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The Valorization and Potential Applications of Orange Byproducts and Waste in Poultry Feeding: A Review

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ABSTRACT

Some chemicals have been utilized as a feed additive and growth stimulator to boost poultry performance in recent decades. Cereals have been one of the most extensively utilized feed in the rearing period of broiler chickens but due to their highly price it can present an economic consequence and some limitations of their use, alternatives such as orange byproducts have been recommended. In the second point there is a large utilization of growth stimulants during the rearing period of broilers, but due to the adverse consequences of antibiotic resistance and the limitations of their use, alternatives such as probiotics, prebiotics, plant essential oils, essences and by-products have been recommended. Orange waste can be found in abundance in some parts of the world. Aldehydes, esters, terpenes, alcohols, ketones, carotenoids, nobiletin, pectin and bioflavonoids such as hesperidin and naringenin are among the volatile substances found in orange waste. The practical applications of orange by-products and pomace in chicken feeding are presented in this review paper. This review presented the effects of orange waste and by-products on chicken performance and carcass components.

Key words: Feed additive, Orange, Peel, Pomace.

Orange waste are rich in pectin, cellulose, hemicellulose, pigment, dietary fiber, oil and they contain several bioactive compounds such as flavanones, flavones, flavanols and phenolic acids (Mohanta *et al*, 2021). Including orange wastes into poultry feed can assist to reduce waste and environmental pollution. The use of agro-industrial by-products could be a potential solution to the high cost of feed components, which leads to high production costs, because some can be obtained at a low cost (Orayaga *et al*., 2015). The orange accounts for more than 61% of global citrus fruit production. Some of varieties include pigmented or blood oranges, common oranges and navel oranges (Stinco *et al*., 2016).

Essential oils, flavonoids, carotenoids, saponins, phenolic compounds, tannins, quinones, coumarin, lectin, polypeptides, insoluble non-starch polysaccharides and oligosaccharides had all been shown to improve the immune system and poultry performance (Azizi *et al.* 2018).

A significant part of the world harvest of citrus is destined to production of citrus juices, generating tons of residues formed by peel (constituted by flavedo and albedo, the non-edible parts of the fruit) and seeds. Industrial orange juice extraction generates substantial quantities of waste. Citrus peel and pulp contain a significant amount of crude protein, metabolizable energy, phenolic compounds, ascorbic acid, pectin, coumarin and flavonoids and the peel are a rich source of antioxidants used in the food, cosmetics and pharmaceutical industries (Abbassi *et al*., 2015).

In this connection, the purpose of this paper is to show findings and applications of agricultural orange wastes in poultry diets.

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I. Chemical composition of orange waste

Orange by-products are generated during the processing of oranges for juice production and include orange pulp, peels and seeds. However, in general, orange by-products are high in fiber, carbohydrates, minerals and contain moderate amounts of protein and fat. The peel and seed presented the majority of the waste, accounting for around 50-60% of the overall yield (Negro *et al*., 2017). The chemical composition of *C. sinensis* peel L. powders are represented in (El-Beltagi *et al*., 2022), contains ash (3.0%), fiber (13.3%)

and total carbohydrates (33.55%). On the other hand, it includes 9.18% of moisture, 6.72% of crude protein and 3.52% of crude fat. Teixeira *et al*. (2020) studied the composition of orange pulp and peel. In comparison to the peel, the pulp had a greater moisture content ($P<0.05$). Total dietary fiber (TDF), soluble dietary fiber (SDF), total caloric value, ascorbic acid, carotenoids and phenolic components were all higher in Orange Peel (Table 1).

The chemical composition and metabolizable energy concentration of orange by-products include two varieties of orange pulp (clementine and orange). For instance, the crude protein content ranged from 7.3 g/kg DM in clementine to 110 g/kg DM in orange pulp and the ME concentration ranged from 9.1 MJ/kg DM in the second orange pulp to 11.7 MJ/kg DM in the first orange pulp. Additionally, the study noted that orange pulps are high in ether extract, while clementine pulp is high in non-structural carbohydrates. Finally, it mentioned that citrus pulp (clementine) is high in organic matter (García-Rodríguez *et al*., 2019). Another two studies utilized orange peel and their respective compositions. In the first study by (Pourhossein *et al*., 2019), the orange peel had a composition of 88.00% dry matter, 5.46% protein, 1.10% calcium, 0.05% phosphorous, 7.00% ash, 63.54% carbohydrate, 2.00% ether extract and 10.0% Fiber. The second study by (Akpe *et al*., 2019) showed that the biodegraded sweet orange peel had a composition of 7.18% crude protein, 12.76% crude fiber, 2.70% ether extract, 7.50% ash and 2648.82 kcal ME/kg.

Sunmola *et al*. (2018) provided a characterization of sweet orange peel meal (SOPM) and corn. The crude protein content of sweet orange peel meal (*Citrus sinensis*) was 8.20%. The peel has 13.30% crude fiber which was higher than 2.20% CF recorded for corn. Both SOPM and corn have similar energy levels. Agu *et al*. (2010), reported a value of 89.65% of dry Matter, 10.74% CP, 7.86% ash, 11.90 per cent CF and 3988.70 kcal/kg ME for sun-dried sweet orange peel meal.

II. Nutritional composition of orange byproducts

Orange is a valuable source of vitamins, minerals and phytochemicals. The production of oranges generate significant amounts of waste, including pulp, peel and seeds. In oranges, the peel and seed presented the majority of the waste, accounting for around 50-60% of the overall yield (Negro *et al*., 2017). Orange peel is a rich source of dietary fiber, including pectin, cellulose and hemicellulose, which contains a variety of bioactive compounds, including flavonoids, carotenoids and limonoids. The major flavonoids found in orange peel are hesperidin and narirutin, which have been shown to have antioxidant and anti-inflammatory properties and essential oils are all regarded possible nutritious components in citrus peels (Ebrahimi *et al*., 2013). Soluble sugars and insoluble polysaccharides are abundant in orange peels. Orange peel consists of sugars (30-40%), pectin (15-25%), cellulose (8-10%) and hemicellulose (5-7%) (Grohmann *et al*., 1995).

El-Beltagi *et al*. (2022), showed that the methanolic extract had the highest total phenolic content and contained the major flavonoids compounds (naringin and hesperidin). The water and methanolic extracts also contained higher concentrations of total flavonoids and showed higher antioxidant activity than the ethanolic extract. In addition, the concentrations of total flavonoids content were about 22.2 and 15.7 mg QE/g in water and methanolic extract of the orange peel, respectively.

The results in this study indicated that antioxidant activity by DPPH was higher in the water and methanolic extract of *C. sinensis* peel than in ethanolic extract. Teixeira *et al*. (2020) concluded that orange peel had a higher antioxidant capacity than orange pulp. This study indicated that orange pulp had a higher value (31.15 mg GAE 100 g^{-1}) of phenolics compounds contrary to orange peel (11,75 mg GAE 100 g^{-1}).

The fresh orange peel extract presented a total phenolic content of 27.14±0.23 mg GAE/g of extract, regarding the flavonoid content was estimated to be 86.82±1.82 mg QE/g of extract and an approximate tannins content of (28.50±6.80 mg TE/g of extract). While, the concentration of phenolic compounds were (3.64±0.09 mg GAE/g of extract), flavonoids (59.94±0.06 mg QE/g of extract) and tannins (8.00±0.33 mg TE/g of extract) in dried peel extract (Oikeh *et al*., 2020). The results obtained in (Casarotti, 2018) study reported that orange byproducts had a (39.14 µg β-carotene/g and 18.51 µg lycopene/g. Regarding the bioactive compounds the results demonstrated that orange byproducts had phenolics compounds (420.89 mg GAE/100 g) and a good potential antioxidant product (11.38 µmol TE/g).

The levels of phenolic compounds and antiradical activity varied significantly depending on the variety of orange and the plant part studied. In the same line, a study conducted by (Lagha-Benamrouche *et al*., 2013) examined seven varieties of oranges from Algeria and analyzed the presence of phenolic compounds in their peels and leaves. The Bigarade variety peel had the highest levels of total phenols and the greatest ability to reduce the oxidation rate of linoleic acid and carotene, followed by Portugaise. The total phenol contents of orange peels ranged from 9.608 to 31.623 mg GAE/g DM.

Table 1: Proximate composition of orange byproducts.

Material	Chemical composition (g/100 g dw)					Reference
	Dry matter	Crude protein	Ash	Carbohydrate	Crude fiber	
Orange peel	88.00	5.46	7.00	63.54	10.00	Pourhossein *et al.*, 2019
Orange pulp	89.24	0.83	0.41	9.47	2.35	Teixeira *et al.*, 2020
Orange byproducts		5.23	2.73	24.40	58.20	Casarotti *et al.*, 2018
C. sinensis peel	88.0	5.46	7.00	63.54	10.0	Ebrahimi *et al.*, 2013

III. Orange byproducts as feed ingredients for broiler chickens

III.1. Effect of orange byproducts on broiler chicken performance

The study of Majekodunmi *et al*. (2021) revealed the effects of supplementing drinking water with sweet citrus peel powder (SCPP) on the performance, ileal microbial count and relative weight of organs of broiler chickens. The results showed significant variations were observed in the final weight and feed conversion ratio (FCR) with birds in 6 g SCPP having the highest final weight and the lowest FCR compared with the control group. Significant variations were observed in the live weight and relative weight of heart and pancreas. Overall, the study indicates that SCPP has a positive effect on the performance and ileal microbial count of broiler chickens, as evidenced by higher live weight with lower FCR and TBC recorded in the treatment groups. The addition of 2% Orange pulp supplement to the experimental diets differed from the control diet. The OP group had a substantial rise in body weight (Vlaicu *et al*., 2020) (Table 2).

Aydin *et al*. (2018) found that giving broiler chicks different doses (50, 100, or 150 mg/kg) of essential oil extracted from *Citrus sinensis* L. resulted in significant benefits in terms of live weight, feed intake, feed efficiency and carcass features. Additionally, all the treatment groups (50, 100 and 150 mg/kg OPEO) gained significantly more weight than the control group. The heart and abdominal fat yields presented a significant effect among the groups. Abbassi *et al*. (2015) reported that the feeding of dried orange pulp boosted feed intake and body weight while lowering liver weight and abdominal fat weight in broiler chicks.

Further, Siyal *et al*. (2016) investigated the effects of different levels of orange (1.5% and 3.0%) and banana peels (1.5% and 3.0%) on the growth of broilers. The results showed that the higher (3687.82 g). Live body weights were obtained in the group birds fed with 1.3% orange peels compared to the control group. The addition of fruit peels in the feed had a significant impact on the liver, spleen and heart weights of broilers, with an increase in weight observed in the experimental groups. Agu *et al*. (2010) and Alzawqari *et al*. (2016) indicated that supplementing sweet orange peel and lemon grass leaf may not be an effective strategy to enhance the performance and quality of broiler chickens. Further, Oluremi *et al*. (2006) reported that sweet orange peel could be included in broiler feed at a rate of 15% without negatively affecting the bird performance.

Pourhossein *et al*. (2015) concluded that feeding sweet orange peel extract to broilers had no influence on bursa of Fabricius and spleen weight. Seidavi *et al*. (2015) and Ebrahimi *et al*. (2014), found that the addition of 1000 and 1250 mg/l of orange peel extract during two periods (1-21 and 1-42 days of age) resulted in improved weight gain and a lower feed conversion ratio for broiler chickens.

Similarly, Abbasi *et al*. (2015) and Ebrahimi *et al*., (2015) found that supplementing (DOP) significantly increased feed intake and weight gain during the grower period while

Table 2: Summary of findings on effects of orange by-products on poultry carcass.

Use	Poultry	Findings	References
Essential oil of (*Citrus sinensis*)	Broiler chickens	The OPEO supplement had significantly higher carcass weight than the control group. The carcass weight appears to increase as the dose level is increased. The heart weights presented significant results among the groups.	Aydin *et al*., 2018
Sweet orange peeland lemon grass	Broiler chickens	The supplementation with SOP, LGL or the combination of SOP and LGL, there were no significant variations in carcass dressing percentage and relative weight of the liver, gizzard, spleen, heart and bursa.	Alzawqari *et al*., 2016
SOP and LGL	Broiler chickens	The use of dried orange pulp boosted feed intake and body weight while lowering liver weight and abdominal fat weight.	Abbassi *et al*., 2015

reducing liver and abdominal fat yields. However, the supplementation with 3% DOP reduced feed intake, weight gain, and increased FCR during the starter and growing period (Ebrahimi *et al*., 2013). The supplementation of sweet orange pomace at 30% resulted in a substantial decrease in feed intake, final live weight, weight gain and increased FCR in broiler chickens with or without fermentation (Oluremi *et al*., 2010).

III.2. Effect of orange byproducts on poultry blood constitutes

Fafiolu *et al*., (2020) showed that the combination of lemon peel and orange peel in broiler diets led to higher levels of total protein and albumin in the birds and reduced levels of serum creatinine, uric acid and liver enzymes (AST and ALT) activity in the broilers. Furthermore, higher levels of HDL and lower levels of total cholesterol, LDL and triglycerides were also noticed. Akpe *et al*. (2019) aimed to investigate the effect of biodegraded sweet orange peel (SOP) on the hematological and serum biochemical markers of broiler chickens. The researchers milled and substituted dietary maize in the control diet with dried SOP at varying concentrations ranging from 2% to 10%. The results showed that the dietary substitutions had a significant impact on certain parameters, including globulin, cholesterol, and serum glutamic oxalaacetic transaminase (SGOT) levels. Specifically, as the amount of SOP in the diet increased, globulin levels also increased and Cholesterol levels were decreased (Table 3).

In the study of (Ebrahimi *et al*., 2016), the effect of dried orange peel (DOP) on the plasma components of broiler chickens during the starter and grower periods was evaluated. The researchers examined varying quantities of DOP (0, 1.5 and 3%) in a meal and found that the inclusion of DOP presented a reduction in cholesterol and triglycerides. Interestingly, feeding the chickens with 3% DOP for 42 days also led to a considerable decrease in plasma glucose levels. However, there was no significant change observed in alkaline phosphatase (ALP) activity or uric acid. Alzawqari *et al*. (2016) investigated the effect of dietary supplementation with different levels of sweet orange pulp and Lemon grass leave on the plasma concentrations in broiler chicken. The results showed that the supplementation with 0.8% of SOP or 0.8% SOP and LGL significantly increased the concentration of total protein. Moreover, the concentrations of Serum Glucose, LDL, VLDL and TG levels dropped considerably in the xperimental groups, while the levels of Cholesterol and HDL dropped only in the group supplemented with 0.8% SOP compared to the other groups.

In the experiment conducted by Ebrahimi *et al*. (2015), the supplementation of orange pulp with (0, 5, 1, 1, 5 and 2%) in broilers feed showed no influence on blood components. The findings are similar to those reported by (Abbasi *et al*., 2015), who found that dietary treatment with *C. sinensis* pulp reduced LDL, HDL and triglycerides in broilers. These findings matched those of (Nobakht *et al.*,

Table 3: Summary of findings on effects of orange by-products on poultry blood constituents.

Use	Poultry	Findings	References
Orange peel and grape peel	Broiler chicken	After the addition of GP and OP to broiler diets, serum creatinine, uric acid and liver enzymes (AST and ALT) activity were lowered and the broilers fed with GP and OP had higher HDL levels and lower total cholesterol, LDL and triglycerides.	Vlaicu *et al.*, 2020
Orange peel	Broiler chickens	Cholesterol levels dropped as the amount of SOP in the diet increase. The increase of SOP incorporation in diets had no consistent effect on SGOT.	Akpe *et al.*, 2019
Dried orange peel	Broiler chickens	The reduction of cholesterol, low density lipoprotein (LDL) and triglycerides (TGL) levels, but had no effect on high density lipoprotein (HDL).	Ebrahimi *et al.*, 2016
C. sinensis pulp	Broiler chickens	Reduction of LDL, HDL and triglycerides in broilers but had no effect on blood Glu and Chol.	Abbasi *et al.*, 2015

2013), who discovered that dried citrus pulp had beneficial benefits on lowering blood cholesterol and LDL. Higher doses of Lemon Pulp and Orange Pulp were likewise observed to lower AST activity without affecting blood creatinine levels (Akbarian *et al*., 2013).

III.3. Effect of dried orange pulp on poultry peroxidation status

III.3.1. Effect on poultry meat peroxidation

The addition of 50 g/kg of orange pulp and 0.15 ppm of organic Se to the diets of broiler chicks increased the oxidative stability of breast meat during storage. The synergistic effect of the OP and organic Se implies that supplementing with the citrus industry's byproduct, which is high in natural antioxidants and Se, promotes both the first-line enzymatic and second-line nonenzymatic antioxidant defense mechanisms, extending product shelf life (Zoidis *et al*., 2022).

Faiz *et al*. (2017) described that the supplementation of meals by citrus processing waste has an influence on lowering TBARS of broilers meat. As the amount of citrus waste supplemented in broiler feed grew, the DDPH activity was highest than control broiler meat. The broilers fed a 10% citrus waste (CW10) resulted in the highest ABTS activity of meat compared to control diet (CW0). Dietary dried tangerine peel extract at 80 or 160 mg/kg may improve the immune and antioxidant status of broiler chicks in a normal feeding environment without stress challenges (Jiang *et al*., 2016).

III.3.2. Effect on poultry blood peroxidation

Faiz *et al*. (2017), showed that birds fed a diet supplemented with 10% citrus waste (CW10) had the highest levels of serum superoxide dismutase, catalase and glutathione peroxidase. This suggests that natural antioxidants in citrus waste can improve the activity of antioxidant enzymes in broilers. Additionally, the study found that serum catalase increased significantly in the groups treated with orange waste compared to the control group and serum glutathione peroxidase also increased significantly in the treatment groups.

Alzawqari *et al*. (2016) evaluated the effects of different levels of dried Citrus sinensis peel (DCSP) on selected plasma constituents of broilers. The findings showed that incorporating SOP alone or in combination with LGL in the meals during the grower phase positively modified several antioxidant statuses.

IV. Effect of Feeding dried orange waste on humoral response of broiler chickens

The broiler chicken fed with a diet containing 3% DCSP for 1-42 days had the lowest average IgG titer. On the other point, average anti-AIV (Anti-avian influenza) titers on days 14 and 28 were significantly different among treatments, with the control. Citrus peel does not improve the immune response of broilers to all infections, according to the findings and its activity is selective. On days 14 and 42, average anti-IBD (Anti-infectious bursal disease) titers were significantly different between treatments. The average white blood cell, heterophil, lymphocyte and monocyte counts, as well as the heterophil/lymphocyte ratio, were significantly different among treatments (Pourhossein *et al*., 2019).

Abdulameer (2019), concluded that broiler chickens that were fed with vitamin C or Sweet orange pulp exhibited higher primary and secondary antibody responses to sheep red blood cells (SRBC) and against phytohemagglutinin (PHA-P) antigen compared to the control group. The use of Sop and vitamin C led to an increase in antibody titer against Newcastle disease during the secondary antibody response. Furthermore, the results indicate that the inclusion of 2% Sop during the grower period had a positive effect on the growth performance of broiler chickens under heat stress.

Antibody titer against influenza disease virus and sheep red blood cells decreased when using dried lemon pulp at 7.5 and 10% in broilers diets (Basir *et al*., 2017).

Pourhossein *et al*. (2015) investigated the immune system of broiler chickens at varied amounts of sweet orange extract in drinking water (0, 1000, 1250 and 2000 mg/l). The treatment comprising 1250 mg/l dried orange peel extract had the largest number of red blood cells (RBC), immunoglobulin G (IgG) and immunoglobulin M (IgM) levels. Orange extract boosted white blood cells (WBC) concentration and lymphocytes while decreasing heterophil percentage and the heterophil to lymphocyte (H: L) ratio in broilers. Furthermore, flavonoids in dried orange extract boosted the humoral immune system of chickens by boosting IgG and IgM antibodies. Dietary SOPE had a substantial effect on serum components, raising the amounts of WBC and lymphocytes while decreasing the percentage of heterophils. This study demonstrated that supplementing sweet orange peel extract increased immune response and disease resistance.

Pourhossein *et al*. (2012) investigated the effects of addition 1.5 and 3.0% dried orange peel to broiler diets on the microbial population of the gastrointestinal system. At the age of 42 days, there was no significant difference between the treatments in terms of mean ileum and caecum Lactobacillus spp. The addition of dried Citrus sinensis to the broiler diet improved some immune responses, but these effects were insufficient to protect the birds from infections such as infectious bursal disease, infectious bronchitis, Newcastle disease, or avian influenza.

CONCLUSION

Fruit by-products that are discarded have been shown to have a lot of potential for extracting valuable components including pectin, bioactive chemicals and other phytochemical substances. As a result, innovative scientific approaches to replace traditional extraction techniques for extracting these chemicals from fruit waste are needed.

According to all of these studies, orange waste and by-products can be used as supplements for poultry diets. The amount must be carefully examined and monitored to ensure that product quality and performance of the birds is not compromised. It is possible to generate a healthy, antibioticfree product with no hazardous residues for humans by employing suitable levels of orange waste and by-products in chicken diets. This procedure also reduces the coproducts of orange processing process. The cost of poultry feed will be reduced and poultry producers will profit.

Conflict of interest: None.

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