 2023, the amount of chicken feather waste produced was 159,906.108 – 199,882.635 tons.

A common problem is that chicken feathers are left or discarded. Furthermore, proper waste management is crucial for maintaining ecosystem balance. Chicken feather waste has a significant

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impact on the environment because, in addition to producing an unpleasant odor and spreading disease, scattered chicken feathers also contribute to soil degradation due to their slow decomposition, making them difficult to degrade naturally (Erlita, Puspitasari, and Isbandi, 2016). Chicken feathers have significant economic value despite these negative impacts, particularly when processed into alternative protein feed.

Chicken feather waste is a significant by-product of the poultry industry and contributes to environmental pollution because of its slow biodegradability. Feathers primarily comprise keratin, a fibrous protein resistant to natural degradation because of its disulfide bonds (Tesfaye et al., 2017; Widiana et al., 2020). Sustainable waste management is essential to reduce environmental impact and provide alternative protein sources. Fermentation using indigenous microorganisms (IMO) has been proposed as an eco-friendly solution to convert feathers into feather meal. Previous studies have shown that microbial fermentation can improve digestibility, alter physical properties, and enhance the nutritional quality of feather meal (Mulia et al., 2016; Hendalia et al., 2017; Dalle et al., 2022). However, information on the effect of different IMO concentrations on the physical properties of feather flour remains limited. Therefore, this study was conducted to determine the optimal IMO concentration for feather meal production.

## MATERIAL AND METHODS

The materials used in this study were broiler chicken feathers obtained from slaughterhouses in Bandar Buat, Padang, Indonesia, using the scalding method. Additional materials included IMO chicken feathers fermented for 3 months with coconut water, quicklime, salt, molasses, and chicken feather meal. The equipment used in this study comprised a feather flouring machine, a Hunterlab ColorFlex EZ spectrophotometer, an Optilab Iris 4 Trinocular Microscope at 100× magnification, a Sigma 4 K Camera, a 2000 mL plastic container, a bucket, a plastic bag, a spoon, gloves, scissors, a trust bag, markers, label paper, and a beaker.

This study employed an experimental method using a completely randomized design (CRD) with five treatments and four replications. The treatments were as follows: A (no IMO addition/control), B (1.5% IMO addition), C (3% IMO addition), D (4.5% IMO addition), and E (6% IMO addition).

Making chicken feathers involves obtaining chicken feathers from a slaughterhouse. They were cleaned with an environmentally friendly liquid soap and running water to remove any remaining dirt or blood. They were soaked for 1 h in environmentally friendly soap, then drained. They were dried in the sun and air-dried until they were dry. The dried chicken feathers were cut into pieces approximately 0.5 cm in size. The cut feathers were placed in a bucket with coconut water, salt, molasses, and quicklime. They were then homogenized. The bucket was covered with plastic and sealed with tape to prevent air from entering (optional). The container was then fermented for up to 3 months.

According to Novia et al. (2025), chicken feather meal was produced using IMO chicken feathers by chopping dried chicken feathers into a container, adding distilled water and IMO chicken feather solution at concentrations of 0%, 1.5%, 3%, 4.5%, and 6%. The feather meal was then fermented for five days at room temperature (20–255°C) under facultative anaerobic conditions. The fermented feather meal was drained and dried in an oven at 60°C for three days to form chicken feather meal. The fermented product was analyzed for color and microscopic structure.

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The parameters evaluated in this study were physicochemical tests for color, microscopic structure (Sidik et al., 2016), and crude fiber content (AOAC, 2016). The research results were statistically analyzed using analysis of variance (ANOVA) in SPSS Statistics for Windows. If there were differences among the treatments, further testing was conducted using Duncan's multiple range test (DMRT).

## RESULTS AND DISCUSSION

Analysis of variance showed that the addition of IMO feathers at different concentrations significantly affected ($p<0.05$) the brightness and yellowness of chicken feather meal, but not significantly the redness. Table 1 shows that the average brightness of chicken feather meal with various IMO concentrations ranged from 60.19 to 62.25, while the redness ranged from -0.86 to -0.62, and the yellowness ranged from 8.65 (control) to 9.88 (6% IMO). Duncan's further test results showed that treatment A was significantly different from the other treatments in brightness, but not significantly different from treatment B in yellowness.

The results of this study revealed a decrease in keratin structure density when observed using an Optilab Iris 4 Trinocular Microscope and a Sigma 4 K Camera at 100 × magnification (Figure 1). Observations on chicken feather meals were conducted on the barbules. This was done because barbules (branches) are more easily broken down than the rachis (central shaft). Keratin is present in both barbules and rachis, and barbules in chicken feathers have a lower density than the rachis, which tends to be thicker and stiffer.

Figure 2 shows that the average crude fiber content of chicken feather meal with various concentrations of MOL chicken feathers ranged from 0.91 to 1.62%. The average crude fiber content was determined using dry-weight calculations. Duncan's test results showed that treatment A differed significantly ($p<0.05$) from treatments B, C, D, and E. This indicates that the higher the percentage of chicken feathers, the lower the resulting crude fiber content.

Table 1. Results of the Physical Properties Test of Chicken Feather Meal Color

| Treatments | Color | | |
|---|---|---|---|
| | Lightness (L*) | Redness (a*) | Yellowness (b*) |
| A | 62,25 ± 0,50$^{a}$ | -0,86 ± 0,21 | 8,65 ± 0,31$^{b}$ |
| B | 60,64 ± 0,70$^{b}$ | -0,73 ± 0,13 | 8,69 ± 0,24$^{b}$ |
| C | 60,47 ± 0,39$^{b}$ | -0,69 ± 0,04 | 9,68 ± 0,13$^{a}$ |
| D | 60,36 ± 1,54$^{b}$ | -0,66 ± 0,04 | 9,72 ± 0,39$^{a}$ |
| E | 60,19 ± 0,19$^{b}$ | -0,62 ± 0,08 | 9,88 ± 0,15$^{a}$ |

Notes: Different subscripts for each treatment indicate a significantly different effect ($p < 0.05$) with treatment A: without adding IMO chicken feathers (control); B: adding IMO chicken feathers at 1.5%; C: adding IMO chicken feathers at 3%; D: adding IMO chicken feathers at 4.5%; and E: adding IMO chicken feathers at 6%.

**Lightness (L*)**

Observations of color changes in chicken feather meal indicate variations in brightness levels influenced by the concentration of IMO used in the fermentation process. In this case, lightness was the primary indicator for assessing the brightness of the resulting flour. The average lightness values for chicken feather meal with different concentrations of IMO are shown in Table 1. As the concentration of IMO in chicken feather meal increased, the lightness value decreased.

The lightness (L*) values decreased with increasing IMO concentration, indicating that higher IMO levels produce darker flour, which is consistent with the findings of Mercis et al. (2022) and Wahyuni et al. (2023), who reported reduced brightness in feather meal with higher inoculum or longer fermentation times.

Treatment A, without adding IMO to chicken feathers (the control), produced the highest lightness value (62.25). This was because the treatment did not involve IMO during the fermentation process, and only distilled water was used, resulting in hydrolysis without microbial activity. The absence of microorganisms resulted in no structural changes in keratin, thus maintaining the natural pigment and structure of chicken feathers. This is in line with the findings of Tesfaye et al. (2017), who found that treating chicken feathers with water alone did not result in any changes in feather structure.

Treatment E, which added a 6% concentration of chicken feather IMO, produced the lowest lightness value (60.19). The lightness decreased because of the ingredient used to produce chicken feather IMO, namely, IMOase. IMOase can produce a brown color after fermentation (Susanto, 2016); furthermore, the presence of microorganisms that respond and produce enzymes during fermentation can result in browning. The browning reaction occurs via enzymatic processes; therefore, a higher concentration increases the rate of oxidation catalyzed by the keratinase enzyme (Mulia et al., 2016).

In treatments B, C, D, and E, there was no significant difference ($p>0.05$) in lightness values because of the optimal addition of microorganisms to degrade keratin, which can affect the brightness of chicken feather flour. Enzymes that hydrolyze keratin components regulate carbon metabolism, which can produce browning (Mulia et al., 2016). This indicates that a 1.5% concentration in treatment B is sufficient to alter the lightness of chicken feather meal.

The results of this study showed lightness values ranging from 60.19 to 62.25. Increasing the concentration of IMO chicken feather meal can reduce the lightness value. This is in line with the research of Mulia et al. (2016) and Mercis et al. (2022), who found that fermentation of chicken feather meal using *Bacillus licheniformis* B2560, Bacillus subtilis, and three different types of yeast (bread, tape, and tempeh) can produce a white color that tends to be brownish white, indicating that it can reduce the lightness value.

**Redness (a*)**

Observations of redness (a*) levels of chicken feather meal treated with various concentrations of IMO indicated a color change due to fermentation. After this treatment, the redness parameter was used to quantify the extent of green and red coloration in the chicken feather meal samples. The average redness values of chicken feather meal with different IMO concentrations are listed in Table 1.

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All treatments underwent hydrolysis during fermentation, resulting in no significant changes in redness. This indicated a stable green-red balance during fermentation. Similar findings were reported by Li et al. (2020), in which fermentation with *Streptomyces* spp. Only slight shifts in values were observed. Hydrolysis of the ingredients produces a green color. This is in line with the research of Li et al. (2020), who found that feather degradation by *Streptomyces* (thermolineatus, fradiage, and cattleya) on the fifth day of fermentation resulted in a color change from white to grayish-green.

**Yellowness (b*)**

Observations of the fermentation level of chicken feather meal treated with IMO chicken feathers at various concentrations showed color changes due to the fermentation process. The yellowness parameter was used to measure the amount of blue and yellow. The average yellowness values of chicken feather meal with different concentrations of IMO chicken feathers are listed in Table 1. These results indicate that the IMO concentration is critical in modulating feather flour color characteristics. The yellowish color of chicken feather meal is caused by carotenoid production during microbial activity (Cámara et al., 2021). This indicates that the higher the IMO chicken feather concentration, the higher the yellowness value.

Treatment E, with the addition of 6% chicken feather IMO, produced the highest yellowness value for chicken feather meal (9.88). The increase in yellowness of chicken feather meal is due to the production of carotenoids by microorganisms during fermentation. The feather degradation process can produce keratin during fermentation. Microorganisms, including bacteria and fungi, produce carotenoids as secondary metabolites during growth on substrates. Carotenoids provide a natural, corrosive color to living microorganisms, such as bacteria, algae, and fungi (Cámara et al., 2021). The presence of keratin increases the yellowness of stains.

Treatment A, without adding chicken feather IMO (control), produced the lowest yellowness value for chicken feather meal (8.65). This treatment had the lowest value because microorganisms did not degrade chicken feather keratin. Hydrolysis with water alone cannot degrade carotenoid pigments (Mulia et al., 2016). The absence of chicken feathers and IMO prevented the presence of microorganisms capable of forming carotenoid compounds during fermentation. Increasing the inoculum concentration does not always result in increased enzyme activity. At a specific concentration, microorganisms reach a balance in pigment production and enzyme activity; therefore, increasing IMO concentrations within a specific range does not result in significant color changes. In a study by Mulia et al. (2016), adding 10 mL of Bacillus subtilis resulted in a yellowish-white chicken feather meal.

**Microscopic Structure**

As shown in Figure 1, in treatment A without the addition of IMO, chicken feathers had a keratin structure in the barbules that appeared very dense compared to the other treatments. This is because the treatment used only distilled water; therefore, the resulting hydrolysis did not involve microbial activity or the keratinase enzyme that degrades keratin. Keratin degradation is difficult because of the insoluble nature of keratin polypeptides in water and their high rigidity (Srivastava et al., 2020).



(a)



(b)



(c)



(d)

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(e)

Figure 1. Microscopic structure of chicken feather meal at 100 × magnification, observed using an Optilab Iris 4 Trinocular Microscope and a Sigma 4K Camera.
Notes: (a) without the addition of chicken feather IMO (control), (b) with 1.5% chicken feather IMO, (c) with 3% chicken feather IMO, (d) with 4.5% chicken feather IMO, and (e) with 6% chicken feather IMO.

In treatments B, C, D, and E, adding chicken feather IMO at concentrations of 1.5%, 3%, 4.5%, and 6%, respectively, led to keratin structure degradation. This indicates that fermentation of chicken feather meal is effective in hydrolysis. The successful hydrolysis of chicken feather meal can be attributed to the fermentation process, driven by multiplying microorganisms that produce the keratinase enzyme, which breaks down complex keratin bonds into simpler ones. When keratinase enzyme is produced by Bacillus subtilis, it can break down protein, lipid, and amylase bonds, resulting in the decomposition of components that can change the texture to a smoother, softer, and crumblier texture (Mulia et al., 2016).

A decrease in the density of the resulting keratin structure may indicate the decomposition of keratin protein in chicken feather meal. These decomposed components can create a smoother, softer, and crumblier texture (Mulia et al., 2016). This is in line with the findings of Mulia et al. (2016) and Mercis et al. (2022), who found that increasing the addition of *Bacillus licheniformis* B2560, *Bacillus subtilis*, and various types of yeast can soften the texture of chicken feather meal. The fungi *Aphanoascus keratinophilus* and *Chrysosporium tropicum* can degrade keratin (Bohacz et al., 2017).

**Crude Fiber Content**

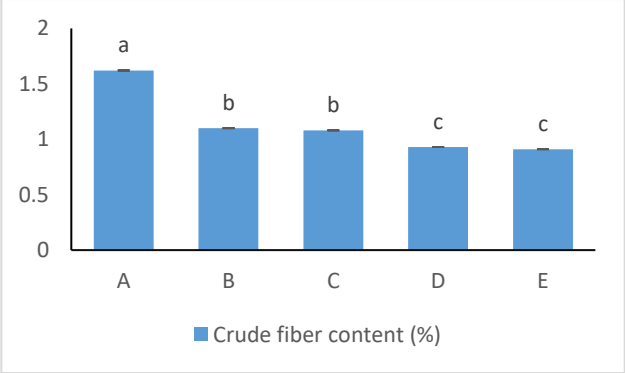



Figure 2. Results of the Crude Fiber Test of Chicken Feather Meal
A: without adding IMO chicken feathers (control); B: adding IMO chicken feathers 1.5%; C: adding IMO chicken feathers 3%; D: adding IMO chicken feathers 4.5%; and E: adding IMO chicken feathers 6%

Treatment A, without adding chicken feather IMO, produced the highest crude fiber content (1.62 %). This was due to the absence of microbial activity in the degradation of keratin during fermentation. Therefore, the keratinase enzyme was absent, utilizing the fiber-containing carbon source in chicken feather meal, and keratin fibers were not fully decomposed. Feather keratin is insoluble in water due to hydrogen and disulfide bonds (Adler et al., 2018).

Treatment E, which added 6% chicken feather IMO, produced the lowest crude fiber content (0.91 %). The decrease in crude fiber content in chicken feather meal occurred with an increasing percentage of added chicken feather and IMO. Microbes play a crucial role in reducing crude fiber content because fiber serves as a food source for microbes during fermentation (Ly et al., 2017). Furthermore, the decrease in crude fiber content indicates the activity of the keratinase enzyme, which breaks down keratin in chicken feather meal into simpler compounds. Microbes break down the chemical structure of cell walls, disrupting the hydrogen and disulfide bonds in keratin. The decrease in crude fiber content can be attributed to a decrease in the fiber content of keratin protein (Mulia et al., 2016). The fermentation process produces keratinase and reductase enzymes, which can hydrolyze peptide and disulfide bonds in keratin protein (Afriani & Hasan, 2020). The resulting fiber fraction is the keratin fiber residue remaining after fermentation.

The crude fiber content reported in this study ranged from 0.91% to 1.62%. This result is higher than that of Mulia et al. (2016), who found that fermentation of untreated chicken feather meal and the addition of different concentrations of Bacillus subtilis inoculum resulted in crude fiber content ranging from 0.04% to 21.61%. In a study by Dalle, Tukan, and Nugraha (2022), untreated chicken feather meal and a mixture of fermented cassava and bread yeast fermented for 2 days produced a higher crude fiber content, ranging from 1.25% to 2.79%.

In a study by Mercis et al. (2022), untreated chicken feather meal and fermentation with three types of yeast (bread, cassava, and tempeh) for 2 days produced lower crude fiber content, ranging from 0.09 to 2.74%. Furthermore, a study by Wahyuni et al. (2023) using fermentation with soaking periods of 1, 3, and 5 days and different concentrations of Bacillus subtilis found that each treatment produced lower crude fiber content, ranging from 0.30 to 1.67%. Fitriana et al. (2025) reported that feather meal using 0.5% proteolytic enzymes had a higher crude fiber content than in this study, namely 3.93%.

## CONCLUSION

The study concludes that increasing IMO concentration in chicken feather fermentation significantly decreases lightness (L*) and crude fiber content, increases yellowness (b*), and modifies the microscopic structure. At the same time, redness (*a) remains unaffected. The optimal treatment was 4.5% IMO, yielding feather flour with improved physicochemical quality and a degraded keratin structure, with a lightness (L*) of 60.36, a redness (a*) of -0.66, and a yellowness (b*) of 9.72, with a hydrolyzed keratin structure. These findings support the use of IMO as a sustainable method for feather waste valorization.

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