

Study on the Potential use of Tomatoes and their By-Products in Poultry Nutrition

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Abstract

The study evaluates the potential use of tomato processing by-products (pomace, peels and seeds) in poultry nutrition, within the content of circular economy and environmental sustainability. These by-products are valuable sources of nutrients and bioactive compounds, including proteins, crude fiber, lipids, essential minerals, polyunsaturated fatty acids and antioxidants such as carotenoids, polyphenols and tocopherols. Their composition may vary depending on tomato variety and processing conditions. In laying hens, dietary inclusion at low to moderate levels (5–15%) does not negatively affect productive performance, while improving yolk colour, oxidative stability and, in some cases, reducing cholesterol levels. In broiler chickens, inclusion levels up to 8–10% can be used without major adverse effects, with potential benefits on antioxidant status and immune response, particularly under stress conditions. However, higher inclusion levels ($\geq 15\%$) may reduce feed intake, growth performance and feed efficiency due to high fiber content and reduced nutrient digestibility. Processing methods such as fermentation or supplementation with exogenous enzymes can partially alleviate these limitations. In conclusion, tomato by-products represent sustainable alternative feed ingredients with important nutritional, economic and environmental benefits in poultry production systems.

Keywords: bioactive compounds, broiler chickens, egg quality, laying hens, meat quality

1. Introduction

In recent years, the accelerated development of the agri-food industry has led to a significant increase in the volumes of vegetal residues from the processing of agricultural raw materials. Identifying efficient strategies for reusing agro-industrial residues is a crucial area of research, particularly in animal husbandry, where feed costs significantly impact the profitability of production [1]. At the international level, the Food and Agriculture Organization (FAO) promotes the use of alternative feeds and agro-industrial by-products in animal nutrition, aligning with the

principles of the 3 R's (reduce, reuse, recycle) [1, 2]. Globally, tomatoes (*Solanum lycopersicum* L.) are one of the most widely cultivated agricultural products, with approximately 186 million tons annually produced at the global level. Tomatoes are used as raw materials in various industries, including the production of juices, canned tomatoes, and sauces. As a result, the industrial processing of tomatoes generates waste—such as seeds and peel [3, 4]. However, the disposal of these by-products involves high costs and has an important impact on the environment, considering that the microbial degradation leads to greenhouse gas production [5]. In this context, the industries developed a waste management system, including the recycling of these by-products and using them in animal feeding, as they contained valuable nutritional compounds [4]. By-products obtained

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from tomatoes have a composition rich in protein fiber, minerals, and lipids [6]. The dried pomace and peels contained the highest fiber content among tomato by-products, compared to pulp and other vegetable residues. Tomato by-products also provide protein fractions with essential amino acids [3], as well as polyunsaturated fatty acids (PUFA) and important macro- and micro-minerals [3, 7]. From an antioxidant perspective, tomato peels and seeds are particularly rich in bioactive compounds, including polyphenols, carotenoids (lycopene, β -carotene, lutein), and flavonoids, which contribute to their high antioxidant potential. In poultry nutrition, the use of tomato by-products can lead to an improvement in animal performance and enhance the nutritional and functional quality of poultry products, such as meat and eggs. Nobakht & Safamehr, [8] reported that the inclusion of 10% tomato pomace in laying hens can increase egg production and egg mass. Also, the inclusion of 100 g/kg tomato pomace in hens' diets led to improvement of yolk colour score [9]. Moreover, the tomato by-products can positively influence the antioxidant status of animals. The inclusion of 1% tomato pomace in broiler chicks' diets, under heat stress conditions, led to a decrease in serum malondialdehyde (MDA) values and an increase in the antioxidant activity. Also, the inclusion of 15 % tomato powder in laying hens led to a decrease in MDA level in the liver [10]. However, the use of tomato by-products in poultry feed has certain nutritional and technological limitations. This is primarily due to their high levels of insoluble fiber and lignin, which can decrease nutrient digestibility and feed conversion efficiency [11]. Moreover, the variability in the chemical composition of tomato by-products, influenced by their variety and degree of maturity, underscores the importance of nutritional characterization before using them as feed ingredients. This variability can affect both the nutrient content and the concentrations of bioactive compounds [12]. In this context, this review aims to synthesize the literature on the use of tomatoe by-products in poultry nutrition, focusing on productive performance and eggs and meat quality, in order to highlight their potential as sustainable alternative feed ingredients.

2. Methodology

The present review was conducted to synthesize current knowledge regarding the nutritional potential of tomato by-products (peels, seeds, and pomace) in poultry nutrition. A comprehensive literature search was performed across major electronic databases, including Web of Science, Scopus, PubMed, and Google Scholar. The search covered peer-reviewed articles published containing keywords, both individually and in combination: "tomato pomace", "lycopene", "poultry nutrition", "broiler performance", "egg quality", and "tomato waste valorization".

3. Nutritional composition of tomato processing by-products

In addition to their consumption as fresh products, tomatoes are extensively processed into derivatives such as paste, juice, sauce, puree, and ketchup, thereby enhancing their versatility and culinary applications. The processing methods employed to obtain these products typically involve the separation of the liquid and solid fractions through techniques such as pressing, concentration, and sterilization. The solid residue generated during processing, known as tomato pomace, consists primarily of seeds, peels, and residual pulp, and generally accounts for approximately 3% to 5% of the raw material entering the process [13]. Although the consumption of fresh tomatoes is relatively modest compared to processed products, the large-scale production of the latter results in a substantial generation of by-products [14]. Despite its rich content of nutrients, including proteins and lipids, as well as bioactive compounds, tomato pomace and its management pose a significant challenge for the food industry, as improper disposal may lead to environmental degradation and resource wastage.

3.1. Protein

Numerous studies have shown that tomato seeds contain significant amounts of nutrients, with proteins accounting for approximately 20% to 40% of the total weight on a dry matter basis [15-17]. A range of amino acids, both essential and non-essential, such as lysine, methionine, and cysteine, have been identified in tomato skins and seeds [18]. The main amino acids identified in tomato seeds are glutamic acid and aspartic acid [19], which can be used as flavor enhancers in

foods with umami and sour taste profiles [20]. According to the literature, the most abundant essential amino acids in tomato seeds are arginine, threonine, lysine, and leucine [21]. Sogi et al. [22] reported that proteins from tomato seeds have a high lysine content, and that their nutritional quality, evaluated through the protein efficiency ratio (PER) and net protein utilization (NPU), is comparable to that of other plant proteins. The relatively high lysine content (1.34%) in tomato seeds makes the extracted proteins particularly valuable as functional ingredients, especially for improving the protein quality of cereal-based products and for developing protein-rich dietary supplements with enhanced functional properties [21]. Lysine plays a key role in calcium absorption, muscle protein synthesis, and the production of hormones, enzymes, and antibodies [23]. The amino acid profile of tomato seed proteins, as reported in the study conducted by Knoblich et al. [18], is presented in Table 1.

Table 1. Amino acid composition of tomato by-products, dry matter basis

Amino acids	Peel (g/kg)	Seed (g/kg)
Alanine	3.8	6.0
Arginine	2.3	7.6
Aspartic acid	12.3	15.1
Cystine	0.7	2.1
Glutamic acid	38.5	29.5
Glycine	3.7	7.2
Histidine	0.7	2.6
Isoleucine	2.3	4.6
Leucine	3.8	7.8
Lysine	1.4	6.1
Methionine	0.9	1.9
Phenylalanine	2.6	5.4
Proline	2.3	5.3
Serine	2.5	5.6
Threonine	2.4	4.5
Valine	3.2	5.6
Total amino acids	83.4	116.9

3.2. Fat

Tomato seeds can be considered an excellent source of vegetable oil (17.8–24.5 g/100 g seeds), rich in bioactive compounds such as polyphenols, tocopherols, and phytosterols, with strong antioxidant capacity [24] and beneficial effects on human health [14], including improved immune function and blood pressure regulation, as well as the prevention of aging and atherosclerosis [25]. Beyond these bioactive components, tomato seed oil mainly contains saturated and unsaturated fatty

acids in proportions of 14% to 18% and 76–80%, respectively [26, 27]. The fatty acid composition identified in different tomato-derived by-products is presented in Table 2, highlighting variations associated with different processing methods and extraction conditions [17, 28]. Among polyunsaturated fatty acids (PUFAs), linoleic acid and alpha-linolenic acid stand out due to their multiple physiological roles, including blood pressure regulation. These are essential fatty acids that cannot be synthesized by the human body [17]. Therefore, tomato seed oil represents an important source of PUFAs, and its valorization from tomato seeds can be considered for obtaining a final product suitable for food, pharmaceutical, and cosmetic applications [21].

Table 2. Fatty acid profile of tomato by-products (%)

Fatty acid, %	Tomato peel residues	Tomato seed oil	Dried pomace
C6:0	0.71 ± 0.04	-	-
C8:0	0.68 ± 0.04	-	-
C12:0	-	-	-
C14:0	1.22 ± 0.15	-	0.41 ± 0.02
C15:0	0.43 ± 0.35	-	0.09 ± 0.03
C15:1	-	-	0.09 ± 0.02
C16:0	35.60 ± 1.00	14.42	16.32 ± 0.65
C16:1	-	-	0.64 ± 0.03
C16:1-9c	-	0.07	-
C17:0	0.49 ± 0.03	-	0.19 ± 0.01
C17:1	-	-	0.52 ± 0.02
C17:1-10c	1.95 ± 0.23	-	-
C18:0	11.96 ± 0.85	3.95	5.43 ± 0.34
C18:1	-	-	18.50 ± 0.83
C18:1-9c	14.59 ± 0.37	17.88	-
C18:2 (n-6)	-	-	51.91 ± 1.91
C18:2-9,12c	13.48 ± 0.23	61.73	-
C18:3 (n-3)	-	-	3.35 ± 0.24
C18:3 (n-6)	-	-	-
C18:3-6,9,12	8.74 ± 0.27	-	-
C18:3-9,12,15	0.69 ± 0.16	1.5	-
C18:4n3	-	-	0.48 ± 0.03
C20:0	1.37 ± 0.03	0.13	-
C20:2n6	-	-	0.15 ± 0.01
C20:3n6	-	-	0.07 ± 0.01
C20:5n3	-	-	0.26 ± 0.01
C22:0	1.17 ± 0.08	-	-
C22:2n6	-	-	0.39 ± 0.02
C22:3n6	-	-	0.55 ± 0.03
C22:3n3	-	-	0.13 ± 0.01
C24:0	1.21 ± 0.06	-	0.29 ± 0.02

3.3. Fiber

Fiber represents a major component of tomato by-products and constitutes a valuable source for nutrition. Dietary fiber is composed of polymers containing ten or more monomeric carbohydrate units, including polysaccharides, oligosaccharides, and lignin. These components are resistant to digestion by human enzymes [29]. Both soluble and insoluble fibers play an important role in modulating glucose absorption and lowering plasma cholesterol levels, thereby contributing to obesity prevention, reducing the risk of cardiovascular diseases and colon cancer, and supporting overall digestive health [29]. During different stages of tomato processing, the neutral detergent fiber content in tomato pomace ranged between 44.8 and 216.6 g/kg on a wet weight basis [30]. Other studies have reported a dietary fiber content in tomato pomace ranging from

50.74 to 59.03 g/100 g [31], of which 40.5 g/100 g represents insoluble fiber [32].

3.4. Minerals

Studies have shown that the most important minerals in tomatoes are potassium (K), phosphorus (P), calcium (Ca), and magnesium (Mg). Other minerals present in smaller amounts, including iron (Fe), zinc (Zn), copper (Cu), sodium (Na), boron (B), and manganese (Mn), have also been reported in tomatoes (Table 3). It has been found that the stage of ripeness [33] and cultivation conditions [34] influence the mineral composition of tomatoes. Mehta et al. [35] highlighted that the incorporation of tomato pomace into bread and muffins led to their enrichment with minerals such as P, Ca, Mg, Fe, and Na.

Table 3. Mineral content of tomato by-products (mg/kg), after [36, 37]

Minerals	Tomato fruit	Tomato peels	Tomato pulp	Tomato seeds	Tomato pomace	Tomato waste
P	160–5160	2620.0–3430	1.5–4	10737.6	-	-
K	900–62920	10970–45830	23–42	9765.3	2686.9	30301.7
Fe	1.81–317.58	15–56.2	16–32	240.9	29.2	56.3
Zn	1.34–40.35	5.30–39.02	17–42	96.8	-	63.3
B	25.84–55.64	25.84–48.59	4.5–16.5	-	-	19.5
Cu	0.39–11.39	2.44–11	1.0–5.8	18.8	-	11.5
Mg	64.5–2655.9	1356.1–2655.9	0.75–1.5	5037.1	281.3	2109.7
Ca	70.8–6020	398.3–1600.	0.60–1.25	1347.6	146.40	1318.5
Mn	0.1–3.6	0.5–14.	5–13	77.7	-	13.5
Na	20.4–320	720–783.3	-	-	210.3	665.5
S	620–830	-	0.8–2.0	-	-	-
Cr	-	-	-	-	-	3.5

3.5. Bioactive compounds

Bioactive compounds present in tomatoes, and their by-products include tetraterpenoids (α - and β -carotene, lycopene, lutein, zeaxanthin, β -cryptoxanthin), tocopherols (tocopherols and tocotrienols), polyphenols (phenolic acids and flavonoids), policosanols, canolols, and phytosterols. These bioactive compounds are distributed in different parts of the tomato. Carotenoids represent one of the main constituents of tomato pomace. Lycopene is a pigment mainly found in tomato peels, which degrades rapidly upon exposure to light, although it is resistant to thermal processing [38]. The lycopene content in tomato pomace varies significantly depending on the tomato variety and extraction conditions. In addition, lycopene has demonstrated very strong

antioxidant activity, one hundred times greater than that of tocopherols [39]. Other bioactive molecules identified in tomato pomace include tocopherols, phytosterols, and vitamin C, which are often extracted together with lycopene and other hydrophilic antioxidant molecules such as flavonoids and phenolic acids [40]. Tocopherols are mainly found in tomato seeds. Individual tocopherols, including α -tocopherol, γ -tocotrienol, γ -tocopherol, and δ -tocopherol, have been identified in tomato pomace. Tomato pomace represents a source of phenolic compounds, such as phenolic acids and flavonoids. The total phenolic content in tomato pomace ranges between 0.94 mg GAE/g and 1.03 mg GAE/g, depending on the extraction techniques used [41]. Bao et al. [41] reported that the main phenolic

compounds in tomato pomace are gallic acid, chlorogenic acid, naringenin, and rutin. Other phenolic compounds, such as p-coumaric acid,

kaempferol 3-O-glucoside, and (+)-catechin, have been identified in tomato pomace extracts obtained using deep eutectic solvents [42].

Table 4. Bioactive compounds in tomato by-products

Sample type	Analyzed component	Extraction / processing method	Content	Reference
Fresh tomato pomace	Total carotenoids	Not specified	9.37 – 10.81 mg/100 g	[43]
Dried tomato pomace	Total carotenoids	Supercritical extraction	CO ₂ 34.86 – 195.99 mg/100 g	[44]
Tomato pomace	β-carotene	Not specified	3.40 – 5.55 mg/100 g	[45, 46]
Tomato peels	Carotenoids (total)	Not specified	up to 288 mg/100 g	[14]
Tomato pomace	Lycopene	Not specified	0.001 – 7.74 mg/100 g	[45, 46]
Freeze-dried tomato pomace	Lycopene	Freeze-drying	32 g/100 g dry matter	[47]
Tomato pomace	Lycopene	Ultrasound-assisted extraction	5.11 mg/g	[48]
Tomato pomace	Lycopene	Drying + extraction methods	5.66 – 59.66 µg/g	[49]
Tomato pomace	α-tocopherol	Not specified	88 – 3600 µg/g	[44, 50]
	γ-tocotrienol		96 – 1655 µg/g	
	γ-tocopherol		17 – 922 µg/g	
	δ-tocopherol		11 – 913 µg/g	
Tomato pomace (dry matter)	β-sitosterol	Not specified	0.68 – 6.21 mg/100 g	[44]
Tomato pomace	β-sitosterol	Not specified	8236 µg/g	[50]
	Campesterol		1359 µg/g	
	Stigmasterol		2027 µg/g	
Tomato pomace	Total phenolic content	Microwave-assisted extraction	2.85 – 17.87 mg GAE/g	[51]
Tomato pomace	Total phenolic content	Ultrasound-assisted extraction	1.81 – 18.65 mg GAE/g	
Tomato pomace	Vanillic acid	Not specified	31.50 µg/g	[40]
	Syringic acid		12.90 µg/g	
	p-Coumaric acid		59.70 µg/g	
	Sinapic acid		32.30 µg/g	
	Myricetin		98.00 µg/g	
	Apigenin		14.70 µg/g	

4. Study on the effects of tomato industry by-products in poultry feed: Effects on zootechnical performance

The valorization of agro-industrial by-products in animal nutrition represents a major research direction, due to both economic pressures and the need to reduce waste and its impact on the environment.

4.1. Use of tomato pomace in laying hens' feed

Most studies report that inclusion levels between 5.00% and 10.00%, and sometimes up to 15-19.00%, do not negatively affect egg production or egg weight (Table 5). Tufarelli et al. [10], found that 15.00% tomato pomace, with or

without linseed meal did not significantly influence production parameters, although yolk color increased. Similarly, heat-treated tomato waste (3–12%) did not affect performance or egg quality, suggesting that moderate inclusion levels may be safe [52]. In contrast, other results indicate both positive and negative responses depending on inclusion level [53]. Moderate supplementation (5–10%) improved feed intake, egg production and yolk color, while reducing feed conversion [54].

Negative effects at higher inclusion levels are mainly associated with increased dietary fiber, which reduces energy density and nutrient

digestibility. Differentiated results were reported by Panaite et al. [55]. Egg yolk color increased linearly with the dose of pomace administered to the hens. One of the arguments frequently invoked in favor of using tomato pomace in the feed of laying hens is its carotenoid content, especially lycopene, which can contribute to the enhancement of yolk color. Other studies [55-57] reported an increase in yolk color score with the supplementation of the diet with tomato-derived by-products. However, these results are difficult to compare between studies, as the source of pomace, the method of tomato processing (air drying, high-temperature drying, fine grinding) and the level of inclusion vary significantly. In addition, many of the published experiments do not rigorously control the intake of other pigments (corn xanthophylls or commercial additives), which limits the exclusive attribution of the effect to tomato compounds. From a mechanistic point of view, these differentiated results from the literature can be attributed to the effects of tomato pomace fiber. Insoluble fibers (cellulose, lignin) are not digestible for the bird and can accelerate intestinal transit, reducing the time available for the absorption of essential nutrients involved in egg synthesis (amino acids, fatty acids, calcium). Although some studies suggest that fiber may have a beneficial effect on intestinal health, this hypothesis is less experimentally supported in laying hens, where energy and nutrient requirements are extremely precise [58-59].

4.2. Use of tomato pomace in broiler chicken feed

In the case of broiler chickens, the main objective is to maximize growth rate and feed conversion efficiency, which makes the impact of fiber and energy density even more critical than in laying hens. The literature on the use of tomato pomace in broiler chickens is also contradictory, reflecting the sensitivity of this production system to relatively small changes in diet composition. In Cobb 500 broiler feed, tomato pomace with addition of 5.00%, 10.00%, 15.00% and 20.00% negatively affected feed intake, weight gain and specific feed intake during the growing period (28

days) [60]. Regarding the carcass weight (g) and the weight of the parts (breast, leg and drumsticks) decreased linearly depending on the use of tomato waste in the pre-initial and initial phase, i.e. up to 28 days of age, but the yield (%) was not affected, except for the yield of heart and liver. The use of tomato pomace in percentages ranging from 8.00%, 16.00%, 24.00% with or without digestive enzyme supplementation, did not show significant differences compared to the control group, in broiler chickens (1 to 35 days) [61]. Similarly, Hady et al. [62] reported that 8.00% or 16.00% tomato pomace with or without digestive enzymes, led to significant results. Growing broiler chickens under heat stress conditions is and remains a challenge for the poultry industry. Thus, the antioxidant potential of tomato pomace was tested with a varied inclusion rate (10.00%, 15.00% and 20.00%) to counteract the effects of heat stress in chickens during the finishing period (4-6 weeks) [63]. At the end of week 6, chickens fed 20.00% tomato pomace had an increase in body weight (2.36 kg) compared to the control group (2.11 kg).

Another approach is the fermentation process. One of the most commonly used methods is solid-state fermentation, which is very useful for the use of agro-industrial residues. The effects of tomato pomace compared to tomato pomace fermented with *Aspergillus niger* on growth performance in broilers were evaluated with a 1.00% pomace supplement [64]. The results showed an increase in serum glutathione peroxidase (GPx) and superoxide dismutase (SOD), but did not affect growth performance, while fermented pomace in the diet improved feed conversion ratio and increased serum GPx and SOD [64]. An important aspect, often underestimated, is the variability of the chemical composition of tomato pomace [65]. The protein, fiber and energy content can vary considerably depending on the tomato variety, degree of maturity, processing method and proportion of seeds. This variability partly explains why the results in the literature are often divergent and raises serious problems for practical application on an industrial scale.

Table 5. Effect of tomato pomace on laying hens and broiler chickens' production performances

Inclusion level	Species	Observed effects	References
15% + 4% or 8% flaxseed meal	Laying hens	No significant effects on performance were recorded. Yolk color increased significantly.	[10]
3%, 6%, 9% or 12%	Laying hens	No significant effects on performance were recorded.	[52]
15%, 17%, or 19%	Laying hens	No significant effects on performance or egg characteristics were recorded.	[53]
5% or 10%	Laying hens	Increased feed intake, egg production, egg weight and yolk color and a decrease in specific feed intake. Shell weight, shell thickness and Haugh unit were not affected.	[54]
17%	Laying hens	Decreased egg weight and increased egg production. Did not affect egg characteristics or egg yolk color.	[56]
4%	Laying hens	Increased feed intake, egg weight and egg production compared to the control group. The yellow color of the egg yolk (a) increased significantly compared to the control.	[57]
2.5%, 5%, or 7.5% + 5% flaxseed meal	Laying hens	The groups with 5% and 7.5% tomato pomace had a significantly lower average daily feed intake and egg laying percentage compared to the control group. The group with 2.5% pomace had the highest egg laying percentage but still lower than the control group.	[55]
5%, 7.5% or 10%	Laying hens	Increased egg production, egg weight and egg mass. No effects on serum and yolk cholesterol content.	[8]
8% or 16% with enzyme	Broiler chickens	The use of 16% tomato waste as an enzyme supplement significantly increased feed consumption and chick weight and significantly decreased specific intake.	[62]
8% or 16% without enzyme	Broiler chickens	The use of 8% tomato waste without enzymes led to the best results regarding productive performance.	[62]
4% or 6%	Broiler chickens	The productive parameters were not influenced.	[66]
3%, 6% or 9%	Broiler chickens	In the starter phase, no significant differences were reported.	[67]
6%, 9% or 12%	Broiler chickens	In the growth phase, tomato waste without enzyme supplement, the average daily gain decreased, but insignificantly.	[67]
9%, 12% or 15%	Broiler chickens	In the finishing phase, the average daily consumption increased significantly. Enzyme supplementation decreased feed consumption.	[67]
3% or 5%	Broiler chickens	The high level counteracted the effects of thermal stress induced by high temperature.	[68]

5. Effects of tomato industry by-products in poultry feed: impact on egg quality

By-products from the tomato processing industry represent an accessible, cost-effective alternative resource with significant potential for use in laying hen feed. Among them, tomato pomace stands out for its high content of proteins, vitamins, and carotenoids, such as α -tocopherol, lutein, β -carotene, and lycopene. These compounds exhibit strong antioxidant activity and can reduce oxidative stress when included in laying hen diets [69]. However, high inclusion levels may influence egg quality particularly yolk color, antioxidant capacity and oxidative stability, which highlights the importance of establishing optimal inclusion rate in diets [10].

Yolk color is an important criterion for consumers, often associated with higher nutritional value and quality. Lycopene, the pigment responsible for the characteristic red color of tomatoes, can be partially deposited in the yolk when tomato by-products are included in the diet contributing to improved nutritional value and lipid profile by increasing HDL and reducing LDL cholesterol [70]. However, the chemical composition and nutritional value of these by-products can vary depending on the cultivation conditions and processing methods, which determine differences in the optimal level of inclusion [71]. One of the most commonly reported effects is the enhancement of yolk color, due to the high content of carotenoids, especially

lycopene, lutein and zeaxanthin. Table 6 presents their use in laying hen feed. a summary of tomato industry by-products and

Table 6. Tomato industry by-products used in laying hen feed

Bird type	By-product used	Inclusion level	Main findings	Reference
Tetra SL (42 weeks)	Tomato peels	2%	-increase content of vitamin E in eggs ($P < 0.05$); -delay in the lipid peroxidation process of eggs by 15%-25% after 40 days of storage.	[72]
Tetra SL (28 – 37 weeks)	Dried whole tomato; Dried tomato pomace	4%	-enhancing the yolk color score; -increasing the antioxidant content of yolks; -improving the oxidative stability of yolk lipids, evidenced by reducing MDA concentrations in both fresh eggs and those stored for 30 days at 4 °C.	[73]
Hy-Line W-36 White Leghorn (57 weeks)	Tomato pomace	15%	- intensification of the yolk color; -optimal inclusion level 5–15%, without affecting egg quality.	[10]
Lohmann LSL-Lite (65 weeks)	Dried tomato pomace	15%, 17%, 19%	-enhancement of yolk color score; -no differences in terms of egg weight and mass, eggshell weight and thickness, or Haugh unit; -no significant effects for serum levels of total protein, cholesterol, LDL, HDL, albumin, glucose, and triglycerides.	[53]
Hy-Line W-36 (33 weeks)	Tomato pomace	4%, 8%, 12%	- reduced serum cholesterol levels ($P < 0.05$); -improved egg yolk color; -no effects on egg mass and quality characteristics (specific gravity, yolk index, shell thickness and weight, Haugh unit).	[74]
Hy-Line W-36 (65 - 73 weeks)	Dried tomato pomace	5%, 7.5%, 10%	-both egg weight and mass, as well as eggshell weight, were significantly affected ($P < 0.05$); -no significant effects ($P < 0.05$) on serum and yolk cholesterol content; -optimal inclusion levels were up to 10%, without producing negative effects on egg performance or quality.	[8]
White leghorn (41 weeks)	Tomato waste meal	6.5%, 13%, 19.5, 26%	-significant increase ($P < 0.001$) in yolk color intensity with increasing inclusion level in the rations;	[75]
Tetra SL (53 weeks)	Dried tomato waste	2.5%, 5.0%, 7.5%	-intensification of the Roche color score in egg yolk; -inclusion levels of 5% and 7.5% led to increased concentrations of lutein and zeaxanthin in yolks; -prevention of lipid oxidation of eggs at an inclusion level of 5%.	[55]
Isa Brown (32 weeks)	Boiled tomato waste	3%, 6%, 9%, 12%	-decrease in total cholesterol content in yolks; ($P < 0.05$); -intensification of the color index of yolks ($P < 0.05$); -12% was the optimal level for reducing yolk cholesterol and improving their color.	[76]
Rhode Island red (36 weeks)	Tomato waste meal	3%, 6%, 9%	-egg weight, Haugh unit and yolk index were not influenced by the experimental recipes; -intensification of yolk color concomitant with the level of inclusion in the diet; -increase in carotenoid and lycopene concentration proportional to the inclusion rate; -reduction in yolk lipid content, including cholesterol, in the experimental groups with 6% and 9% tomato waste meal.	[77]

6. Study on the effects of tomato industry by-products in poultry nutrition: implications for broiler meat quality

Tomatoes and their derivatives, including extracts and by-products, are recognized as valuable sources of nutrients and bioactive compounds

such as lycopene and other carotenoids, which exhibit antioxidant properties and confer health benefits.

In a study conducted by Mohammed et al. [66], diets supplemented with tomato pomace–showed improvements in meat quality, including reduced

lipid oxidation, improved color and better water retention capacity. Adeyemi & Olorunsanya [78] showed that tomato powder improved oxidative stability and sensory characteristics of the meat, without negative effects on technological quality. Selim et al. [79] also reported improved oxidative stability without affecting chemical composition. Similarly, Sahin et al. [80] demonstrated that lycopene supplementation enhances antioxidant status and reduces lipid peroxidation in broiler meat. Dotas et al. [81] and Hidayat et al. [82] reported improvements in meat quality traits such as pH stability, color and water-holding capacity following the inclusion of tomato-derived compounds. Wu et al. [83] further highlighted improvements in meat tenderness and color, while Boulaajine et al. [84] observed positive effects on both visual and nutritional quality of the meat.

Güngör [85] emphasized that processing methods such as fermentation may enhance the technological quality of meat, likely due to improved bioavailability of bioactive compounds. In addition, studies such as those of Olumide [86] and Ishola et al. [87] reported improvements in sensory characteristics and overall meat quality, along with favorable effects on body composition. According to the analyzed studies, the positive effects of tomatoes and their by-products on broiler meat quality are primarily attributed to their antioxidant compounds, particularly lycopene, carotenoids, and phenolics. These compounds reduce lipid peroxidation and improved oxidative stability. Additionally, they contribute to the intensification of meat redness (a*) and may influence water-holding capacity and muscle texture.

Table 7. Effects of tomatoes, by-products, and extracts used in broiler chicken diets

Ingredient type	Inclusion level	Meat quality parameters evaluated	Main effects on meat	References
Tomato pomace	5%, 10%, 15%	Meat quality, TBARS, post-mortem pH, color (a*), WHC, antioxidant gene expression	Improved meat quality, reduced TBARS, stabilized post-mortem pH, enhanced redness (a*), increased WHC, upregulation of antioxidant gene expression	[66]
Dried tomato pomace	5–10%	TBARS, chemical composition, oxidative stability	Reduced TBARS, improved oxidative stability, no negative effects on composition	[79]
Fermented tomato pomace	5–10%	WHC, post-mortem pH	Increased WHC, improved pH stability, superior technological quality	[85]
Tomato powder	2–6%	Oxidative stability, sensory characteristics (color, flavor, acceptability)	Significant TBARS reduction, improved color and flavor, maintained technological quality	[78]
Lycopene	50–100 mg/kg	Antioxidant enzymes, lipid peroxidation, meat quality	Increased antioxidant enzyme activity, reduced lipid peroxidation, improved oxidative stability	[80]
Lycopene	20–40 mg/kg	TBARS, cooking losses	Reduced TBARS, decreased cooking losses, increased WHC, enhanced antioxidant protection	[82]
Lycopene	10–30 mg/kg	pH, L*, a*, b*, shear force	Improved pH, enhanced color, reduced shear force → more tender meat	[83]
Tomato by-products	5%	Post-mortem pH, color (a*)	Stabilized pH, increased redness (a*), improved commercial appearance	[81]
Tomato by-products	3–6%	Color, mineral composition	Improved color and mineral content, enhanced nutritional and visual quality	[84]
Tomatoes and derived products	Not specified	Sensory quality (color, flavor, juiciness, acceptability)	Improved sensory scores, reduced oxidative processes, no negative effects on quality	[86]
Tomato powder + spices	Not specified	Performance, meat quality, abdominal fat, physical and oxidative parameters	Improved oxidative stability, enhanced quality of commercial cuts, reduced abdominal fat; synergistic antioxidant and metabolic effects	[87]

In practical terms, the inclusion of tomatoes, tomato by-products, or extracts in broiler diets can be considered an effective strategy for improving

meat quality by reducing lipid oxidation, stabilizing color and post-mortem pH, increasing water-holding capacity, and enhancing sensory

characteristics. Moderate inclusion levels (typically 5–10% for pomace or 10–50 mg/kg for pure lycopene) appear to provide optimal benefits without negative effects on chemical composition or performance. Furthermore, the use of tomato by-products, including through fermentation or in combination with spices, offers increased nutritional and economic value, representing a sustainable solution for the valorization of agro-industrial waste and optimization of poultry feeding strategies.

Conclusions

In conclusion, the valorization of tomato processing residues in poultry feeding represents a promising strategy for enhancing the nutritional quality of animal products, reducing environmental impact, and improving the sustainability of agri-food systems. Future research should focus on standardizing the chemical characterization of these by-products, optimizing inclusion levels under different production conditions, and developing innovative processing technologies to maximize their bioavailability and functional effects.

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