

## INTEGRATING CARROT AGRO-INDUSTRIAL WASTE INTO SUSTAINABLE POULTRY FEEDING SYSTEMS

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### ABSTRACT

*Integrating agro-industrial waste into poultry feeding systems is a strategic approach to enhancing sustainability and feed resource efficiency. This study evaluated the potential of carrot agro-industrial waste as an alternative feed ingredient in broiler diets, focusing on its effects on crude protein and crude fiber contents. The experiment employed a completely randomized design with four dietary treatments containing carrot waste flour at 0, 3, 6, and 9%. Diets were formulated to be isoenergetic and isoprotein. Crude protein and crude fiber contents were analyzed using standard AOAC methods and subjected to analysis of variance. The results indicated that carrot waste flour inclusion significantly affected crude protein and crude fiber contents ( $P < 0.01$ ). Crude protein content increased with carrot waste inclusion up to 6% and declined at the 9% level, while crude fiber content increased with higher inclusion levels. The 6% inclusion level provided the most optimal balance between enhanced crude protein and acceptable crude fiber content. In conclusion, moderate inclusion of carrot agro-industrial waste, particularly at 6%, improves the nutritional quality of broiler diets and supports integrated and sustainable poultry feeding systems within circular agriculture frameworks.*

### Kata kunci:

bahan pakan alternatif, limbah agroindustri wortel, protein kasar, ransum ayam broiler, serat kasar, sistem peternakan unggas berkelanjutan.

### ABSTRAK

Mengintegrasikan limbah agroindustri ke dalam sistem pemberian pakan unggas merupakan pendekatan strategis untuk meningkatkan keberlanjutan dan efisiensi sumber daya pakan. Studi ini mengevaluasi potensi limbah agroindustri wortel sebagai bahan pakan alternatif dalam ransum ayam broiler, dengan fokus pada pengaruhnya terhadap kandungan protein kasar dan serat kasar. Percobaan menggunakan rancangan acak lengkap dengan empat perlakuan ransum yang mengandung tepung limbah wortel pada kadar 0, 3, 6, dan 9%. Ransum diformulasikan agar isoenergetik dan isoprotein. Kandungan protein kasar dan serat kasar dianalisis menggunakan metode standar AOAC dan dianalisis menggunakan analisis varians. Hasil menunjukkan bahwa penambahan tepung limbah wortel secara signifikan memengaruhi kandungan protein kasar dan serat kasar ( $P < 0,01$ ). Kandungan protein kasar meningkat dengan penambahan limbah wortel hingga 6% dan menurun pada kadar 9%, sedangkan kandungan serat kasar meningkat dengan kadar penambahan yang lebih tinggi. Kadar penambahan 6% memberikan keseimbangan paling optimal antara peningkatan protein kasar dan kandungan serat kasar yang dapat diterima. Kesimpulannya, penambahan limbah agroindustri wortel dalam jumlah sedang, khususnya sebesar 6%, meningkatkan kualitas nutrisi pakan ayam broiler dan mendukung sistem pemberian pakan unggas terpadu dan berkelanjutan dalam kerangka pertanian sirkular.

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## INTRODUCTION

Sustainable poultry production systems are facing increasingly complex global challenges, particularly related to feed availability, resource efficiency, and environmental impacts. Feed accounts for more than 60% of total poultry production costs (Anggitasari et al., 2016; Prayitno et al., 2019); thus, heavy reliance on conventional feed ingredients such as maize and soybean meal not only increases production expenses but also intensifies environmental footprints due to competition with human food demands and global market volatility (Makkar, 2018). Consequently, the development of efficient, adaptive, and sustainable poultry feeding systems has become a major priority in modern agricultural systems (Hasan et al., 2018).

Over the past decades, integrated and circular agriculture approaches have gained increasing attention as strategic solutions to optimize the use of local resources and minimize agro-industrial waste. By-products derived from agricultural and horticultural processing can be reutilized as alternative feed ingredients (Lau et al., 2021; Malenica et al., 2022), thereby improving the efficiency of livestock production systems while simultaneously reducing environmental burdens (Sandström et al., 2022; Xu & Geelen, 2018). This approach is closely aligned with global sustainable agriculture agendas that emphasize cross-sectoral integration within agricultural systems.

One promising horticultural agro-industrial by-product is carrot waste, which is generated in substantial quantities during sorting and processing activities but remains largely underutilized (Bakshi et al., 2016; Fitriani et al., 2020; Kaur et al., 2022). Carrot waste contains valuable nutrients, including carbohydrates, crude fiber, and bioactive compounds, which may support poultry nutritional requirements (Muzaki et al., 2017; Sejati et al., 2017). However, most existing studies have primarily focused on the general utilization of horticultural wastes or specific feed substitution levels, without situating carrot waste utilization within a broader framework of integrated and sustainable poultry feeding systems.

At the international level, research on the integration of agro-industrial waste into poultry feeding systems still reveals a significant research gap, particularly regarding the evaluation of the nutritional contribution of such wastes to overall diet quality. Information on the effects of carrot waste inclusion on crude protein and crude fiber contents of poultry diets remains limited, despite the importance of these parameters in determining nutritional quality and feed utilization efficiency (Andriani et al., 2022; Silondae et al., 2023; Yitbarek, 2019). Furthermore, system-based approaches that explicitly link carrot waste utilization to integrated and sustainable agricultural concepts are still rarely reported (Kalogiannidis et al., 2022; Salinas-Velandia et al., 2022; Seljåsen et al., 2016).

Based on this background, the present study aimed to evaluate the potential of carrot agro-industrial waste as an alternative feed ingredient within sustainable broiler feeding systems, with particular emphasis on its effects on crude protein and crude fiber contents of the diet. The findings of this study are expected to provide a scientific basis for the development of efficient, environmentally friendly, and integrated poultry feeding systems that support sustainable agriculture principles.

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## RESEARCH METHODOLOGY

### Materials and Feed Ingredients

This study utilized carrot agro-industrial waste obtained from local horticultural sorting and processing activities. The carrot waste was selected based on acceptable physical condition, free from foreign material contamination, and without signs of spoilage. The waste was washed with clean water to remove adhering impurities, chopped into small pieces, and dried until a relatively stable moisture content was achieved before being processed into carrot waste flour.

Other feed ingredients used in diet formulation included ground maize, rice bran, soybean meal, fish meal, vegetable oil, mineral supplements, and vitamin premix. Diets were formulated to meet the nutritional requirements of broiler chickens according to established standards.

### Experimental Design and Treatments

The experiment was arranged using a completely randomized design (CRD) with several treatments representing different inclusion levels of carrot waste flour in broiler diets. Each treatment was formulated by partially replacing conventional feed ingredients with carrot waste flour at predetermined levels, as specified in the manuscript. The treatments were formulated by partially substituting conventional feed ingredients with carrot waste flour at graded levels. The dietary treatments were defined as follows: P0, control diet without carrot waste flour (0%); P1, diet containing 3% carrot waste flour; P2, diet containing 6% carrot waste flour; and P3, diet containing 9% carrot waste flour. Each treatment was replicated multiple times to ensure data reliability and minimize experimental variation.

### Diet Formulation and Preparation

Experimental diets were formulated to be isoenergetic and isoprotein to ensure that observed differences among treatments could be attributed primarily to the inclusion of carrot waste flour. All feed ingredients were accurately weighed using a digital balance and thoroughly mixed using a stepwise mixing procedure to ensure homogeneity. The formulated diets were stored in sealed containers under room conditions prior to laboratory analysis.

### Nutrient Composition Analysis

The primary parameters analyzed in this study were crude protein and crude fiber contents of the diets. Crude protein was determined using the Kjeldahl method, while crude fiber analysis was conducted following standard AOAC procedures. All analyses were performed under identical laboratory conditions for each treatment to maintain consistency and data validity.

### Statistical Analysis

Data obtained from nutrient composition analyses were subjected to analysis of variance (ANOVA) according to the completely randomized design. When significant differences among treatments were detected, post hoc tests were applied to determine specific treatment differences. Statistical significance was declared at a 5% probability level.

### Ethical Considerations and Research Validity

This study focused exclusively on feed quality analysis and did not involve direct experimentation on live animals; therefore, ethical approval for animal use was not required. All research procedures were designed to ensure reproducibility, methodological transparency, and

data reliability, providing a robust foundation for the development of integrated and sustainable poultry feeding systems.

## RESULTS AND DISCUSSION

### Effect of Carrot Waste Flour Inclusion on Crude Protein Content of the Diet

The results demonstrated that the inclusion of carrot waste flour in broiler diets had a highly significant effect ( $P < 0.01$ ) on crude protein content. The crude protein values ranged from 27.57% to 29.53%, showing clear variation among dietary treatments (Figure 1).

An increase in crude protein content was observed at P1 (3%), with the highest value recorded at P2 (6%), reaching 29.53%. These findings indicate that the inclusion of carrot waste flour at a moderate level can positively contribute to the nutritional quality of broiler diets. From a theoretical perspective, carrot waste still contains protein fractions and soluble nutrients that can enhance diet composition when used as a partial feed ingredient substitute. Previous studies have reported that carrot waste flour contains approximately 4–10% crude protein (Ikram et al., 2024; Sharma et al., 2012), thereby supporting its potential role in improving dietary protein levels when appropriately formulated (Begum et al., 2023; Kausar et al., 2024; Stamatovska et al., 2024; Surbhi et al., 2018).

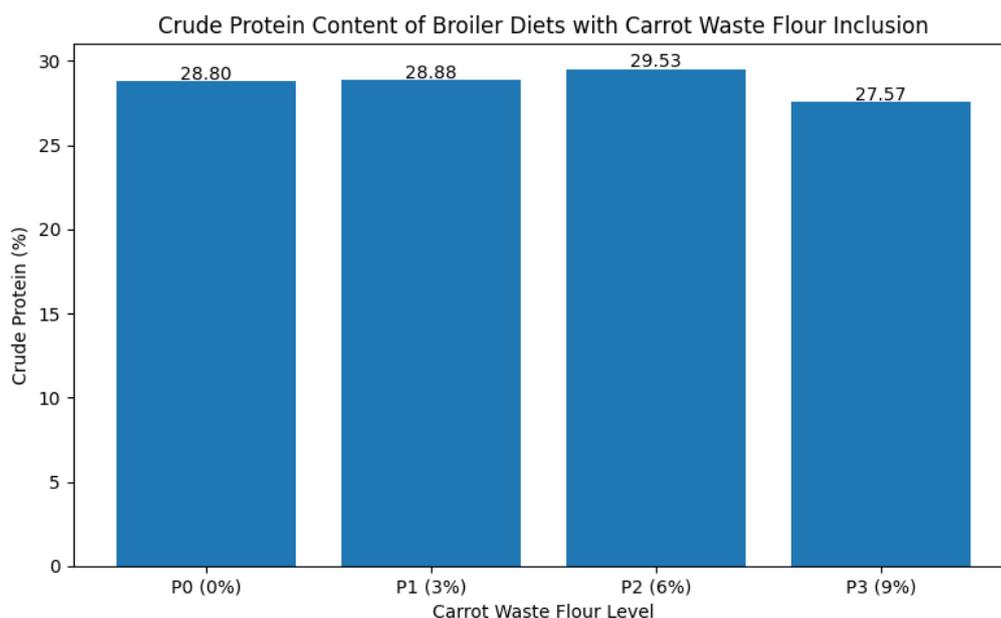


Figure 1. Crude protein content of broiler chicken rations with the addition of carrot waste flour at different levels.

In contrast, a reduction in crude protein content was observed at P3 (9%), indicating that excessive inclusion of carrot waste flour does not necessarily yield beneficial effects. This decline can be explained by the concept of nutrient dilution, whereby increasing proportions of fiber-rich ingredients reduce the relative concentration of protein in the diet. This finding is consistent with poultry nutrition theory, which emphasizes that the substitution of alternative feed ingredients must consider the balance between protein content and fiber fraction to avoid compromising overall diet quality (Halmemies-Beauchet-Filleau et al., 2018; Rodiallah et al., 2023; Shah et al., 2022; Utomo et

al., 2021). Accordingly, the results of this study confirm that a 6% inclusion level represents the optimal proportion of carrot waste flour for enhancing crude protein content in broiler diets.

### Effect of Carrot Waste Flour Inclusion on Crude Fiber Content of the Diet

The inclusion of carrot waste flour also exerted a highly significant effect ( $P < 0.01$ ) on the crude fiber content of broiler diets (Figure 2). Crude fiber values ranged from 6.41% to 6.97%, indicating compositional changes in the diet with increasing levels of carrot waste flour.

The lowest crude fiber content was observed at P1 (3%), whereas a gradual increase occurred at P2 (6%) and became more pronounced at P3 (9%). This trend is directly associated with the inherent characteristics of carrot waste, which contains relatively high levels of structural carbohydrates, particularly cellulose and hemicellulose.

Physiologically, broiler chickens have a limited capacity to digest crude fiber (Has et al., 2014; Jha & Mishra, 2021; Pardosi, 2022), and excessive fiber inclusion may reduce nutrient digestibility and feed efficiency (Adams et al., 2019; Andriani et al., 2022; De Vries et al., 2012). Nevertheless, moderate levels of dietary fiber can still be tolerated and may even support gut function (Tejeda & Kim, 2021; Zhang et al., 2023). In this context, the P2 (6%) treatment exhibited the most favorable balance, as it enhanced crude protein content while maintaining crude fiber levels within an acceptable range for broiler diets.

These findings are consistent with previous studies reporting that moderate inclusion levels of horticultural waste-based feed ingredients can improve feed efficiency without adversely affecting nutritional quality (Anugrah et al., 2024; Bakshi et al., 2016; Raza et al., 2019; Santoso et al., 2021; Shaffitri et al., 2024).

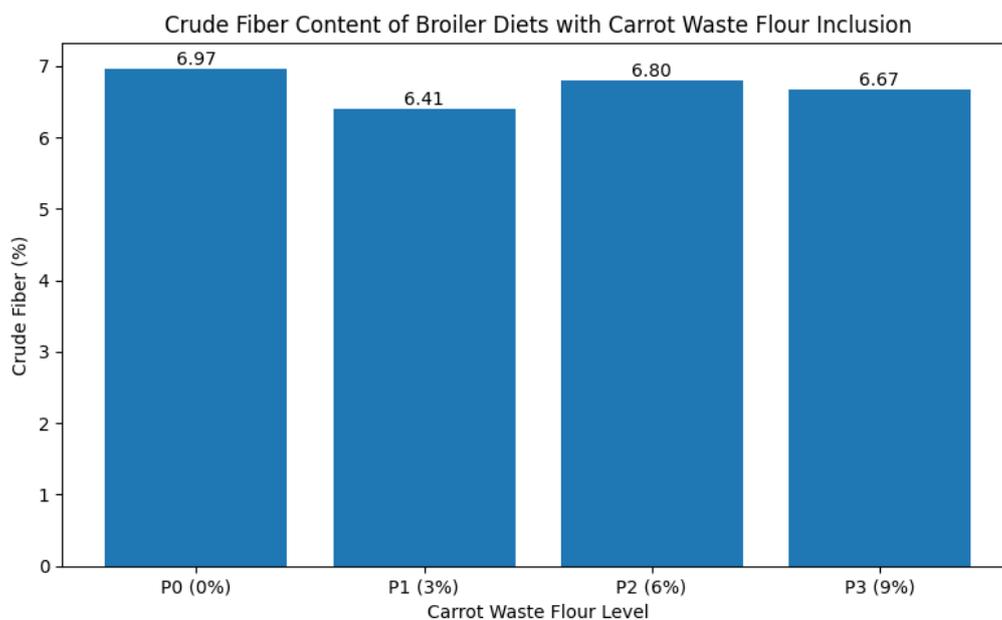


Figure 2. Crude fiber content of broiler chicken rations with the addition of carrot waste flour at different levels.

## Implications for Integrated and Sustainable Poultry Feeding Systems

Overall, the findings of this study highlight the substantial potential of integrating carrot agro-industrial waste into broiler diets as part of integrated and sustainable poultry feeding systems. The P2 (6%) formulation was identified as the most optimal treatment, as it enhanced crude protein content while maintaining crude fiber levels within acceptable limits.

These results reinforce the principles of integrated and circular agriculture, where agro-industrial waste is no longer viewed as a low-value residue but rather as a valuable resource capable of improving livestock production efficiency. Therefore, the optimal utilization of carrot waste flour not only improves feed quality but also contributes to waste reduction, feed cost efficiency, and the long-term sustainability of agricultural systems.

## CONCLUSION

The inclusion of carrot waste flour significantly influences the nutritional composition of broiler diets, particularly crude protein and crude fiber contents. Among the evaluated treatments, a 6% inclusion level was identified as the optimal formulation, as it maximized crude protein content while maintaining crude fiber within acceptable limits for broiler nutrition. Future research should extend this work by evaluating animal performance, nutrient digestibility, and economic feasibility to strengthen the scalability and practical implementation of carrot waste-based feed formulations under diverse production conditions.

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