

## Characterization of the whiteness degree of calcium citrate synthesized from broiler chicken bone waste

### *Karakterisasi derajat putih kalsium sitrat yang disintesis dari limbah tulang ayam broiler*

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**Abstract.** The whiteness degree characterization was performed to assess the brightness and purity of calcium citrate, as a higher whiteness degree indicates better product quality and greater potential for application. This study aimed to characterize the degree of whiteness of calcium citrate synthesized from broiler chicken bone waste. The study materials included broiler chicken bone waste, citric acid, ethanol, and distilled water. Calcium oxide derived from broiler chicken bones was mixed with distilled water. Citric acid and 95% ethanol were then added and stirred for 30 minutes using a hotplate magnetic stirrer at 75 °C and 500 rpm. The sample was subsequently sun-dried for 14 days and ground for 1 minute using a blender. The observed parameter was the degree of whiteness, measured using a color reader. The whiteness data were analyzed descriptively. Calcium citrate synthesized from broiler chicken bone waste using citric acid had a whiteness degree of  $74.40 \pm 0.02$ , indicating that the product exhibited good visual quality and a stable synthesis process. These results demonstrate that broiler chicken bone waste has strong potential as an environmentally friendly alternative source of calcium.

**Keywords:** whiteness degree, calcium citrate, waste, synthesis, broiler chicken bone.

**Abstrak.** Karakterisasi derajat putih dilakukan untuk menentukan tingkat kecerahan dan kemurnian kalsium sitrat, karena derajat putih yang tinggi menunjukkan kualitas produk yang lebih baik serta potensi aplikasi yang lebih luas. Penelitian ini bertujuan untuk mengkarakterisasi derajat putih kalsium sitrat yang disintesis dari limbah tulang ayam broiler. Materi penelitian terdiri atas limbah tulang ayam broiler, asam sitrat, etanol, dan akuades. Kalsium oksida tulang broiler dicampur dengan akuades. Asam sitrat dan etanol 95% ditambahkan lalu diaduk selama 30 menit dengan *hotplate magnetic stirrer* pada suhu 75°C pada kecepatan 500 rpm/menit. Sampel lalu dikeringkan matahari selama 14 hari dan dihaluskan selama 1 menit dengan *blender*. Parameter yang diamati yaitu derajat putih menggunakan *color reader*. Data hasil uji derajat putih dianalisis secara deskriptif. Kalsium sitrat yang disintesis dari limbah tulang ayam broiler menggunakan asam sitrat memiliki derajat putih sebesar  $74,40 \pm 0,02$  yang mana produk yang dihasilkan menunjukkan kualitas visual yang baik dan proses sintesis yang stabil.

Hasil ini membuktikan bahwa limbah tulang ayam broiler berpotensi sebagai sumber kalsium alternatif yang ramah lingkungan.

**Kata kunci:** derajat putih, kalsium sitrat, limbah, sintesis, tulang broiler.

## INTRODUCTION

Indonesia, with a population of approximately 280 million, is a country with a high level of consumption of animal-based foods. One of the most widely consumed animal-based foods in Indonesia is chicken meat, particularly broiler chicken. Effendi, Ahmad, & Saleh (2023) reported that broiler chicken meat production in 2021 reached 3,426,042 tons. This figure reflects the high consumption of poultry products among the Indonesian people. Along with the increasing consumption of chicken meat, waste generated from slaughtering processes, such as chicken bones, is also becoming more abundant. This waste is produced from various sources, including poultry slaughterhouses, chicken-based food processing industries, restaurants, and households. Unfortunately, to date, the utilization of broiler chicken bones has been very limited, generally processed only into bone meal for animal feed or fertilizer, with relatively low economic value.

Broiler chicken bones have great potential to be utilized as a calcium source. According to Ningsih, Zulfian, Gading, & Zuprizal (2022) the percentage of chicken bones is about 12.28-21.96% in breast meat, 23.29-26.60% in thigh meat, and 31.96-37.14% in wing meat. This composition makes chicken bones a potential natural calcium source to be further developed, especially in the food industry. Chicken bones are composed of approximately 21% collagen, 9% water, 69% calcium phosphate, and 1% other components. The proportion of chicken bones accounts for about 22.49-30.27% of the live weight of broilers (Patriani & Hafid, 2019). The high calcium content in broiler chicken bones makes them a promising raw material to be processed into food-grade calcium. Therefore, based on the national broiler production volume, a very large amount of chicken bone waste is generated annually.

Calcium is one of the essential minerals that plays a crucial role in the human body, particularly in the formation and maintenance of bones and teeth. Prolonged calcium deficiency can lead to various health problems, one of which is osteoporosis. Jahari & Prihatini (2014) reported that the prevalence of osteoporosis among Indonesian women aged 50-70 years reached 23% and increased to 53% among those over 70 years old. Meanwhile, men also showed an increased risk of osteoporosis after the age of 55. This indicates that the need for calcium supplements in society is becoming increasingly urgent, along with growing awareness of bone health.

One of the calcium forms widely used as a supplement is calcium citrate. Calcium citrate has several advantages compared to other calcium forms, such as calcium carbonate, including being more soluble in the digestive tract and absorbable by the body even without large amounts of gastric acid. Therefore, calcium citrate is often recommended for the elderly or individuals with digestive disorders. Generally, calcium citrate is produced through a reaction between calcium compounds (such as calcium carbonate or calcium phosphate) and citric acid, a weak organic acid that is easily obtained and relatively safe for consumption (Li et al., 2013).

Previous studies have developed calcium citrate from inorganic calcium sources or other organic wastes, such as eggshells and fish bones. However, studies focusing on the characterization of the degree of whiteness of calcium citrate synthesized from broiler chicken bone waste remain very limited. In fact, the degree of whiteness is one of the key parameters in evaluating the quality of calcium citrate, as it is closely related to purity level, aesthetic value, and suitability for use in the food and pharmaceutical industries. A high degree of whiteness indicates a low content of organic and inorganic impurities in the product, thus serving as a primary indicator of calcium citrate quality.

Based on this background, this study was conducted to synthesize calcium citrate from broiler chicken bone waste using citric acid and to characterize its degree of whiteness. The results of this study are expected to provide scientific contributions to the utilization of broiler chicken bone waste as an alternative calcium source, while also increasing the added value of by-products from the poultry industry in Indonesia.

## **MATERIALS AND METHODS**

### **Materials and Equipment**

The equipment used in this research included a measuring cylinder, digital balance, beaker glass, magnetic stirrer, hotplate, pipette, furnace, and color reader. The materials consisted of broiler chicken bone waste, citric acid, ethanol, and distilled water.

### **Preparation of Broiler Bone Flour**

The preparation of chicken bone flour was carried out following the method described by Prayitno, et al. (2025). Broiler bones were thoroughly washed and then boiled for 1 hour. The bones were mixed with water at a ratio of 1:6 (w/v) and pressure-cooked for 2 hours. The sample was then oven-dried at 105 °C for 24 hours and ground using a sample mill.

### **Preparation of Broiler Bone Calcium Oxide**

The preparation of calcium oxide (CaO) from broiler chicken bone flour was conducted according to the method of Prayitno et al. (2021) with modifications. The chicken bone flour was calcined at 650°C for 4 hours to obtain CaO powder.

### **Preparation of Nano Calcium Citrate from Broiler Bones**

Calcium citrate was prepared using the precipitation method described by Prayitno, Umam, Ridho, Safitri, & Roihan (2025). Broiler bone-derived calcium oxide was mixed with distilled water. Citric acid and 95% ethanol were then added and stirred for 30 minutes using a hotplate magnetic stirrer at 75 °C with a speed of 500 rpm. The sample was sun-dried for 14 days and ground with a blender. The resulting calcium powder was then tested for degree of whiteness using a color reader.

### **Whiteness Degree**

The degree of whiteness was measured using a color reader (Park, Byeon, Kim, & Kim, 2021). Before use, the color reader was calibrated with standard white paper. The sample was placed in a container, and measurements were taken at five points to obtain the values of dL, da, and db. The L, a\*, and b\* values of the sample were calculated by adding the values of dL, da, and db to the corresponding standard values, specifically  $L = 94.35 + dL$ ,  $a^* = -5.75 + da$ , and  $b^* = 6.51 + db$ . The L value represents color brightness ranging from 0 to 100 (from black to white), a\* ranges from -80 to +100 (from blue to red), and b\* ranges from -50 to +70 (from blue to yellow). The degree of whiteness (W) was then calculated using the formula  $W = 100 - \{(100-L)^2 + a^2 + b^2\}^{0.5}$ .

### **Data Analysis**

The research data were analyzed descriptively by evaluating the results obtained from the characterization of the degree of whiteness of calcium citrate synthesized from broiler chicken bone waste (Prayitno, Prasetyo, & Sutirtoadi, 2020).

## **RESULTS AND DISCUSSION**

### **Whiteness**

The test results showed that calcium citrate synthesized from broiler chicken bone waste using citric acid had a whiteness degree of  $74.40 \pm 0.02$ . This value indicates that the final product has a high level of brightness, suggesting the successful removal of organic compounds and other impurities during synthesis. The degree of whiteness is one of the key parameters in evaluating the quality of calcium citrate, especially for food or pharmaceutical applications. Products with a whiteness degree above 70 are considered to have good visual quality and are suitable for further development (Wijayanti, Benjakul, Saetang, Prodpran, & Sookchoo, 2025).

The use of citric acid in the bone demineralization process is highly effective due to its environmentally friendly nature, biodegradability, and strong ability as a calcium complexing agent. Research findings Burke & Kerton (2023) showed that citric acid applied to fishery by-products successfully extracted calcium in the form of calcium citrate with competitive whiteness values, particularly compared to strong acids such as HCl or HNO<sub>3</sub>, which may damage the material's

structure. A two-step synthesis process involving citric acid has also been proven to enhance purification effectiveness and improve the visual whiteness of the final product.

Additionally, Patil, Nilswan, & Benjakul (2024) reported that the combination of pretreatments (such as heating and drying) and dissolution with citric acid on marine fish bones produced bio-calcium powder with an  $L^*$  value (the whiteness component in the CIE Lab color system) close to 75. This supports the findings of calcium citrate synthesized using citric acid from chicken bone waste, which showed a whiteness degree of 74.40 as a valid achievement. The very small standard deviation ( $\pm 0.02$ ) indicates that the synthesis process proceeded stably and reproducibly, an essential requirement for industrial-scale production (Wijayanti et al., 2025).

Therefore, it can be concluded that broiler chicken bone waste is a promising raw material for producing high-quality calcium citrate. Efforts to increase the whiteness degree above 80 can be made by optimizing temperature, reaction time, and applying additional purification processes such as activated carbon filtration or recrystallization. This utilization of waste also supports the principles of circular economy and environmental sustainability (Patil et al., 2024).

## CONCLUSION

Calcium citrate synthesized from broiler chicken bone waste using citric acid had a whiteness degree of  $74.40 \pm 0.02$ , indicating that the product exhibited good visual quality and a stable synthesis process. These results demonstrate that broiler chicken bone waste has strong potential as an environmentally friendly alternative source of calcium.

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