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A review on practical applications of *Citrus sinensis* by-products and waste in poultry feeding

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Abstract In recent decades, in order to improve livestock and poultry performance, some compounds have been used as a feed additive and growth stimulator. Some of the most widely used growth stimulants have been antibiotics but, due to the harmful effects of antibiotic resistance and the limiting of their use, alternatives have been suggested such as probiotics, prebiotics, plant essential oils, essences and by-products. The orange is one of the earliest fruits used by humans. Orange by-products and waste are found extensively in some parts of the world. Orange waste contains ascorbic acid, phenolic compounds, coumarin and several volatile compounds, some producing orange aroma:aldehydes, esters, terpenes, alcohols, ketones, carotenoids (beta-carotene, lutein and beta-cryptoxanthin), nobilitin, pectin and bioflavonoids including hesperidine, naringenin and hysteritine. This paper reviews the practical applications of orange by-products and waste in poultry feeding. Advantages and disadvantages of effects of orange waste and by-products on poultry (broiler, laying hen, quail, etc.) performance, carcass components, immunity, blood constitutes, and gastrointestinal microflora are reviewed and discussed.

Keywords Orange · Pulp · Peel · Extract · Concentrate · Poultry · Dietary supplement · Feed additive

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Introduction

In recent years, in order to raise animal production efficiency, feed additives and growth promoters such as antibiotics have been widely used in poultry rations, but the harmful effects of these compounds have been identified (Yang et al. 2009) and they are being replaced by natural additives and supplements. Farmers prefer to use compounds that are healthy for the poultry and have no side effects for humans (Ellin-Doyle 2001). Among the substances introduced in place of antibiotics are probiotics, prebiotics, synbiotics, essential oils, plant extracts, agricultural wastes, etc. (Frank 1994).

Plants and their effective compounds have played a major role in improving human welfare, including health, for thousands of years. These herbal compounds include plant extracts and their active but natural and harmless compounds (Liu 1999). The term "plant additives" known as "botanicals" and "phytobiotics" are commonly referred as plant materials,

derived from plant sources and included into diet for improvement of the nutrition in humans and other animals. Phytobiotic additives can be the whole plant, its parts, or essential oil and extracts. Compared with synthetic antibiotics and chemical substances, compounds derived from plants can be ideal dietary additives for poultry and other farmed animals (Peric et al. 2009).

Phytobiotics (Yang et al. 2009) and other active substances of plants may occur in some or all parts of the plant. Some have therapeutic medicinal properties. These substances, mainly derived based on secondary metabolism and low molecular weight, include glycosides, alkaloids (lactones, esters, ethers, ketones, aldehydes and alcohols), polyphenolic and phenolic compounds (coumarins, tannins, flavones and quinones), terpenoids (steroids and sesquiterpenes), flavonoids, oil essences, mucilages, saponins. Many of such compounds are produced to defend against external factors such as climate conditions, pathogens and physiological stressors (Barreto et al. 2008).

Phytobiotics generally affect animal growth, performance, and health through antimicrobial activity and enhancing immunity. The exact mechanisms for stimulation of broiler growth by phytobiotics are often not known. Some researchers have concluded that these materials have beneficial effects on broiler performance, while others have not observed a positive effect on feed conversion ratio, feed intake and weight gain (Yang et al. 2009).

In spite of the fact that botanicals are known as natural additives, study on their dietary adaptation, toxicity, action mechanism and safe use (since some herbal compounds have harmful effects) is necessary before their extensive application (Yang et al. 2009).

The limitation of antibiotics for the poultry industry that is now very important and the anti-bacterial and anti-toxic properties of some herbs and their extracts are the main motivations for the use of plant supplements in animal feeding (Bombik et al. 2002; Bourke 1997).Plant compounds can help improve microflora balance by affecting intestinal microbes (Hernandez et al. 2004).

More research is needed to maintain and improve the health of consumers, as well as to provide new and cheap growth promoters for poultry diets (Yasoubi et al. 2007). For this reason, in recent years, a lot of attention has been paid to agricultural wastes, one of which is the waste from the factories producing orange juice and concentrates (Pourhossein et al. 2015). The aim of present article is to collect and review useful information on the use of orange by-products and waste in poultry diets.

Orange (*Citrus sinensis*)

Orange is one of the oldest fruits used by humans. Orange waste is found in the production areas of this fruit as well as its processing factories. From a chemical point of view, orange is considered as a rich source of vitamin C. This vitamin has powerful effects against known cancer causative agents i.e. nitrosamines (Wattenberg and Coccia 1991). Researchers have found that oranges and other citrus fruit slower blood cholesterol, and this property is present in the fiber material of the peel and thin sheets between the orange textures. Orange peel contains pectin which has antidiarrhea properties and also affects glucose metabolism (Sharma et al. 1998). The amounts of nutrients, minerals, and vitamin C in orange pulp is given in Table 1.

Do orange by-products affect poultry or not?

The effect of dried orange pulp on poultry feeding

A summary of findings is presented in Table 2. Dried orange pulp is generally used as a condensed carbohydrate. It contains small amounts of metabolizable energy (5.5 MJ/kg), crude protein (6.5%), crude fiber (13%), calcium (2%), phosphorus (0.12%), lemonen (0.01%), fat (4.6%) and essential amino acids.

Oluremi et al. (2006a, b) revealed dried orange pulp could replace by $< 15\%$ for broiler diets. Agu et al. (2010) used 20% dried orange pulp for broiler feeding and found orange pulp led to an increased size of the proventiculus and gizzard and enhanced feed intake. These researchers also demonstrated the 20% dried orange pulp did not have a negative effect on broiler health.

Nazok et al. (2010) revealed the application of dried orange pulp up to 12% not only had no significant negative effect on the laying hen yield, but it also reduced the level of egg cholesterol and hence could improve human health. In same study, dried orange

Table 1 Nutritional contents of orange (100 g)

Nutrient	Content
Energy	49 kcal
Carbohydrates	11.89 g
Protein	0.94 g
Total Fat	0.30 g
Cholesterol	0 mg
Dietary Fiber	2.50 g
Vitamins	**Content**
Folates	39 µg
Niacin	0.274 mg
Pantothenic acid	0.250 mg
Pyridoxine	0.063 mg
Riboflavin	0.040 mg
Thiamin	0.087 mg
Vitamin C	48.5 mg
Vitamin A	230 IU
Electrolytes	**Content**
Sodium	0 mg
Potassium	179 mg
Minerals	**Content**
Calcium	40 mg
Copper	39 µg
Iron	0.09 mg
Magnesium	10 mg
Manganese	0.023 mg
Zinc	0.06 mg

Source: USDA National Nutrient database

pulp reduced diet costs and hence increased economic profit.

The use of *citrus* pulp, as much as 20% and above in practical diets, had negative effects on broiler performance (Buriel et al. 1976). El Moghazy and El Boushy (1982) found that as much as 7.5% dried orange pulp can used in broiler feeding without negative effects.

Abbasi et al. (2015) revealed that the dried orange pulp is an antioxidant for broiler chicks. In this study, 2% dried orange pulp significantly improved weight gain and feed intake of broilers for growth period, as well as decreasing abdominal fat weight, liver weight and blood triglyceride level.

The effect of dried orange peelin poultry diets

Orange peel containing coumarin,volatile oils, nobiliitin, ascorbic acid, phenolic compounds, vitamin C (Fernandez-Lopez et al. 2005), flavonoids (Cheng et al. 1991), pectin (Kalapathy 2001), and bioflavonoids such as hesperidine (Balakrishnan and Menon 2007), naringin and hesperidine (Harats et al. 1998) (Table 3). Chemical compounds from orange peel also included crude protein (5.6%), moisture (2.6%), fat (3.7%), crude fiber (20%), calcium (0.45%), ash (3%), hydrocarbon (55.1%) and total phosphorus (10.3%) (Hasin et al. 2006).

Mona and Hanan (2007) observed that the use of dietary dried orange peel and dried Egyptian clover leaves improved the egg yield, egg quality and immunity in laying hens.

Ebrahimi et al. (2013a, b) suggested dried orange peel as an antimicrobial agent and growth promoter in broiler diets. In this study, the highest carcass weight (2507.550 g) was for chicks fed 1.5% dried orange peel during 1–42 days of age. Also, 3% dried orange peel during 1–21 days of age led to the highest breast weight (576.25 g) and the highest pancreas weight (6.52 g). The highest thigh weight (482.5 g), the lowest pancreas weight (5.487 g), the highest gizzard weight (63.33 g), and the highest heart weight (16.47 g) were for 1.5% dried orange peel for 1st–21st days of age. The lowest abdominal fat weight (34.71 g) was also detected for broilers fed 3% dried orange peel 1st–42nd days of age.

Ebrahimi et al. (2013a, b) studied dietary dried orange peel as much as 1.5 and 3% in starter and grower periods. In the grower period, broiler chickens responded to all treatments. However, chicks fed dried orange peel as much as 1.5% in the starter duration had higher average feed intake.

Alefzadeh et al. (2016) concluded that dried orange peel as much as 1.5 and 3% had same effects on ileal *lactobacillus*. The highest amounts of ceca *lactobacillus* were for 3% dried orange peel from 1 to 42 days of age and the lowest amount of ceca *lactobacillus* were for the 1.5% dried orange peel from 1 to 21 days of age. The researchers found dietary dried orange peel reduced blood cholesterol, triglycerides and LDL. Blood glucose was significantly decreased using dried orange peel as much as 3%. Alkaline phosphatase activity and uric acid was not changed significantly. Generally, the application of dietary dried orange peel

Table 2 Summary of findings on effects of orange pulp on poultry productivity

Shape of use	Poultry	Summary of findings	References
Sweet orange fruit peel	Broiler chickens	The use of dietary dried orange pulp as much as 20% increased feed intake	Agu et al. (2010)
Fruit diret peel	Laying hens	The use of dietary dried orange pulp as much as 20% decreased egg cholestrol	Nazok et al. (2010)
Citrus pulp	Broiler chickens	Dietary *citrus* pulp can not be used as much as more than 20%	Buriel et al. (1976)
Dried *Citrus* pulp	Broiler chickens	The consumption of dietary dried *citrus* pulp as much as 7.5% is affected positively on broiler performance	El Moghazy and El Boushy (1982)
Sweet orange fruit peel	Broiler chickens	Sun dried orange peel can replace with corn in broiler chicken diets up as much as 15%.	Oluremi et al. (2006a, b)
Dried orange pulp	Broiler chickens	The use of dried orange peel increased feed intake body weight and decreased liver and abdominal fat weight and blood triglyceride	Abbasi et al. (2015)
Dried orange peel	Broiler chickens	The use of dried orange peel in the first week of age reduced the growth rate and also dried orange peel as much as 20% increased the mortality rate	Ewing (1963)
Sweet orange fruit peel	Broiler chickens	The use of dried orange peel did not affect on feed and water intake, body weight and feed conversion ratio	Oluremi et al. (2010)
Dried egyptian clover and orange peel	Laying hens	The use of dried orange peel and dried clover powderaffected blood triglyceride, aspartate amino transferase (AST), alanine amino transferase (ALT) levels and increased the amount of red blood cells and white blood cells	Ragab and Hassan (2006)
Dired sweet orange fruit peel	Broiler chickens	Dried orange peel can replace with corn in broiler chicken diets up as much as 20%	Oluremi et al. (2010)
Citrus pulp	Broiler chickens	The use of dried orange peel increased the concentration of unsaturated fatty acids in broiler meat	Mourao et al. (2008)

Table 3 Summary of findings on effects of orange peel on poultry productivity

Shape of use	Poultry	Summary of findings	References
Dried orange peels	Laying hens	The use of dietary dried orange peel increased egg productivity, quality and hen immunity	Mona and Hanan (2007)
Dried orange peel	Broiler chickens	Dried orange peel improved the performance as growth promoter and antimicrobial replacement in the diet of broiler chickens	Ebrahimi et al. (2013a, b)
Dried orange peel powder	Broiler chickens	The use of dried orange peel did not affect on the microbial population of the digestive tract (ileum and cecum) and lactobacilli population.	Alefzadeh et al. (2016)
Dried *Citrus sinensis* peel	Broiler chickens	Dried orange peel had not effect plasma constitutes	Ebrahimi et al. (2015)
Orange peel	Laying hens	Orange peel and parsley improved the egg yolk colour without negative effect on egg quality, productivity, body weight, and feed conversion ratio	Hasin et al. (2006)

had no negative effect on plasma constituents (Ebrahimi et al. 2015).

In an experiment, the effect of orange peel extract was investigated on the broiler production (Table 4). The results showed this by-product can be used as a feeding supplement for improvement of productivity and meat quality. In this study, the broilers fed 1000 mg/L orange peel extract in starter period (1–21 days of age) had the highest carcass weight and chickens fed 1250 mg/L orange peel extract in the

whole period (1–42 days of age) had the lowest abdominal fat (Ebrahimi et al. 2014).

Pourhossein et al. (2015) revealed the highest amounts of immunoglobulin M (IgM), immunoglobulin G (IgG) and red blood cells was in chicks fed with 1000 mg/L orange peel extract. Orange peel extract feeding enhanced lymphocytes and white blood cells and decreased heterophil count and heterophil:lymphocyteratio (H/L). Chicks fed this extract had higher responses to sheep red blood cells (SRBC) than control chicks. IgM and IgG titers were also improved significantly for chicks fed dried orange peel extract. The dried orange peel extract had no significant effect on feed conversion ratio, feed intake and weight gain. In general, the researchers concluded that this extract as much as 1000 mg/L can improve the immune system, and stated that the flavonoid contents of orange peel stimulates the immune system by means of increasing the anti-inflammatory activity IgM and IgG and hence enhances the humoral immunity in broiler chicks.

Mehmet and Şimşek (2016) used orange peel extract for Japanese quail diet under cold stress. The results showed that the orange peel extract could be significantly improved the feed conversion ratio and body weight. The orange peel extract reduced the blood uric acid, cholesterol, glucose, total protein, triglyceride, and glutathione production in liver and heart tissues, and glutathione peroxidase activity in liver were higher in chickens fed orange peel extract. Feeding with orange peel extract resulted in an increase in the accumulation of C22 6 ω-3, C20 2 ω-6, total ω-3 fatty acids and a decrease in the ratio of total ω-6/ω-3 and C18 0. Obtained findings indicate that dietary supplementation with orange peel extract has positive effect on reducing cold stress.

Seidavi et al. (2015) found addition of orange peel extract in two periods (1–21 and 1–42 days of age) as much as 1000 and 1250 mg/L led to reduced feed conversion ratio and increased weight gain from 22 to 42 days of age. Red blood cell count increased at both levels (1000 and 1250 mg/L) and periods (starter and grower). They recommended the use of orange peel extract as a cheap, healthy and hygienic ingredient for broiler diets.

Orange by-products

The effect of orange by-products on poultry performance

Agu et al. (2010) revealed that the dietary dried orange pulp up to 20% instead of corn could increase broiler feed intake and health (Table 5). Dried *citrus* pulp diets (El Moghazy and El Boushy 1982) were prepared based on 19% soybean meal and 60% corn. Unlike control diets, the diets contained 2.5, 5.0, 7.5, and 10.0% *citrus* instead of corn. All diets were iso-caloric (13.4 MJ/kg) and iso-nitrogenous (22% crude protein). The results showed that the addition of *citrus* pulp at more than 7.5%, reduced body weight at 4th week of age, but did not reduce at the 7th week of age. Meanwhile, feed intake was reduced at the 4th week of age and increased in the 7th week of age.

Chaudry et al. (2004) evaluated the use of dried orange pulp in broiler diets, and showed that the use of 7.5% dried orange pulp in the broiler diet increased

Table 4 Summary of findings on effects of orange peel extract on poultry productivity

Shape of use	Poultry	Summary of findings	References
Citrus sinensis peel extract	Broiler chickens	Orange peel extract can be effective as a dietary supplement for improvment of broiler productivity and quality	Ebrahimi et al. (2014)
Sweet orange (*Citrus sinensis*) peel extract	Broiler chickens	Orange peel extract increases the concentration of white blood cells, lymphocytes, decreases heterophil count and heterophil:lymphocyte (H/L) ratio and increases immunoglobulin G and immunoglobulin M	Pourhossein et al. (2015)
Orange peel extract	Quail	Orange peel extract increases the body weight, improves the feed conversion ratio, decreases triglyceride, and has positive effects on tolerance of cold stress	Mehmet and Simsek (2016)
Citrus sinensis peel extract	Broiler chickens	Orange peel extract increases body weight, improves the feed conversion ratio, and increases red blood cell count	Seidavi et al. (2015)

weight and yield. Oluremi et al. (2006a) found that dried orange pulp had positive effects on the body weight and performance of broiler chicks. They evaluated levels 5, 10, 15 and 20% dried orange pulp instead of corn, and demonstrated that replacement of corn with dried orange pulp had no effect on feed conversion ratio, body weight, feed intake, water consumption. Chicks fed diets containing 5–15% dried orange pulp had heavier body weight, and breast and tights relative weights than control chicks.

Oluremi et al. (2010) used dried orange pulp as a feed source at levels of 0, 10, 20, 30, 40 and 50% in broiler diets. Orange pulp had no positive effect on water consumption, feed conversion ratio, body weight feed intake in starter and finisher periods; but it affected positively body weight and feed intake in the whole period. The 30% dietary dried orange pulp increased the percentage of carcass, thigh and wings. Liver, heart, spleen, gallbladder and lungs had not affected significantly based on studied diets. Dried orange pulp could be a good substitute for corn up to 20% for chicken diets. Where dietary dried orange pulp was tested at 0, 20, 30, and 40%, then 20% or higher in broiler diets had a negative effect on performance so high levels of these substances should not be used in the diet (Buriel et al. 1976).

Ewing (1963) reported that orange pulp in broiler diets during the first four weeks reduced the growth rate compared with control chicks. The use of *citrus* pulp up to 20% in the diet caused an increase in mortality, while the inclusion of 10% of the *citrus* pulp caused an increase in the feed intake and no additional mortality. The positive effect of dried orange pulp supplementated with Egyptian clover leaves had a positive effect on the performance and quality of eggs (Mona and Hanan 2007). El Moghazy and El Boushy (1982) also found that *citrus* pulp as much as 7.5% reduced feed intake and body weight by 4 weeks, however it increased the feed intake and body weight by 7 weeks.

Effects of orange by-products on carcass characteristics

Oluremi et al. (2010) found dietary orange pulp as much as 30% had positive effects on the percentage of carcass, thigh and wing, while the percentages of other organs such as breast, neck and wings were not different (Table 6). Oluremi et al. (2006a, b) reported the relative weight of thigh and breast as well as abdominal fat increased significantly in broiler chickens that received dried orange dried up to 15%. Agu et al. (2010) found dietary dried orange pulp as much as 20% increased the feed intake, proventiculus and gizzard sizes and also had no adverse effect on the health of the chickens.

Effects of orange by-products on the poultry blood constitutes and immunity

Ragab and Hassan (2006) studied dietary orange pulp and dried clover powder for hen farms and reported dietary orange pulp had a significant effect on triglyceride, alanin amino transferase and aspartate amino transferase and levels (Table 7). Also, red blood cells and white blood cells in broiler chickens fed with supplementary ration increased rather than control hens.

Based on two joined trials, the first experiment showed that the use of 5% orange peel in broiler diets did not affect weight gain rather than control chicks, but decreased significantly the blood cholesterol level. In the second experiment, the use of 7.5% of dried orange peel in the broiler diet caused significant improve for body weight and significant decrease in plasma cholesterol due to the presence of pectin in the orange peel supplement (Chaudry et al. 2004). Di Majo et al. (2005) found dietary orange peel could enhance the immune system and performance and correlated these positive effects with the presence of antioxidants in orange peel. Nazok et al. (2010)

Table 5 Summary of findings on effects of orange pulp on poultry productivity

Shape of use	Poultry	Summary of findings	References
Dried orange pulp	Broiler	Increased feed intake	Agu et al. (2010)
Dried orange pulp	Broiler	Increased weight gain	Chaudry et al. (2004)
Dried orange pulp	Broiler	Positive effect on final body weight	Oluremi et al. (2006a, b)
Dried orange pulp	Broiler	Increased body weight feed intake	Oluremi et al. (2010)

Table 6 Summary of findings on effects of orange by-products on poultry carcass

Shape of use	Poultry	Summary of findings	References
Dried orange pulp	Broiler chickens	The use of dried orange pulp increased feed intake and body weight and reduced liver weight, abdominal fat weight and blood triglyceride levels in broiler chicks	Abbasi et al. (2015)
Citrus sinensis peel extract	Broiler chickens	The essential oil of orange peel can be effective as a feeding supplement for improving productivity and carcass quality of broiler chicks	Ebrahimi et al. (2014)
Orange peel extract	Quail	The use of orange peel extract increased body weight, improved the feed conversion ratio, and reduced plasma triglyceride	Mehmet and Simsek (2016)
*Citrus sinensis*peel extract	Broiler chickens	Orange peel extract increased weight gain.	Seidavi et al. (2015)
Citrus waste	Broiler chickens	Use of 7.5% of orange waste increased weight gain	Chaudry et al. (2004)
Orange dried pulp	Broiler chickens	The use of *citrus* pulp during the first week reduced the growth rate and *citrus* pulp as much as 20% increased the mortality rate	Ewing (1963)
Citrus pectin	Broiler chickens	The use of orange pectin did not affect the performance index and growth rate	Langhout et al. (1999)
Citrus by-products	Broiler chickens	Increased levels of dietary *citrus*by-products had negative effects on body weight and feed intake	Yang and Chung (1985)
Orange peel	Laying hens	Orange peel had no negative effect on the egg quality, egg yield, egg weight or body weight of laying hens	Hasin et al. (2006)

Table 7 Summary of findings on effects of orange by-products on poultry blood constituents and immunity

Shape of use	Poultry	Summary of findings	References
Dried fruit pulp	Laying hens	The use of dried orange pulp up to 12% caused decreased egg cholesterol	Nazok et al. (2010)
Dried orange peel	Laying hens	Dried orange peel improved egg production, egg quality and immune system	Mona and Hanan (2007)
Dried orange pulp	Broiler chickens	The use of dried orange pulp increased the bloodtriglyceride in broiler chicks	Abbasi et al. (2015)
Dried *Citrus sinensis* peel	Broiler chickens	Dried orange peel had no negative effect on blood constituents of broilers	Ebrahimi et al. (2015)
Sweet orange (*Citrus sinensis*) peel extract	Broiler chickens	Sweet orange peel extract increased the concentration of white blood cells, and lymphocytes, decreased heterophil count and heterophil: lymphocyte (H/L) ratio, and increased immunoglobulin G and immunoglobulin M	Pourhossein et al. (2015)
Orange peel extract	Quail	Orange peel extracts decreased blood triglycerides	Mehmet and Simsek (2016)
Citrus sinensis peel extract	Broiler chickens	Orange peel extracts increased red blood cell count	Seidavi et al. (2015)
*Citrus*waste	Broiler chickens	Orange waste as much as 7.5% increased body weight and decreased blood cholesterol	Chaudry et al. (2004)
Dried egyptian clover and orange peel	Laying hens	The use of orange peel and dried clover powder affected blood triglyceride, AST and ALT, and increased the amounts of red and white blood cells	Ragab and Hassan (2006)

showed dietary dried orange pulp at up to 12% inlaying hen diet, had no negative effects on egg production but decreased egg cholesterol. The results of Mona and Hanan (2007) were that the application of dried orange peel and dry Egyptian clover leaves for laying hens may improve the immune system.

Conclusion

According to all of these studies, it can be concluded that the use of orange waste and by-products can be included as supplements for poultry diets, although the amount needs to be checked and monitored carefully to ensure that product quality and performance of the birds are not decreased. By using appropriate levels of orange waste and by-products in poultry diets, a healthy, antibiotic-free product without harmful residues for humans can be produced. This action also prevents the waste of materials from orange processing. The poultry feed costs will be decreased and poultry farmers will gain more profit.

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