

Effect of Freeze-Dried and Oven-Dried Cilembu Sweet Potato Flour on the Antioxidant Activity of Chicken Meatballs.

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Abstract: This study evaluated the effect of different dehydration methods, specifically oven drying (60°C) and freeze-drying (-20°C to 65°C), on the antioxidant activity of Cilembu sweet potato (*Ipomoea batatas* L. Lam) flour and its functional application in chicken meatballs. The antioxidant capacity was measured using the DPPH radical scavenging assay, with results showing that freeze-drying significantly preserved higher levels of bioactive compounds compared to thermal evaporation. Freeze-dried tuber flour reached a radical scavenging activity of 55.74 mg/ml, and when applied to meatballs as a 15% substitute for tapioca flour, it exhibited a superior antioxidant activity of 41.7%. This value was significantly higher ($P < 0.01$) than the oven-dried treatment (28.85%) and the control group (13.22%). The enhanced retention of antioxidants in freeze-drying is attributed to the sublimation process, which minimizes the oxidation and thermal degradation of heat-sensitive molecules such as beta-carotene and phenolic compounds inherently found in Cilembu sweet potatoes. In conclusion, freeze-drying is the more effective processing method for maintaining the functional integrity of local Indonesian tubers, providing a high-quality ingredient for the development of standardized functional foods.

Keywords: Local tubers flour; Cilembu sweet potato; antioxidant activity; Freeze drying



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Introduction

Broiler chicken is commonly used in the manufacture of comminuted meat products, such as meatballs (*bakso*), due to its high-quality protein content, mild taste, and wide consumer acceptance. Meatballs are rich in protein and lipids, which makes them highly susceptible to oxidative deterioration caused by free radicals during processing and storage. Chicken-based meat products especially chicken meatballs are particularly vulnerable because chicken meat contains relatively high levels of unsaturated, especially polyunsaturated, fatty acids that readily undergo lipid oxidation, leading to the formation of hydroperoxides and other oxidation products. These reactions can promote rancid flavor, discoloration, nutrient loss, and overall sensory deterioration in meat products (Ali et al., 2025; Domínguez et al., 2019). In addition to lipid oxidation, oxidative reactions may also affect proteins, causing structural modifications that impair texture, reduce water-holding capacity, and lower the overall acceptability of the product (Nawaz et al., 2022). Therefore, uncontrolled oxidative reactions can substantially reduce the physicochemical and sensory quality of meatballs, making oxidative stability an important factor in maintaining product quality and shelf life (Ali et al., 2025; Nawaz et al., 2022).

Cilembu sweet potato is recognized as a functional food ingredient rich in antioxidant compounds, which may help scavenge free radicals and improve the oxidative stability of food products. Cilembu sweet potato is recognized as a promising functional food ingredient because it

contains considerable amounts of bioactive compounds with antioxidant properties. Like other sweet potato cultivars, Cilembu tubers are rich in carbohydrates and dietary fiber and also contain phenolic compounds, flavonoids, carotenoids, and vitamin C, all of which contribute to their antioxidant potential. These compounds are able to scavenge free radicals and may help reduce oxidative stress, thereby improving the functional value of food products. Reviews on *Ipomoea batatas* have consistently shown that sweet potato tubers possess antioxidant activity associated with their phytochemical composition, although the level of activity may vary depending on cultivar, processing method, and storage conditions (Laveriano-Santos et al., 2022; Suhendy et al., 2023). In addition, recent studies have reported that sweet potato tubers contain polyphenols and other antioxidant-related compounds that remain important contributors to their bioactivity even after processing, supporting their use as natural antioxidant sources in food formulations (Hapke et al., 2024; Musilová et al., 2024).

Previous studies have shown that tapioca starch plays an important role in improving the physicochemical and sensory properties of comminuted meat products, particularly through its effects on texture formation, water-holding capacity, and overall product acceptability (Nimitkeatkai et al., 2022). At the same time, sweet potato has been widely recognized as a functional food source because of its dietary fiber, phytochemical content, and antioxidant potential, which make it promising for food product development (Rosell et al., 2024). In meat systems, plant-derived bioactive compounds have also received increasing attention because they may help delay oxidative deterioration and support product quality during processing and storage (Olvera-Aguirre et al., 2023). However, based on the recent literature, these lines of research have largely been explored separately; therefore, studies that specifically examine the optimization of tapioca starch level in broiler chicken meatballs enriched with Cilembu sweet potato flour, while simultaneously evaluating antioxidant activity and sensory quality, remain limited. Therefore, the objective of this study was to evaluate the effect of freeze-dried and oven-dried Cilembu sweet potato flour on the antioxidant activity of chicken meatballs.

Materials and Methods

The raw material used in this study was Cilembu sweet potato (*Ipomoea batatas* L. Lam). The preparation process began with peeling the tubers, followed by thorough washing to remove impurities. The cleaned tubers were then sliced to a uniform thickness of 2 mm to ensure consistent drying. Furthermore, tuber drying was carried out using oven and freeze drying. Drying in the oven was carried out at 60°C for 48 hours. Drying using a freeze dryer is carried out in 2 stages, the first is put into the freeze dryer at a temperature of -20°C for 4 hours and then continued into the dryer for 10 hours until the material temperature becomes 55-65°C. Selected tubers that have been dried using an oven and freeze dryer are put into aluminium foil packaging before proceeding to the flouring stage. Furthermore, the dried tubers in aluminium foil which have been produced from drying using an oven and freeze-dryer are then ground with a milling unit and sieved with an 80 mesh size sieve. Then the selected tuber flour was stored back to proceed to the testing stage.

Chicken breast meat was cut into small pieces and finely ground. The ground meat was then mixed with fried onions, pepper, salt, and garlic that had been previously ground, until a homogeneous batter was formed. Ice cubes were added during mixing to maintain the temperature and improve the consistency of the mixture. The resulting flour was subsequently applied as a functional ingredient in chicken meatball production. The meatballs were formulated by substituting 15% of the tapioca flour with either oven-dried (P1) or freeze-dried (P2) Cilembu sweet potato flour, while a control group (P0) was prepared using 100% tapioca flour. The process involved blending minced chicken breast with ice, salt, garlic, pepper, and the respective flour treatments in a food processor to form a homogeneous paste. The batter was shaped into uniform spheres and cooked in

two stages: pre-heating at 60°C for 10 minutes followed by boiling at 100°C for 10–15 minutes until fully cooked. Finally, the meatballs were cooled to room temperature and prepared for antioxidant activity analysis using the DPPH assay.

Antioxidant activity (DPPH)

Antioxidant activity measurement test of sweet potato was conducted with DPPH (1,1-diphenyl-2-picrylhydrazyl) radical scavenging method [12]. 0.007 gram of DPPH powder was weighed then dissolved with 50 mL of ethanol, vortexed until dissolved. Furthermore, 1 mL of DPPH solution was taken then added ethanol to 5 mL and let stand for 30 minutes. The solution was taken using a pipette as much as 1 mL then added 5 mL of ethanol solution and left for 30 minutes in a dark place and the absorption at a wavelength of 517 nm.

$$\%ARA = \frac{\text{control absorbency} - \text{sample absorbency}}{\text{control absorbency}} \times 100\%$$

Results and Discussion

Antioxidant activity on Cilembu sweet potato (*Ipomoea batatas* L. Lam), local Indonesian tuber, on different drying methods shown on Figure 1.

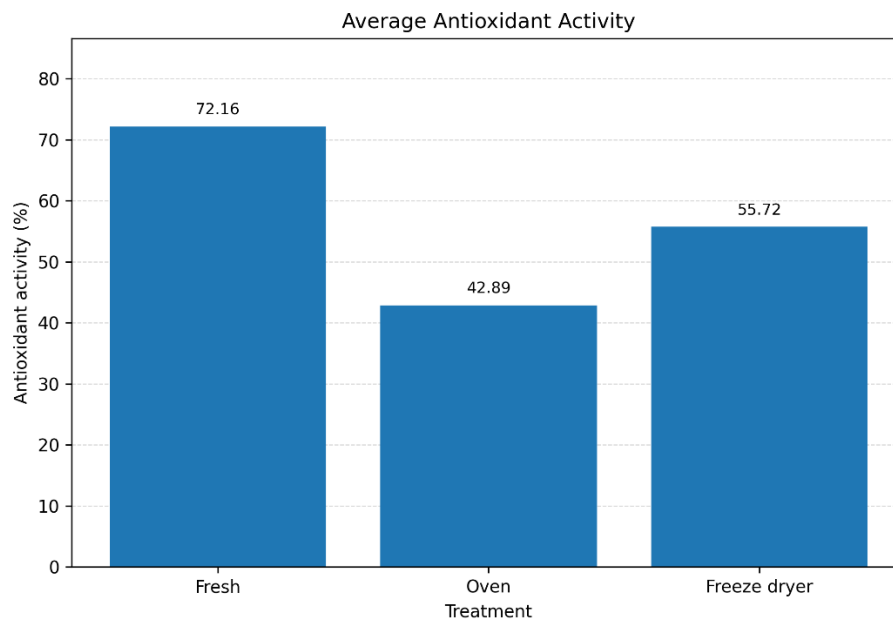


Figure 1. Antioxidant activity on Cilembu sweet potato with different processing method

The antioxidant activity test used the DPPH (1,1-diphenyl-2-picrylhydrazyl) method. DPPH works as a free radical compound, so that antioxidant activity is the ability of antioxidants to capture free radicals. The presence of antioxidant compounds in the sweet potato samples will neutralize the free radicals contained in DPPH by donating electrons to the DPPH free radicals so that a colour change in the solution will occur from purple to yellow which is then read for absorbance by spectrophotometry (Molyneux, 2004). Antioxidant activity shown that drying with freeze dryer given lower antioxidant loss than oven method. Oven drying is a popular method used for the preservation process by reducing the moisture content of various types of food because the technique is relatively inexpensive and easy to apply. With reduced water content, it is hoped that food can be more durable and last longer. In the results of the study using an oven in the drying process of Cilembu sweet potato, it produced fewer antioxidant compounds than freeze drying. This is because the drying process using the oven can damage the antioxidant compounds contained in Cilembu sweet potatoes

due to the use of high temperatures. Antioxidants are compounds capable of scavenging free radicals and suppressing oxidative stress by stabilizing reactive species through electron- or hydrogen-donating mechanisms. Nevertheless, antioxidant compounds are highly sensitive to processing conditions, especially temperature, and thermal exposure can significantly promote their degradation, thereby reducing their functional activity (Ammar et al., 2022; Gulcin, 2025). So, the use of freeze-drying method with low temperature can reduce antioxidant damage. The drying process that uses low temperatures and at vacuum pressure can maintain the nutritional value and bioactive components in a food product (Bhatta et al., 2020).

Table 2. Antioxidant activity of chicken meatballs supplemented with Cilembu sweet potato flour (%)

Variable	Replication					Mean ± SD
	I	II	III	IV	V	
P0	12.45	15.8	14.17	11.51	12.25	13.22 ± 1.72 ^a
P1	28.52	29.93	29.15	28.34	26.41	28.85 ± 1.98 ^b
P2	42.31	41.85	39.16	42.55	42.73	41.7 ± 1.48 ^c

P0 = control (without Cilembu), P1 = oven drying, P2 = Freeze drying; (^{a,b,c}) different superscripts on the same row indicate a significant difference. (P<0,01)

Based on the statistical analysis, the addition of Cilembu sweet potato flour significantly increased the antioxidant activity of chicken meatballs (P<0.01). The control group (P0) exhibited the lowest antioxidant activity 13.22%, which may be attributed to the natural presence of carnosine or anserine in chicken meat. However, the incorporation of Cilembu sweet potato flour in P1 (Oven Drying) and P2 (Freeze Drying) resulted in a substantial increase in radical scavenging capacity, reaching 28.85% and 41.7%, respectively. The superior performance of Freeze Drying is primarily due to the sublimation process at low temperatures. Cilembu sweet potatoes are rich in beta-carotene and phenolic compounds, which are highly sensitive to thermal degradation. In Oven Drying, the prolonged exposure to heat and oxygen triggers the oxidation of these bioactive molecules, leading to a significant loss of their antioxidant capacity. In contrast, the freeze-drying method maintains the porous structure of the flour and minimizes chemical changes, thereby preserving the functional properties of the tubers when applied to the meatball matrix.

The higher antioxidant activity in the freeze-drying treatment may be explained by the greater retention of antioxidant compounds during low-temperature dehydration. Freeze-drying is widely recognized as a gentle drying technique because water is removed by sublimation under low temperature and reduced pressure, thereby minimizing thermal degradation and oxidative damage to heat-sensitive bioactive compounds. In contrast, oven drying exposes plant materials to elevated temperatures for a prolonged period, which may accelerate the degradation of phenolics, carotenoids, anthocyanins, and other antioxidant constituents. Consequently, although oven drying still improved antioxidant activity compared with the control, its ability to preserve antioxidant compounds appeared inferior to freeze-drying in the present study (Coşkun et al., 2024). Pereira et al. (2024) reported that the drying method significantly affected the quality and bioactivity of sweet potato flour, including antioxidant-related parameters, and that freeze-drying generally preserved bioactive compounds more effectively than hot-air drying. Similarly, Kumar et al. (2022) found that freeze-dried citrus materials retained higher total phenolics and antioxidant capacity than oven-dried samples, demonstrating that conventional thermal drying can reduce the antioxidant potential of plant tissues. Therefore, the superior antioxidant activity observed in P2 in the present study is consistent with current evidence indicating that freeze-drying better preserves antioxidant compounds than heat-based drying methods.

The relatively low antioxidant activity in the control treatment also strengthens the interpretation that Cilembu sweet potato flour was the main contributor to the increased antioxidant capacity of the meatballs. Since P0 did not receive Cilembu sweet potato flour, its lower value suggests that the native antioxidant components of the meatball matrix were limited compared with the phytochemical contribution provided by the flour. Sweet potato is known to contain antioxidant compounds such as phenolics, carotenoids, and, depending on the variety, anthocyanins, all of which may contribute to radical-scavenging activity. Therefore, the marked increase from P0 to P1 and P2 indicates that supplementation with Cilembu sweet potato flour successfully enhanced the functional quality of the product, especially when the flour was produced by freeze-drying (Pereira et al., 2024). Overall, from a practical standpoint, freeze-drying appears to be the most suitable method when the objective is to maximize retention of antioxidant compounds and enhance the bio functional value of the final product (Coşkun et al., 2024). Although oven drying also improved antioxidant activity relative to the control, the improvement was substantially lower than that achieved by freeze-drying.

Conclusion

In conclusion, the drying method significantly affected antioxidant activity. Freeze-drying was more effective in preserving the antioxidant activity of tuber flours while reducing moisture content to a level acceptable for flour production.

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