Dietary Dried Orange Pulp as a Functional Feed Ingredient to Improve Broiler Chicken Productivity

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Abstract

Dried orange pulp (DOP), a by-product of the fruit processing industry, is a valuable source of nutrients such as flavonoids, isoflavones, and flavones, with potential applications in animal and poultry nutrition. The present study aimed to evaluate the effects of incorporating dried sweet orange by-products (DOP) into broiler diets on growth performance, serum metabolites, and antioxidant status. A total of 200 broiler chicks (15 days old) were randomly assigned to four dietary treatments in a completely randomized design. Each treatment included five replicates of 10 birds. The treatments consisted of a control diet (0% DOP) and three experimental diets in which corn was partially replaced with 5%, 10%, or 15% DOP during the grower and finisher periods. Body weight (BW), feed conversion ratio (FCR), and carcass characteristics were recorded. Broilers fed increasing levels of DOP exhibited significantly improved FCR compared to the control group ($P < 0.05$), along with higher BW in the 5%, 10%, and 15% DOP groups ($P < 0.05$). Eviscerated carcass yield (% of live body weight) was statistically similar across groups ($P = 0.057$). However, abdominal fat was significantly reduced by 22% in broilers fed 15% DOP ($P < 0.001$), and liver yield was significantly higher in the 10% and 15% DOP groups compared to the control ($P < 0.05$). These findings suggest that dietary inclusion of DOP can enhance growth performance and carcass traits in broiler chickens, supporting its potential as a sustainable feed ingredient.
Key Words: *Broilers, Dried orange pulp, Feed Conversion Ratio, Liver, Eviscerated carcass yield*

Introduction

Broiler chicken meat production is a rapidly expanding industry, primarily due to the fast growth rate of chicks, the availability of high-quality meat at relatively low prices, and the birds' quick response to dietary modifications. Traditionally, antibiotics have been extensively used in poultry diets to prevent disease and enhance growth performance. However, there is a growing global movement toward reducing or eliminating antibiotics in poultry feed, driven by concerns over antibiotic residues in meat and the emergence of antimicrobial resistance (Alzawqari et al., 2016).

In recent years, the use of essential oils and aromatic herbs as feed additives has gained considerable attention in poultry nutrition, serving as natural alternatives to antibiotic growth promoters. Among these, *Citrus sinensis* (sweet orange) stands out as the most widely cultivated citrus species globally, valued for its high content of bioactive compounds and dietary fiber (Nieto et al., 2021). Oranges are consumed in various forms fresh, peeled, or processed into juice—contributing significantly to global citrus production. Notably, orange cultivation accounts for approximately 54.84% of the world's total citrus output, followed by mandarins (24.70%) and grapefruits (6.47%) (Nieto et al., 2021). Algeria alone contributes over 2% to global citrus production, with the orange juice industry generating approximately 390,000 tons of by-products annually (Lagha-Benamrouche and Madani, 2013). These by-products, if appropriately valorized, represent a promising source of nutritional and functional feed ingredients for poultry.

The incorporation of non-conventional feedstuffs such as fruit processing by-products represents a strategic approach to reducing animal feed costs. These alternative ingredients are typically inexpensive, readily available, and nutritionally valuable, contributing to enhanced feed intake and animal performance. The continuous rise in the prices of conventional feed components, particularly corn and soybean meal, combined with the European Union's ban on antibiotic growth promoters (Alzawqari et al., 2016), has intensified the search for sustainable and effective alternatives in animal nutrition. In this context, the valorization of citrus by-products—particularly those derived from juice production has emerged as a promising avenue within the framework of sustainable agriculture. Citrus co-products, mainly composed of peel and pulp, are rich in bioactive constituents including dietary fibers (e.g., pectin, cellulose, hemicellulose), essential minerals (e.g., potassium, calcium, magnesium), organic acids (e.g., citric, oxalic, malic acids), vitamins (notably vitamin C), and various phenolic and flavonoid compounds such as hesperidin and narirutin (Seidavi et al., 2018). Despite their potential, limited studies have investigated the effects of dried orange pulp (DOP) on growth performance in broiler chickens.Therefore, the objective of the present study was to evaluate the effects of incorporating optimal levels of dried orange by-products into broiler diets on growth performance, and carcass characteristics during the first six weeks post-hatch.

Materials and Methods

The study was conducted from March to June 2021 at the experimental facilities of the Higher School of Agronomy in Mostaganem, Algeria.

Preparation of Dried Orange Pulp (DOP): Fresh *Citrus sinensis* residues, obtained from a local juice processing facility in Algeria, were processed into dried orange pulp following the procedure described by Readh et al. (2023). The citrus residues including peel, pulp, and seeds underwent to dehydration process. The material was spread in a ventilated greenhouse equipped with air extractors and exposed to direct sunlight for 72 hours. This drying method ensured adequate aeration and minimized the risk of mold development. The sun-dried material was subsequently ground using a 1 mm mesh sieve to produce a fine powder suitable for broiler feed formulation. The dried orange pulp was then stored in opaque, airtight plastic bags at a temperature of 15–22°C in a dry environment until use.

Animals, Diets and Experimental design : At the start of the trial, the brooding temperature in the experimental broiler facility was maintained at approximately 32–34 °C. Beginning on day 4, the temperature was gradually reduced by 0.5 °C per day until reaching a stable level of 20–22 °C, which was maintained for the remainder of the experiment. Relative humidity was controlled within a range of 60–70%. The birds were reared under optimal environmental and hygienic conditions. The poultry house was equipped with a thermostatically controlled ventilation system and cross-ventilation to ensure adequate air circulation. A lighting program was implemented in accordance with the *Arbor Acres* commercial broiler management guide. For the first 21 days, a 23:1-hour light-to-dark cycle was applied, followed by a 22:2-hour cycle from day 22 until day 49.

At 15 days of age, all birds were individually weighed and randomly assigned to four dietary treatment groups. Each treatment consisted of five replicates (floor pens) with 10 birds per replicate. The dietary treatments included: a control diet formulated without feed substitution, and three experimental diets in which corn was partially replaced with 5%, 10%, or 15% dried orange pulp (DOP). The composition and nutrient contents of the experimental diets are presented in Table 1.

Table 1. Ingredients and nutrients composition of different diets

	Control	DOP5%	DOP10%	DOP15%
Corn grains	67,00	62,00	57,00	52,00
Soybean meal	27,00	27,00	27,00	27,00
Wheat bran	4,00	4,00	4,00	4,00
DCP	1,00	1,00	1,00	1,00
Vit-Min Premix	1,00	1,00	1,00	1,00
Dried Orange pulp	0	5,00	10,00	15,00
Metabolizable Energy (kacl/kg)	3121.49	3140.41	3162.50	3187.45

***Vitamin-mineral premix:** Provided (in mg kgG1 of diet), Vitamin E: 6, Vitamin K3: 0.80, Vitamin B1: 1, Vitamin B2: 3, Pantothenate of Ca: 6, Vitamin B6: 1.5, Vitamin B12: 0.006, Folic acid: 0.2, Nicotinic acid: 12, Copper: 5, Cobalt: 0.65, Manganese: 65, Zinc: 65, Selenium: 0.25, Iron: 50, Iode: 0.8, Magnesium: 100. Abbreviations; EM: Metabolizable energy, C: Control diet, CO: Canola seed diet, SFA: Saturated fatty acids, MUFA: Monounsaturated fatty acids, PUFA: Polyunsaturated fatty acids, **DCP:** Calcium + Phosphore, **ME:** Metabolizable Energy.

Sampling and Data Collection

Performance Measurement: Body weight (BW) and feed conversion ratio (FCR) were measured during each phase of the rearing period. Each treatment group consisted of 10 broiler chickens. Feed intake and body weight data were used to calculate FCR as the ratio of feed consumed to body weight gain.

Slaughter Measurements: After 49 days of rearing, ten birds per group were randomly selected based on the average weight of the group and slaughtered. After 8 hours of fasting for total stomach evacuation, these animals were used for measuring carcass yield. Various parts of the carcasses were dissected and weighted separately. The collected carcass parts included liver, and abdominal fat. The relative weights of these organs were also expressed as a percentage of live body weight. Carcass yield was calculated by subtracting eviscerated (liver, heart, gizzard and spleen) weight from the carcass weight.

Stastical Analysis
For determination of the statistical significance of the results, appropriate parametric test ANOVA were used. The results were presented as text and tables as mean values and standard error of mean (SEM). Data were statistically analyzed by SPSS statistical software (IBM SPSS version 26). The statistical comparison was made by Tukey test at the 95% probability level.

Results and Discussion

The results of the experimental trial on broiler performance, and carcass characteristics are summarized in Tables 2–4.
Table 2 presents the effects of incorporating varying levels of dried orange pulp into broiler diets on growth performance parameters, including body weight (BW) and feed conversion ratio (FCR), throughout the rearing period. Broilers fed diets containing 5%, 10%, and 15% DOP exhibited improved body weights by day 49 compared to those in the control group. Notably, the 5% DOP group showed an increase in live body weight of over 12% relative to the control group at the end of the rearing period.
In terms of feed efficiency, the inclusion of DOP led to a reduction in FCR values. Specifically, FCR decreased by approximately 6% and 9% in the 5% and 10% DOP groups, respectively, when compared to the control.

Table 2. Effect of dried orange pulp on the performance of broiler chickens

Item	**Treatments**				**SEM**	**p value**
	Control	**5% DOP**	**10% DOP**	**15% DOP**		
Starter period of Postnatal 1st–21st day						
BW (g/chick/duration)	715^{a}	850^{c}	830^{bc}	785^{a}	17.26	0.00002
FCR	1.15^{bc}	1.05^{a}	1.10^{ab}	1.20^{c}	0.12	0.00009
Grower period of Postnatal 21st–35st day						
BW (g/chick/duration)	1920^{bc}	1960^{b}	1925^{bc}	1910^{a}	19,72	0,07
FCR	1.65^{a}	1.70^{a}	1.95^{a}	1.85^{a}	0.41	0.10
Finisher period of Postnatal 35st–49st day						
BW (g/chick/duration)	2905^{a}	3325^{c}	3075^{bc}	3005^{b}	29.94	0.00015
FCR	2.50^{a}	2.35^{a}	2.25^{a}	2.40^{a}	0.22	0.16

^{abc} Means in each column with no common superscript differ significantly at ($p < 0.05$). (n=10).
Abbreviations: BW: body weight, FCR: feed conversion ratio, SEM**:** standard error of the means
DOP: Dried Orange Pulp

Although no statistically significant differences were observed during the finisher phase (35–49 days), broilers fed DOP diets demonstrated numerically better FCR values, indicating enhanced feed efficiency.
Overall, the incorporation of dried orange by-products contributed to improved body weight gain and feed utilization in broiler chickens.

Table 2. Effect of dried orange pulp on the performance of broiler chickens

Item	Treatments				SEM	p value
	Control	5% DOP	10% DOP	15% DOP		
Carcass yield (%)	76.7^{a}	75.7^{a}	73.3^{a}	78.5^{a}	2.66	0.16
Abdominal fat (%)	1.12^{c}	0.97^{b}	0.96^{b}	0.82^{a}	0.15	< 0.001
Liver yield (%)	2.30^{a}	2.32^{a}	2.35^{a}	2.85^{b}	0.13	0.0005

^{abc} Means in each column with no common superscript differ significantly at (P < 0.05). (n=10).
Carcass yiled % : percentage relative to the whole carcass, abdominal and liver yield % were relative to carcass.
SEM**:** standard error of the means
DOP: Dried Orange Pulp

Eviscerated Carcass Weight and Yield: showed no significant differences (P = 0.057).
Abdominal Fat Yield: was lower in broilers fed dried orange by-products compared to controls (P < 0.001). Control chickens had 1.12% abdominal fat relative to eviscerated weight, whereas those fed 15% DOP showed a 22% reduction.
Liver Yield: broilers in the 10% and 15% DOP groups exhibited significantly higher liver yields than controls (P < 0.05). The average liver weight in the 15% DOP group increased by ~25% compared to controls. Additionally, liver yield (% of carcass) rose proportionally with dietary DOP inclusion, highlighting its stimulatory effect on hepatic tissue mass, particularly at the highest inclusion level.

Discussion

Our findings align with those of Parobali et al. (2024), who reported significant improvements in body weight gain and feed conversion ratio (FCR) in broilers fed 0.25%, 0.5%, and 0.75% *Citrus sinensis* seed at days 21 and 49. Similarly, Ahmad et al. (2024) found that supplementing quail broiler diets with 0.5, 1, and 1.5 mL/kg of dried *C. sinensis* peel methanolic extract improved FCR and weight gain, with the DCSP1.5 group showing the best performance.
Our results are consistent with those of Vlaicu et al. (2020), who reported significant improvements in broiler growth and FCR following supplementation with orange pulp or *Citrus sinensis* essential oil. The enhanced FCR observed in our 5% DOP group during days 1–21 and 35–49 aligns with findings by Abbasi et al. (2015), where dried orange pulp positively influenced weight gain. Improvements at 5% and 10% inclusion levels may be attributed to the high content of soluble carbohydrates, organic acids, and bioactive flavonoids (e.g., hesperidin, naringin), known to promote digestive enzyme activity and gut health (Kamboh and Zhu, 2013; Jiang et al., 2020). Ahmad et al. (2024) also linked weight gain to the citric acid in orange peel, which, through its antimicrobial action and low pH, suppresses harmful gut microbes, reduces toxicity, improves protein digestion and energy utilization.
Our findings align with Pourhossein et al. (2015), who reported a significant increase in liver weight following the addition of orange peel essential oil to broiler diets. Similarly, Goliomytis et al. (2015) observed increased liver yield in broilers fed orange pulp-based diets rich in naringin. The reduction in abdominal fat in our study corroborates results from Abd El Latif et al. (2023) and Ahmed (2022), who found that dried lemon pulp supplementation (0.5–1%) lowered fat deposition. Likewise, Abbasi et al. (2015) and Ebrahimi et al. (2014) showed that dried orange residues and orange peel extract reduced abdominal fat. Naringin, a citrus flavanone, may modulate lipid metabolism and reduce fat accumulation (Guo et al., 2016), while organic acids such as citric acid enhance lipid metabolism (Fik et al., 2021) and lower intestinal pH, potentially influencing fat storage (Pourhossein et al., 2012). Moreover, fruit-derived flavones reduced abdominal adipose tissue weight (Ma et al., 2015), although Basir and Toghyani (2017) found no significant effect with dried lemon pulp.
Croze et al. (2015) proposed that citrus compounds may reduce fatty acid synthesis in adipose tissue. Polyphenols inhibit lipase activity (Kang et al., 2012), hepatic lipogenesis (Saha et al., 2019), and fat absorption. Phytosterols also exert hypolipidemic effects by modulating lipid metabolism in hepatocytes (Dossou et al., 2018; Kesbiç et al., 2020). Furthermore, AMPK activation inhibits lipogenesis by downregulating fatty acid synthase, serving as a metabolic regulator for energy homeostasis (Pu et al., 2012).

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