REVIEW ARTICLE Agricultural Reviews, Volume 44 Issue 4: 493-500 (December 2023)

The Impacts of Vegetables and Fruits by Products on Growth and Health of Broiler Chickens

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10.18805/ag.RF-271

ABSTRACT

Agro-industrial by-products, which are not intended for human consumption, can serve as substitutes for traditional animal feed ingredients in animal nutrition. This can result in the production of animal products without causing competition for land or exacerbating the food versus feed dilemma, ultimately promoting environmental and economic sustainability. Utilizing co-products as animal feed has the potential to reduce feeding costs while enhancing the productive parameters, quality, animal welfare and sustainability of animal products. Numerous studies have indicated that fruits and vegetables are considered as significant sources of bioactive compounds. The extensive process of industrialization leads to the creation of considerable amounts of by-products, giving rise to grave ecological concerns. Hence, such a scenario necessitates the formulation of innovative approaches for effectively utilizing the resultant wastes, ensuring the potential to fabricate novel products with enhanced value. The generated by-products, reveal similar or higher antioxidant activity. It is recognized that these secondary products comprise various bioactive substances and may have the ability to serve as nutraceuticals for poultry, promoting their health and overall wellness. This review aims to summarize the exploitation of fruit wastes, namely, apple, citrus, banana, mango, pineapple and grape as well as vegetable by-products which are derived from tomato and olive cultivation. These byproducts can be in supplementation or substitution format. Some of these byproducts presented the following results: The addition of 2% dried sweet orange pulp to the diet significantly increased feed intake and total weight gain in broilers and the inclusion of dried orange pulp in broiler diets was found to reduce serum triglycerides and cholesterol. Also, the including of 10% apple peel in the diet led to an increase in the weight of the gizzard and small intestine in chickens. Additionally, diets containing 5% and 10% apple peel waste resulted in higher levels of lipids and HDL (high-density lipoprotein) in the blood serum, while LDL (low-density lipoprotein) and malondialdehyde levels decreased. Moreover, the including of 10% banana peel in poultry feed led to improved feed efficiency, feed conversion and the quality of poultry eggs and meat. However, the inclusion of olive cake with phytase to broiler chickens' diet presented an increase of growth parameters increased. The incorporation of 10% of OC with phytase also resulted a reduction in plasma cholesterol and triglycerides and an increase in plasma inorganic phosphorus.

Key words: Bioactive compounds, Broilers, Performance, Serum components, Valorization, Waste and by-products.

The transformation of fruits and vegetables generates a significant quantity of by-products that are abundant in bioactive compounds. Fruit pomace, specifically the seeds and peel, are abundant sources of phenolic compounds (Ajila *et al*., 2007). The projected estimation for the worldwide output of municipal organic waste is anticipated to surpass 1000 million tonnes annually by the year 2025 (Del Pilar *et al*., 2019). Food waste is generated using approximately 30% of the global agricultural land area (Capanoglu *et al*., 2022).

In order to minimize production waste, these by-products can be repurposed as a cost-effective and naturally-derived source of dietary fiber and antioxidants in poultry feed. Dried fruit and vegetables pomace, contain approximately 50-70% dietary fibers and are abundant in polyphenols, making them a valuable resource for improving poultry nutrition (Jaroslawska *et al*., 2011) and (Juskiewicz *et al*., 2015).

The antioxidant compounds found in fruit pomaces have the potential to enhance the stability of food products by inhibiting lipid peroxidation and oxidative damage in living organisms through the scavenging of oxygen free radicals (Makris *et al*., 2007). Dietary factors can have a notable impact on regulating the microbial activity of the gastrointestinal tract, which in turn affects the physiological structure and function of the intestines (Fotakis *et al*., 2017).

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How to cite this article: CHAIB EDDOUR, A.R., LITIM, M., LARBAOUI, A., BELHOCINE, C. and BOUDEROUA, K. (2023). The Impacts of Vegetables and Fruits by Products on Growth and Health of Broiler Chickens. Agricultural Reviews. 44(4): 493-500. doi: 10.18805/ag.RF-271.

Submitted: 17-05-2023 **Accepted:** 25-07-2023 **Online:** 18-10-2023

Strategies for valorizing waste aim to enhance the worth of a product by converting waste into substitute sources for the creation of novel products with elevated value. These newly developed products could be assimilated into the worldwide economy, thereby making a contribution towards minimizing the ecological impact as they conform to established environmental regulations (Hadj Saadoun *et al*., 2021).

The primary aim of this analysis is to explicate the process of valorizing the byproducts of the food industry in contemporary industrial practices. This utilization of waste material illuminates a novel avenue for the creation of new products of elevated value, as they can be employed as supplements in animal feed.

Apple waste

Apple pomace is a valuable source of dietary fiber, pectin, vitamin C and phenolic compounds. Research has demonstrated that incorporating apple pomace into poultry diets can enhance the productivity and reproductive performance of chickens. The study also found that incorporating dried apple pomace and enzyme supplementation significantly affected blood biochemical parameters in broilers. However, there are limitations to its inclusion, such as low digestibility caused by the high levels of lignin/cellulose, as well as limited quantities of minerals and proteins (Aghili *et al*., 2019). Also, the incorporation of apple pomace as a replacement for 10% of maize does not adversely affect the performance and production of broilers (Yitbarek *et al*., 2019).

Heidarisafar *et al*. (2016) conducted a study to investigate the effects of incorporating apple peel into the diet of broiler chickens exposed to heat stress. The results showed that including 10% apple peel in the diet led to an increase in the weight of the gizzard and small intestine in chickens.

Additionally, diets containing 5% and 10% apple peel waste resulted in higher levels of lipids and HDL (high-density lipoprotein) in the blood serum, while LDL (low-density lipoprotein) and malondialdehyde levels decreased. However, the apparent ileal protein digestibility in chickens fed with 5% and 10% apple peel waste was reduced. Additionally, APW were a potential antioxidant due to its ability to reduce serum MDA (malondialdehyde) levels. Previously, (Nobakht *et al*., 2013) recommended that the presence of potassium in apple waste can help improve electrolytic balance, nutrient digestibility and nutrient absorption, ultimately promoting better growth and health in poultry.

Banana waste

With a global annual production of over 7 million tons, bananas are among the most cultivated plants worldwide. However, approximately 30-40% of total banana production is deemed unfit for consumption due to quality standards, making it potentially suitable for use as feed for broilers. Banana leaves contain approximately 8% polyphenols but have low levels of condensed tannins. Banana peels constitute about 30% of fresh bananas weight and banana leaves are reported to contain 85% water and 10-17% protein on a dry matter basis (Hang *et al*., 2018 and Dumorné *et al*., 2020). It was determined that including 10% banana peel in poultry feed led to improved feed efficiency, feed conversion and the quality of poultry eggs and meat. However, using more than 10% banana peel in the feed could potentially decrease the growth rate of poultry (Yitbarek *et al*., 2019).

Abel *et al*. (2015) added 10%, 20% and 30% banana peel as a substitute for corn in broiler chicken diets. They found statistically significant differences in daily live weight gain, daily feed consumption and slaughter weight between the control group and the group with 10% banana peel. Similar significant differences were also observed in the groups with 20% and 30% banana peel. In another study, Haryanto *et al*. (2016) found that after administering banana peel meal to broiler chickens, there were no significant differences in feed conversion ratio (FCR), total cholesterol and LDL levels. However, HDL and triglyceride levels showed significant differences among the treatment groups. In the study of (Okoleh *et al*., 2015), adding banana leaves to the diets of broiler chickens had a significant effect on various parameters including final body weight, daily feed intake, daily live weight gain and feed conversion ratio. Although the groups treated with banana leaves performed better than the control group in terms of mean final body weight, daily body weight gain and feed conversion ratio. It was observed that birds fed with banana leaf extract had numerically higher final body weight and daily weight gain (5.03%) compared to birds fed with banana leaf powder. The study found that the daily weight gain, feed efficiency and carcass yield were significantly affected by the treatments, in which the highest values of daily weight gain, feed efficiency and carcass yield was observed in birds fed diet containing 10% banana leaves fermented for 10 days.

The addition of 10% banana peel powder to conventional feed significantly improves the growth performance compared to the control group and the improved productivity in birds fed with 10% banana leaf pulp fermented for 10 days may be due to enhanced digestion and feed utilization through stimulation of digestive enzymes (Mandey *et al*., 2015).

Citrus waste

The study found that supplementing drinking water with sweet citrus peel powder (SCPP) had a positive effect on the performance and ileal microbial count of broiler chickens. However, there were no significant differences in feed intake and weight gain among the treatments. The live weight and relative weight of heart and pancreas showed significant variations among the treatments. Overall, the study suggests that SCPP can be used as a potential feed additive for broiler chickens (Majekodunmi *et al*., 2021).

The results of the study conducted by (Behera *et al*., 2019), showed that supplementing broiler diets with citrus waste (CW) up to 5% decreased cholesterol, triglyceride and AST levels in the blood and improved the antioxidant status without affecting Total Protein, Albumin, globulin and Blood Urea Nitrogen levels. Vitamin C levels were observed to be highest in birds fed (CW 5%)-based diet supplemented with enzymes. Additionally, catalase and SOD activity increased non-significantly with an increase in inclusion level of CW in the diets, while LPx, GPx and GSH activities decreased up to 5% CW-fed groups.

In a study that investigated the effects of incorporating different percentages (0, 2.5, 5, 7.5, 10%) of orange peel in broiler diets, indicate that the dietary supplementation of natural antioxidants extracted from citrus waste improved the growth performance and blood antioxidant status of broiler chickens. The study found that the broilers fed with the natural antioxidants had higher body weight gain, feed intake and feed conversion ratio compared to the control group. The blood antioxidant status of the broilers was also significantly improved, as indicated by higher levels of total antioxidant capacity and lower levels of malondialdehyde. These findings suggest that natural antioxidants from plant sources can be a potential alternative to synthetic antioxidants in animal feed (Faiz *et al*., 2017).

The results of Abbasi *et al*. (2015) showed that using dried orange residues in the diet significantly increased the feed intake and body weight of broilers. During the ending period, broilers fed a diet supplemented with 1.0% and 2.0% DCSP showed significant improvements in feed intake and feed conversion ratio compared to the control group. During the initial period, the addition of up to 1.0% DCSP resulted in lower feed intake and weight gain and an unbalanced feed conversion ratio. Using dried orange residues significantly decreased the liver and abdominal fat of broilers. Overall, the study suggests that dried orange residues can be a potential source of valuable nutrients and natural antioxidants for poultry feed. The incorporation of dried orange residues into the diets of broiler chickens resulted in improved performance measures such as feed intake and body weight gain, as well as reduced liver and abdominal fat and serum triglyceride levels. Specifically, utilizing 2% DCSP in broiler chicken diets had a significant positive impact on performance, carcass characteristics, blood metabolites, humoral immunity and cecum microbial population (Abbasi *et al*., 2015). The blood parameters of broilers, including cholesterol, uric acid, glucose, low density lipoprotein and high-density lipoprotein, were affected by the addition of citrus peel extract to their feed (Ebrahimi *et al*., 2014). The glutathione peroxidase level in the birds increased when the broilers were given feed that was supplemented with lemon and peel extracts (Akbarian *et al*., 2014).

Olive waste

Olive waste is repurposed as animal feed due to its high content of these useful components. Olives also contain various antioxidants that have the potential to neutralize harmful free radicals and offer antioxidant protection. The utilization of olive waste in animal feed reduces the reliance on other inexpensive feed options, resulting in cost savings for animal feeding (Gerasopoulos *et al*., 2015). In the study conducted by (Agah *et al*., 2019), the broilers were divided into groups that were fed different diets, including a negative control, a positive control with 250 mg and olive leaf supplements at either 200 or 400 mg. They investigated the effects of olive leaf extract (OLE) and α-tocopheryl acetate on growth performance, nutrient digestibility, blood metabolites and antioxidant activities in heat-exposed broiler chickens. The findings of the study showed that there were no significant differences observed in body weight gain (BWG), feed intake (FI) and feed conversion ratio (FCR) among male broilers fed with different diets in this experiment. The study found that supplementation of OLE to broiler diets as an antioxidant component could improve the antioxidant status and reduce the stressor index of heat-stressed broilers. Cholesterol, triglyceride, Alanine transaminase (ALT) and aspartate aminotransferase (AST) in blood were significantly decreased when chickens were fed diets containing OLE. Plasma lipid peroxidation level and glutathione peroxidase activities were reduced in chickens fed diets supplemented with OLE and α-Toc.

Al-Harthi *et al*. (2020), reported that the inclusion of olive cake (OC) broiler chickens' diet (aged 7-28 days) did not affect their growth rate or FCR. However, when phytase was added to the diet, these parameters increased. The addition of OC and phytase also resulted a reduction in plasma cholesterol and triglycerides and an increase in plasma inorganic phosphorus. Among all treatments, broilers fed a diet containing 10% OC showed the highest economic efficiency.In their study (Al-Harthi *et al*., 2017), stated that adding up to 10% Olive Cake had no impact on variables such as BW gain, final BW, FCR, dressing percentage and ratios of immune organs to live BW. However, incorporating 5% OC along with galzyme enzyme resulted in a significant increase in feed intake.

Furthermore, the best FCR was achieved with the combination of 10% OC and galzyme enzyme. In another study (Al-Harthi and Attia, 2016), presented that the inclusion of 10% of olive cake (OC) did not have an impact on various parameters including: body weight gain, feed intake, feed conversion ratio (FCR), survival rate, European production efficiency index, meat pH, meat color, water holding capacity, meat tenderness, dressing percentage, abdominal fat and the proportions of heart, pancreas, intestine and cecum. They also found that there were no changes in red blood cell characteristics and hepatocellular leakage markers; however, the liver proportion was lower in comparison to the control group. Furthermore, they found that the addition of 20% OC and 1 g/kg citric acid did not have any effect on FCR or the health status of broilers.

Tomato waste

Tomato pomace has the potential to be a valuable source of protein, fiber, carbohydrates and carotenoids. Incorporating

tomato pomace into poultry diets can have positive effects on meat and egg quality, such as increasing the concentration of bioactive substances, nutrients, improving fatty acid profiles and reducing lipid oxidation. Dried tomato pomace, has a low energy value that must be considered when formulating poultry feed to minimize adverse effects. It is recommended to add tomato pomace at a level of 15 or 20% in the diet of grown chickens (Yitbarek *et al*., 2019).

Hosseini Vashan *et al*. (2016) showed that including dietary tomato pomace and canola oil in the diet led to improved weight of the spleen, bursa and bone parameters, while reducing ventricular fat. The addition of (3 and 5%) tomato pomace to the diet resulted in increased percentage of dry matter. The researchers attributed the positive effects of tomato pomace to the presence of lycopene, a compound with antioxidant properties. According to another study conducted by (Mohammed *et al*., 2021), the addition of tomato pomace at levels of (4% and 6%) to the diet of broiler chicks did not result in any significant changes in feed conversion ratio (FCR) or daily feed consumption.

Per the research of Shehata *et al*. (2018), the incorporation of tomato pomace in broiler diets leads to elevated feed intake due to its higher fiber content, which helps meet the energy needs of the animals. The same results were observed in (Hosseini-Vashan *et al*., 2016) study, where the inclusion of 5% tomato pomace in broiler diets resulted in improved body weight and performance, particularly when subjected to heat stress conditions.

According to the study conducted by Saed *et al*. (2018), the inclusion of tomato pomace at levels of (1%, 2% and 3%) in the diets resulted in improved blood parameters, including decreased levels of triglycerides and increased concentration of high-density lipoprotein (HDL) cholesterol. Hosseini-Vashan *et al*. (2016), found that the addition of 5% tomato pomace to broiler meals led to a decrease in serum alkaline phosphatase (ALP) and lipase activity, comparable to that of non-stressed broilers. Furthermore, the broilers treated with 5% tomato pomace exhibited lower triglyceride levels and higher HDL cholesterol levels when compared to the other broilers.

Grape waste

Kumanda *et al*. (2019) investigated the effect of including red grape pomace (GP) in broiler diets on growth performance, blood parameters, carcass characteristics and breast meat quality traits. The study found that including GP in broiler diets has the potential to reduce feed costs and improve feed conversion efficiency. However, the inclusion of GP in broiler diets had no significant effect on weight gain and overall feed conversion ratio. The study also found that the dietary inclusion of GP influenced the average weekly feed intake of broilers.

The supplementation of grape pomace did not have a significant effect on body weight gain, but there was a significant effect on body weight gain during the first two weeks of the study. There was no significant effect of grape pomace supplementation on feed intake or feed conversion ratio. Supplementation of grape pomace did not have a significant effect on nutrient digestibility, blood glucose, triglyceride, or HDL cholesterol levels. There was an effect of grape pomace supplementation on total cholesterol and serum immunoglobulin G levels (Aditya *et al*., 2018).

The study of Ebrahimzadeh *et al*. (2018) showed that the inclusion of up to 10% GP in diets did not adversely affect broiler chickens' performance, improved the antioxidant and immune responses of broiler chickens. The addition of GP in the broiler diets could increase the immune responses and reduce the feed cost per kg of live weight. However, the histomorphometrically measurement of the small intestine showed a decrease in crypt depth and epithelial thickness of chicken duodenum and the villus height and crypt depth were significantly reduced in the jejunum. The physiological effects of polyphenols depend on many different factors and more research will be needed in the future to establish appropriate dosages of grape polyphenols to optimize health benefits and minimize possible negative effects.

The findings of Abu Hafsa *et al*. (2018) showed that adding grape seed (GS) to the diet of broiler chickens improved their growth performance, reduced blood lipids, enhanced antioxidant capacity and decreased harmful bacteria in the ileum. The polyphenolic content of GS had antioxidant activity that conferred positive health benefits and improves gut microflora and growth performance of broilers.

Mango waste

In a study of Orayaga *et al*. (2017) investigated the effects of incorporating mango fruit reject meal (MFRM) into broiler diets. They found that the inclusion of up to 10% MFRM in broiler diets had no adverse effects on the performance of broiler chicks. In fact, they found that the cost per kilogram of diet decreased as the level of MFRM increased. There was no significant difference in feed cost per kilogram of weight gain among the treatment groups. Based on these findings, the authors concluded that MFRM can be included in broiler diets at up to 15% without any negative consequences. The cost per kg diet steadily decreased ($0.56 to $0.50) as the level of MFRM increased. There was no significant difference ($P>0.05$) among the treatment's groups for feed cost per kg weight gain.

Therefore, Mango Fruit Reject Meal (MFRM) should be included in broiler chicken diets at 15% level, for optimal carcass yield and good health. A more recent study, published by (Aka-Tanimo *et al*., 2020) found that the addition of 7.5% mango leaf meal (MLM) to broiler chicken feed resulted in improved growth performance. The authors found that the birds that received MLM had a lower feed conversion ratio and daily feed intake than the birds that did not receive MLM. There were no adverse effects on the health status of the birds that received MLM. These two studies suggest that mango fruit and leaf meal can be used as alternative feed ingredients in broiler diets.

Table 1: Inclusion agro-industrial by-products in poultry diets.

Fruit or vegetable	Byproducts		Results	References
Citrus	Dried citrus sinensis peel	1.5% or 3% (w/w)	The addition did not affect the final body and carcass weight There was an increase in the relative length of the small intestine and a decrease in carcass yield. The content of polyunsaturated fatty acids in meat, feed intake and feed conversion rate all increased, while daily weight gain decreased when a diet with a 10% citrus pulp (CP) level was used.	Ebrahimi *et al.*, 2013 Mourão *et al.*, 2008
	Citrus waste	0, 2.5, 5.0, 7.5% CW andmulti-enzyme	There was a decrease in plasma cholesterol, triglyceride and aspartate aminotransferase levels as the levels of Citrus Waste increased.	Behera *et al.*, 2019
Tomato	Lycopene	12 ppm	The addition reduced cholesterol content in thigh muscle	Rozbicka-Wieczorek *et al.*, 2014
		0.5 g/kg	No adverse effects of growth and slaughter performance	Pozzo *et al.*, 2013
	Tomato waste	0, 5, 10, 15, or 20%	Feed intake increased during days 1-7, 8-14 and 29-36. Carcass weight yield (%) was not affected except for heart and liver yields.	Lira *et al.*, 2010
Grape	Grape pomace	0, 3, 6%	There was a greater difference in meat color between breast and thigh meat, increased meat hardness, improved meat color and texture and reduced TBARS in thigh meat. An increase in yellowness value of breast meat when 6% white GP was included in the diet, while the intensity of red color (C*) in breast meat was reduced when 6% red GP was included in the diet.	Turcu *et al.*, 2020
Olive	Olive cake	0, 5, or 10% OC and 0.2, or 0.4 g/kg yeast	The group supplemented with 5% OC plus 0.4 g/kg yeast had the highest values for BW gain and FCR. The groups supplemented with 5% and 10% OC plus 0.2 g/kg yeast, as well as 10% OC plus 0.4 g/kg yeast, had the highest survivability rate. The addition of OC to the diet did not have any effects on carcass traits and inner organs.	Al-Harthi *et al.*, 2016
	Olive pomace	0, 2.5, 5, 7.5%	The 5% and 7.5% OPO groups exhibited elevated rates of growth, while the 5% OPO group demonstrated superior antithrombotic properties when compared to the control group.	Nasopoulou *et al.*, 2018
Mango	Mango leaf Meal	7.5% MLM	Mango meal (MLM) to broiler chicken feed resulted in improved growth performance. Birds that received MLM had a lower feed conversion ratio and daily feed intake than the birds that did not receive MLM. There were no adverse effects on the health status of the birds that received MLM.	(Aka-Tanimo *et al.*, 2020)
Pineapple	Pineapple peel	7.5, 15 and 22,5%	The high crude fiber content of pineapple peels may decrease nutrient digestibility in broilers.	(Ibrahim *et al.*, 2021)

Emshaw *et al*. (2012) conducted a study comparing the weight gain of birds fed diets containing 0% and 10% mango fruit waste, replacing maize in the ration. They reported no significant difference in weight gain between the two groups. Furthermore, the addition of mango seed kernel (MSK) to chicken feed had an effect on slaughter weight. The slaughter weight of chicks decreased across the treatment groups as the level of MSK increased in small amounts from 5% to 15%. This decrease in slaughter weight could be attributed to the presence of anti-nutritional factors in MSK, such as tannins. However, that some of these factors can be reduced through the use of boiling as a processing method (Dakare *et al*., 2012).

Pineapple waste

The search results suggest that the effect of pineapple peel in broiler diets is mixed and may depend on factors such as the level of inclusion and processing method. Pineapple peels have a high sugar content that can provide energy for broilers. The inclusion of fermented pineapple peel meal up to 15% with other medicinal weeds did not influence broiler chicken performance (Ibrahim *et al*., 2021). The inclusion of different amounts of fermented pineapple peel waste in the broiler diet did not significantly affect body weight or carcass characteristics (Heryandi *et al*., 2018). Additional results regarding the incorporation of fruit and vegetable waste in broiler diets are presented in the (Table 1).

CONCLUSION

The increase in environmental pollution necessitates the development of new, viable and sustainable technologies aimed at utilizing the byproducts produced in different sectors, such as the livestock, food and pharmaceutical industries. In addition, feeding of mango seed kernel waste for broiler is so important on solving the problem of competition between poultry and humans for cereal grains.

Similarly, utilization of mango seed kernel waste for poultry ration will reduce the disposal problems of wastes and the increasing cost of poultry rations may be analyzed and competition between animals and humans for food, it is suggested that unused fruits wastes be utilized as an alternative source of feed additives in poultry rations after appropriate processing.

This review shows the nutritional content of waste produced by the transformation of fruits and vegetables and emphasizes its potential for creating new products that can harness their nutritional and functional advantages. It also summarizes the use of fruit and vegetable by-products as additives in broiler chickens' diets to improve FCR like in citrus diets where the flavonoids are an important nutrient for antioxidant effects.

Incorporating these by-products into poultry rations can reduce overall poultry production costs, minimize environmental pollution and positively impact broiler growth performance. Fruits by-products can be used as livestock feed without compromising palatability, digestibility, nutrient content, health, or performance for example: the utilization of 10% of citrus and apple byproducts. However, it is important to consider both the beneficial and harmful effects of adding fruits by-products to livestock diets based on various research findings. In conclusion, all the proposed studies have shown that coproducts can be a valuable source of various nutrients in animal diets.

Conflict of interest

All authors declare that they have no conflicts of interest.

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