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RESEARCH ARTICLE

Valorization of Tomato Processing By-Products in Livestock Feed: Nutritional Value and Inclusion Rates

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ABSTRACT

This study evaluated the effects of substituting corn with tomato byproducts (TBP) on growth performance, carcass characteristics and meat quality in broiler chickens. Two hundred one-day-old "Isa F15" chicks (average initial weight: 35±2g) were randomly allocated to four groups (50 birds/group) with different TBP inclusion levels (0%, 10%, 20% and 30%) over a 48-day trial period. Significant reductions ($p<0.05$) in live weight, average daily gain (ADG) and feed intake at 20% and 30% inclusion. Higher feed conversion ratios (FCR) at elevated levels (2.45 and 2.33 for 20% and 30% respectively). The 10% substitution group showed acceptable performance (final weight: 2206g; ADG: 61.46 g/day; FCR: 2.57). High inclusion (≥20%) negatively affected carcass yield, no significant impact on meat quality parameters. In conclusion, While 10% tomato byproduct substitution proved nutritionally viable, higher inclusion levels (≥20%) significantly impaired broiler productivity. These findings suggest a practical upper limit for (TBP) utilization in broiler diets without performance compromise.

INTRODUCTION

In low-income, food-deficient developing countries, poultry meat and eggs account for about 20 to 30% of total animal protein intake. However, poultry feed remains one of the main challenges in ensuring efficient poultry production in these regions (FAO, 2024). In Algeria, population growth is driving a continuous increase in demand for animal products, requiring improvements in sector efficiency to meet the rising need for protein. Yet, as in many developing countries, poultry production faces significant challenges, particularly regarding the availability and quality of poultry feed-regardless of the scale or type of production. Feed constitutes the largest component of total production costs. In Algeria, livestock production costs are heavily affected by imports of raw materials needed for feed formulation, making meat products vulnerable to fluctuations in the exchange rate between the Algerian dinar and foreign currencies (Meziane et al., 2013).

Although growth performance (Narinc et al., 2013) and meat quality (Narinc et al., 2017) are primarily determined by intrinsic factors, animal feed accounts for 70% of production costs (Guermah et al., 2016; El-Wardany et al., 2016; Thirumalaisamy et al., 2016) a significant portion also influenced by fluctuations in global market prices. This situation drives up costs, making meat products unaffordable for low-income households. viable solution involves incorporating agricultural and agro-industrial by-products into livestock feed formulations (Cherif et al., 2022; Ouzzir et al., 2020; Arbouche et al., 2014; Baa et al., 2019; Sissaoui, 2016; Sissaoui et al., 2025). This approach helps stabilize or even reduce production costs. Notably, by-products from tomato processing can play a key role in this strategy.

The tomato processing industry generates residual biomass, including tomato waste composed of skins, seeds, pulp, and non-compliant tomatoes (Peiretti et al., 2013). Using tomato by-products as animal feed offers a solution to reduce waste management challenges, which are subject to strict regulations and represent a significant cost for the industry (Vasta et al., 2008). Due to its high moisture content (approximately 75%), drying is often necessary, though it can also be preserved through ensiling (Denek& Can, 2006). Its chemical composition, which varies depending on extraction methods, is characterized by high levels of fermentable fiber, proteins, and lipids from residual seeds (Del Valle et al., 2006; Wang et al., 2014).

The oils extracted from seeds predominantly contain fatty acids such as oleic acid and linoleic acid (Romano et al., 2010). Furthermore, tomato pomace represents a concentrated source of carotenoids (particularly lycopene), along with vitamins C and E - all recognized for their antioxidant activity, whether used in animal feed or as additives in meat products (Andrés et al., 2017; Marcos et al., 2019; Azabou et al., 2020; King &Zeidler, 2004; Karadas et al., 2006). The use of tomato waste in poultry feed has been investigated by several researchers (Boulaajine et al., 2024; Gungor et al., 2023; Shengyong et al., 2022; Reda et al., 2022; Omar et al., 2019; Hosseini-Vasha et al., 2016; Melkamu, 2013; Rezaeipour et al., 2009). These studies collectively demonstrate that broilers can effectively utilize tomato byproducts at inclusion rates up to 15%.

However, this optimal incorporation level may vary as the chemical composition and nutritional value of this byproduct depend on growing conditions, soil type, fertilization practices, and processing methods. However, data regarding the impact of incorporating these byproducts in broiler diets remain limited. This study therefore aimed to evaluate the effect of a tomato waste-enriched diet on growth performance and carcass characteristics of broiler chickens. These feed sources were selected based on their availability, chemical composition, and nutritional value (Arbouche et al., 2012, 2018).

MATERIALS AND METHODS

Study Period and Location

Our experiment was conducted in the Jijel Province, located in northeastern Algeria. The trial took place during September-October 2023. During this period, the average temperature and humidity were 18°C and 82%, respectively. The poultry house was a closed-type building with static ventilation. The litter consisted of wood shavings, the water supply was of good quality, and gas brooders provided heating.

Animals, Feed, and Experimental Protocol

Two hundred (200) one-day-old ISA F15 strain chicks with an average weight of 35±2g were obtained from a hatchery located in Bejaia. The chicks were divided into four homogeneous groups: three experimental groups and one control group (50 chicks/group). Each group occupied an area of 6.25 m^2, resulting in a stocking density of 10 birds/m^2. The tomato by-products were collected fresh during industrial tomato processing at the Guelma factory. The tomato by-products were dehydrated before being incorporated into the feed ration.

The tomato byproducts, once collected from the factory, were sun-dried for five days. Prior to their incorporation into feed, the chemical composition of the tomato byproducts was analyzed to accurately estimate the final product's nutrient profile, ensuring it would meet the approximate nutritional requirements of broilers.

Four experimental diets were formulated, containing 0%, 10%, 20%, and 30% dehydrated tomato by-products as partial substitutes for corn (table 1). These diets were administered to the four experimental groups throughout the three rearing phases.

The temperature was maintained between 36°C and 38°C during the first 10 days of rearing, then gradually reduced by 2-3°C each week. Continuous lighting (24 hours/day) was provided initially, later reduced to 18 hours with 6 hours of night lighting. Chicks were vaccinated against Newcastle disease and infectious bronchitis at 7 and 21 days of age, and against Gumboro disease at 14 days of age (single-dose vaccine). Additionally, an anticoccidial agent was administered in drinking water at 17 and 34 days of age for two consecutive days.

The feed was provided as mash and distributed ad libitum along with water. Leftover feed was weighed daily. Body weight (BW), average daily gain (ADG), and feed conversion ratio (FCR) were measured every 10, 20, 33, and 48 days for each group. Daily feed intake (FI) was recorded. Mortality was monitored daily throughout the trial period.

On day 49, 25 randomly selected chickens from each group were slaughtered. Live weight, hot and cold carcass weights, as well as weights of legs, head, feathers, gizzard, viscera, and liver were recorded. Standard slaughter procedures (stunning, bleeding, plucking, and evisceration) were followed. PH was measured directly in the muscle 24 hours post-mortem using a pH meter electrode. The chemical composition of the meat was determined according to the El Rammouz method (2005). Protein, fat, and mineral contents were analyzed and calculated following AOAC (2005) methods.

Table 1. Formulas (kg/100 kg of feed) for starter (1 to 20 days), grower feed (21 to 33 days), and finisher feed (34 to 48 days) distributed to the chickens according to the substitution rate of corn by dehydrated tomato.

Composition	Starter				Grower				Finisher			
Substitution rate (%)	0	10	20	30	0	10	20	30	0	10	20	30
Ingredients (kg/100kg)												
Corn	61	54.9	48.8	42.7	64	57.6	51.2	44.8	70	63	56	49
T.D	0	6.1	12.2	18.3	0	6.4	12.8	19.2	0	7	14	21
Soybean meal	30	30	30	30	27	27	27	27	21	21	21	21
By-products of milling	6	6	6	6	6	6	6	6	6	6	6	6
Bi-calcium phosphate	1.5	1.5	1.5	1.5	1	1	1	1	1	1	1	1
Limestone	0.5	0.5	0.5	0.5	1	1	1	1	1	1	1	1
MVS	1	1	1	1	1	1	1	1	1	1	1	1
Nutrient content as % of DM												
Metabolizable energy (kcal/kg)	2995	2980	2975	2896	3004	3054	3034	2907	3120	3105	3002	2989
Crude protein (%)	18.93	19.13	19.35	19.92	17.85	18.92	18.29	18.51	15.7	15.94	16.18	16.42
Fat content (%)	3.15	2.38	2.16	1.95	2.66	2.45	2.22	2	2.84	2.60	2.57	1.48
Mineral matter (%)	2.76	4.6	6.44	8.29	2.62	4.55	6.49	8.43	2.35	4.46	6.58	8.7
Crude fiber (%)	3.53	4.07	4.63	5.18	3.38	3.96	4.51	5.12	3.1	3.73	4.37	5
Lysine (%)	1.07	1.12	1.17	1.21	1	1.04	1.09	1.14	0.83	0.89	0.94	1
Methionine (%)	0.32	0.32	0.34	0.35	0.30	0.32	0.33	0.34	0.28	0.29	0.30	0.31
Cysteine (%)	0.33	0.34	0.35	0.36	0.31	0.32	0.33	0.34	0.28	0.29	0.30	0.31

MVS (mineral-vitamin supplement) composed of:

Calcium: 16.8%

Magnesium: 0.1%

Sodium: 12.8%

Chlorine: 20.5%

VitaminA: 750,000 IU

VitaminD3: 160,000 IU

Vitamin E: 1,280 mg/kg

Vitamin B1: 100 mg/kg

Vitamin B2: 300 mg/kg

Calcium Pantothenate: 570 mg/kg

Niacin: 1,750 mg/kg

Vitamin B6: 99 mg/kg

Vitamin K3: 190 mg/kg

Folic Acid: 35 mg/kg

Biotin: 1 mg/kg

Choline Chloride: 25,000 mg/kg

Iron Carbonate: 2,500 mg/kg

Copper (sulfate): 970 mg/kg

Zinc (sulfate): 6,080 mg/kg

Manganese (oxide): 7,500 mg/kg

Iodine (iodate): 120 mg/kg

Selenium (selenite): 25 mg/kg

Other additives:

DL-Methionine: 180 g/kg

Antioxidant

Citric Acid

Orthophosphoric Acid.

Statistical Analyses

Descriptive statistics and analysis of variance using the univariate general linear model (ANOVA) were conducted with SPSS software (Version 26, 2012). The general linear model was applied to test the effects of factors (ration) on variables (BW, ADG, FI, FCR, and various slaughter yields). Post hoc tests comparisons were conducted using the SNK (Student-Newman-Keuls) were used to estimate the significance or homogeneity between between different subsets (mean comparison tests). Diffrenceswere considered significant at a 5% error risk.

RESULTS AND DISCUSSION

Chemical Composition

Table 2. Chemical Composition of Dehydrated Tomato (DT) in % Dry Matter (DM).

Chemical composition	Content
Dry matter (DM)	82.03
Organic matter (OM) (% of DM)	68.31
Protein (% of DM)	11.58
Crude fiber (CF) (% of DM)	11.30
Fat content (FC) (% of DM)	0.25
Mineral matter (MM) (% of DM)	31.69
Nitrogen-free extract (% of DM)	27.21
NDF	45.65
ADF	22.54
ADL	11.15
Gross energy (GE) (Kcal/kg of DM)	4035
Metabolizable energy (ME)* (kcal/kg of DM)	2251.19
Lysine (Lys) (g/100g of proteins)	1
Methionine (Meth) (g/100g of proteins)	0.36
Cystine (g/100 g of proteins)	0.31

DM: dry matter

∗ Estimated according to the formula developed by Carpenter and Clegg (1956) with ME (kcal/kg of DM) = 35.3 x CP (%) + 79,5 x EE (%) + 40.6 x NFE (%) + 199 (EM: metabolizable energy, PB: crude protein, EE: ether extract, NFE: nitrogen-free extract).

Growth Performance

Table 3. Growth Performance Evolution during Starter, Grower, and Finisher Phases in Broilers Fed Diets with Varying Inclusion Levels of Dehydrated Tomato By-products as Corn Replacement.

	Percentage of corn replaced by dehydrated tomato by-products				SEM	P
	0	10	20	30		
Starter phase						
Initial Weight (g)	35	35	35	35		
Weight on 10 days (g)	180[a]	178[a]	145[d]	120[c]	2.62	0.03
ADG_{1-10j} (g/d/animal)	14.55[a]	14.36[b]	11.05[a]	8.57[c]	0.26	0.03
Weight on 20 days (g)	542[a]	515[b]	460[c]	405[d]	8.20	0.04
ADG_{11-20j} (g/d/animal)	36.16[a]	33.66[a]	31.46[b]	28.44[b]	1.15	0.02
ADG_{1-20j} (g/j/sujet)	25.35[b]	24.01[a]	21.25[b]	18.50[c]	0.46	0.01
Growth phase						
Weight on 33 days (g)	1394[a]	1284[b]	1105[c]	984[b]	2.31	0.03
ADG_{21-33j} (g/d/animal)	65.56[a]	59.16[a]	49.61[b]	44.55[b]	1.49	0.04
Finisher phase						
Weight on 48 days (g)	2405[a]	2206[b]	2010[ab]	1848[b]	42.43	0.02
ADG_{34-48j} (g/d/animal)	67.42[b]	61.46[a]	60.32[a]	57.64[c]	1.20	0.02
ADG_{1-48j} (g/d/animal)	49.39[b]	45.23[a]	41.15[a]	37.78[b]	0.78	0.01

ADG: Average daily gain

The Presence of different letters on the same line indicates a significant difference between diets treats ($p < 0.05$). Data are presented as mean ± standard error of the mean (SEM).

No mortality was recorded during the whole breeding in all groups. During the starter phase, the growth performance (BW and ADG) showed similar body weights between the control group (0% substitution) and the 10% substitution group. During the starter phase, body weights were similar between the control (0% substitution) and 10% substitution groups (180g vs 178g). However, a significant growth retardation (p=0.03) was observed in the 20% and 30% substitution groups (145g and 120g respectively), indicating negative impacts as early as 10 days post-hatching with high substitution rates.

By day 20, the control group maintained superiority (542g), followed by the 10% (515g), 20% (460g) and 30% (405g) groups, with notable declines in ADG (Average Daily Gain) starting at 10% substitution (36.16 g/d at 0% vs 28.44 g/d at 30%). Substitutions ≥20% significantly impaired early growth performance, likely due to reduced digestibility or nutritional imbalances.

Our findings contrast with Aragaw*et al* (2022) who reported improved performance in Cobb 500 broilers fed 6-9% tomato waste meal compared to controls. During the grower phase, the control group dominated (1394g), while substitution groups (10%, 20%, 30%) showed growth deficits (1284g to 984g) (P=0.03). The 30% group exhibited the most pronounced difference, with ADG decreasing by >20g/day versus controls.

The negative effects appeared dose-dependent, particularly during critical growth phases. While Yitbarek (2013) reported no growth impairment at 20% dried tomato waste inclusion, Yalao and Yamuen-art (2016) observed improved BW and ADG at 10-20% in Cobb 500 broilers (4-6 weeks). Conversely, Rezaeipour*et al.* (2009) found 15-20% inclusions reduced performance in Ross 308 broilers (21-42 days). Hosseini-Vashan*et al.* (2016) demonstrated that 5% tomato product (TP) supplementation enhanced body weight and production index in 1-28 day-old broilers.

During the finisher phase, final weights were 2405g (control) versus 1848g (30% group) - a 550g reduction. All substitution groups had lower ADG (61.46 g/d at 10% vs 67.42 g/d at 0%). Overall ADG (1-48 days) decreased progressively with increasing substitution rates. Lu et al. (2022) recommended not exceeding 15% tomato waste in poultry diets, though ducks tolerated 20% - possibly due to physiological differences (Yalcin and Siegel, 2003). Corn serves as the primary energy source, and its excessive replacement by fiber-rich tomato byproducts (skins/seeds) may impair digestion, palatability, and performance. Substitution up to 10% appears acceptable without major adverse effects.

Feed Intake and Feed Conversion Ratio (FCR)

This table presents the impact of replacing corn with dehydrated tomato byproducts (0%, 10%, 20%, and 30%) on feed intake and the feed conversion ratio (FCR) in broiler chickens, divided into three phases: starter (1-20d), grower (21-33d), and finisher (34-48d).

Table 4. Evolution of Feed Intake (FI) and Feed Conversion Ratio (FCR) during the Starter, Grower, and Finisher Phases in Broiler Chickens Based on the Percentage of Corn Substitution with Dehydrated Tomato Byproducts

		Percentage (%) of corn replaced by dehydrated tomato by-products				**SEM**	**P**
		0	**10**	**20**	**30**		
Starter phase (1 to 20d)	Daily feed intake (g)						
	From 1 to 10 days	180^a	175^a	140^b	130^c	1.53	0.01
	From 11 to 20 days	668^a	650^b	580^c	550^a	6.82	0.01
	From 1 to 20 days	849^a	825^b	721^c	680^a	7.85	0.02
	Feed efficiency (g/g)						
	From 1 to 10 days	1.00^a	0.98^a	0.96^a	1.07^b	0.035	0.04
	From 11 to 20 days	1.23^a	1.26^b	1.26^b	1.35^d	0.466	0.008
	From 1 to 20 days	1.56	1.60	1.56	1.67	0.045	0.03
Growth phase (21 to 33d)	Daily feed intake (g)	1748^a	1735^a	1235^b	985^c	12.54	0.04
	Feed efficiency (g/g)	1.25^a	1.35^b	1.11^b	1.00^a	1.87	0.05
Finisher phase (34 to 48 d)	Daily feed intake (g)	3285^a	3125^a	2980^b	2654^c	20.56	0.02
	Feed efficiency (g/g)	1.36^a	1.41^b	1.48^b	1.40^a	0.127	0.04
Breeding cycle (1to 48d)	Daily feed intake (g)	5883^a	5686^a	4937^b	4320^c	54.8	0.03
	Feed efficiency (g/g)	2.44^a	2.57^b	2.45^a	2.33^{ab}	0.33	0.01

The Presence of different letters on the same line indicates a significant difference between diets treats ($p < 0.05$). SEM= Standard error of the mean

The results show that during the starter phase, a significant reduction was observed starting at 20% substitution (180g at 0% vs. 130g at 30%). At the age of 11-20 days, a progressive decrease was recorded (668g at 0% vs. 550g at 30%). By the end of this phase, a linear decrease was observed with increasing substitution levels (849g at 0% vs. 680g at 30%). In contrast, there was an increase in the feed conversion ratio (FCR) at 30% substitution (1.00 at 0% vs. 1.07 at 30%). This aligns with studies showing that substitution levels exceeding 10% reduce feed intake and impair FCR in young chicks (an effect likely linked to palatability or fiber digestibility).

Our findings differ from those reported by Ayhan and Aktan (2004), who observed no significant differences in FCR among groups fed diets containing varying levels of dried tomato pomace during the first 0-3 weeks of age. During the grower phase, a drastic decline in feed intake was observed starting at 20% substitution (1748g at 0% vs. 985g at 30%). The best-feed conversion ratio (FCR) was recorded in the 30% substitution group (FCR: 1.00), but deteriorated at 10-20% (1.35). Our results agree with those of Mohammed et al. (2021), where moderate substitution (10-20%) may compromise feed efficiency, while a higher rate (30%) reduces intake but paradoxically improves FCR (possibly due to metabolic adaptation).

During the finisher phase, feed intake significantly decreased at 30% substitution (from 3285g to 2654g), with FCR deterioration at 20% (1.48) but stabilization at 30% (1.40). These results align with findings reported by Yitbarek (2021): broilers appear to partially adapt during the finisher phase, though substitution exceeding 20% maintains a negative impact on consumption. From these results, we can conclude that the feed conversion ratio improves at 30% despite reduced intake, suggesting enhanced metabolic efficiency at higher inclusion levels, as observed in ducks (Tamasgen et al., 2021). The reduction in final weight indicates that this 'efficiency' does not compensate for the growth loss.

Slaughterhouse Products

Table 5. Changes in Slaughter Yields and Meat Chemical Composition According to Substitution Rate (at 49 Days).

Parameters	Substitution rate %				SEM	P
	0	10	20	30		
Live weight (g)	2508^{c}	2245^{a}	2152^{b}	1986^{b}	124.1	0.01
Hot carcass weight (g) Hot carcass yield (%)	1755^{c} 69.9^{b}	1585^{a} 70.6^{a}	1530^{a} 71.0^{a}	1410^{b} 70.9^{b}	42.58 0.14	0.01 0.01
Cold carcass weight (g) Cold carcass yield (%)	1605^{c} 64.0^{b}	1490^{a} 66.3^{a}	1435^{a} 66.6^{a}	1234^{b} 62.1^{c}	46.2 1.85	0.01 0.01
Visceral weight (g)	229	220	198	184	5.1	0.98
Weight of head (g)	68	65	62	64	7.54	0.35
Weight of feet (g)	102	98	95	98	12.64	0.45
Weight of feathers (g)	145	144	146	135	12.04	0.84
Weight of liver (g) Pf/Pvaratio (%)	62^{a} 2.47^{a}	58^{a} 2.58^{b}	55^{b} 2.55^{b}	50^{b} 2.52^{b}	7.85 0.55	0.03 0.01
Weight of gizzard (g) Pg/ Pv ratio (%)	65^{b} 2.59^{b}	70^{a} 3.11^{a}	64^{b} 2.97^{a}	62^{b} 3.12^{a}	10.06 0.85	0.02 0.02
Chemical composition of the meat pH Crudeprotein content Fat content Mineral content	 6.25^{a} 17.50^{b} 3.09^{a} 0.78^{b}	 6.23^{a} 17.39^{a} 2.98^{b} 0.88^{a}	 6.20^{a} 16.30^{b} 2.88^{b} 0.84^{a}	 6.15^{b} 15.20^{b} 1.94^{d} 0.98^{a}	 0.036 0.65 0.187 0.145	 0.01 0.004 0.001 0.02

The Presence of different letters on the same line indicates a significant difference between diets treats ($p < 0.05$). SEM= Standard error of the mean

The slaughter yield results revealed a significant decrease (p=0.01) in live weight with increasing substitution rates (2508g at 0% vs. 1986g at 30%). This trend aligns with findings by Hassan et al. (2024) and Rezaeipour*et al.* (2012), who reported that high inclusion levels of tomato byproducts might reduce live weight, likely due to lower digestibility or nutritional imbalances. A slight improvement in hot carcass yield was observed at 10–20% substitution (70.6–71.0%) compared to the control group (69.9%), but it declined at 30% (70.9%). Similarly, cold carcass yield peaked at 10–20% (66.3–66.6%) before dropping at 30% (62.1%).

These results partially differ from those of Café et al. (2002), who observed no significant impact on carcass yield with 5-15% byproduct inclusion. The decline at 30% suggests a critical threshold beyond which substitution impairs growth performance. Liver weight decreased from 20% onward (p=0.03), though yield (percentage) remained stable, while gizzard weight peaked at 10% (70g) before declining. Our findings align with Lira *et al.* (2010), who reported no significant liver differences at 5% substitution, but contrast with Tabook*et al.* (2006)'s observations on fiber effects on visceral organ development. The pH showed a slight decrease (6.25 to 6.15) while remaining within acceptable limits, indicating no detrimental impact on technological quality. These findings align with Sahin*et al.* (2008), who reported no significant pH modifications with moderate byproduct incorporation (5-10%). A significant reduction in protein content was observed from 20%

substitution onward (17.5% to 15.2%), accompanied by a progressive decline in fat content that was most pronounced at 30% inclusion (1.94% vs 3.09%).

This correlation supports the findings of Kachenpukdee*et al.* (2016) ; King and Zeider (2004), who associated these effects with both the fiber-mediated lipid dilution and the antioxidant properties (particularly lycopene) of tomato byproducts that inhibit fat deposition. Mineral content demonstrated a consistent increase from 10% substitution (0.78% to 0.98%). The discrepancy with Café *et al.* (2002) suggests the test substitute has elevated ash content, potentially rich in minerals like calcium and phosphorus.

CONCLUSION

The study shows that incorporating dried tomato waste at a rate of 10% into the feed has no negative effect on zoote chnical performance, carcass characteristics, or animal health. However, at 20% or more, performance drops significantly, confirming that the digestibility and nutritional value of tomato by-products are lower compared to corn. Thus, dietary supplementation with tomato by-products had a positive effect on zootechnical performance and most of the biochemical parameters of chicken meat. These results suggest that tomato by-products can be a cost-effective feed supplement.

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