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RESEARCH ARTICLE

Impact of Agro-Industrial Waste Supplemented Diet on Lipid Profile and Oxidative Stability of Broiler Meat

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ABSTRACT

The increasing population has led to the rising demand of poultry meat and eggs due to its exceptional nutritional value. To meet these environmental demands, studies are being conducted on innovative approaches to enhance the sustainability of poultry feed. Research has depicted alternative feed formulations that are low-cost yet high in nutrition. Fruits processing industries produce plethora of fruits waste every year. The utilization of agro-industrial (fruit) waste is considered as a potential source of low cost, highly nutritious poultry feed. In current research study fruits (apple, mulberry, apricot and pomegranate) waste (peel, pomace and leaves), rich in dietary fiber, protein, vitamins, minerals, amino acids, antioxidants, bioactive phytochemicals, tocopherols, flavonoids, polyphenols, phyto-sterols and essential fatty acids were focused to enrich poultry feed. Study results showed that with increasing concentration of fruits waste from T_0 (Controlled diet) to T_4 (87.5% commercial diet and 12.5% supplementation) in poultry feed, the phenolic content and antioxidants potential was increased (TPC: T_o = 0.25 g GAE/g → T_4 =0.67 mg GAE/g, DPPH: T_0 =1.64 → T_4= 2.17, OH: T_0 =1.84 →T_4 =2.35). Mineral profiling of broiler feed showed a significant increase in potassium, calcium, magnesium, and phosphorus by the addition of agricultural wastes. On 42nd day of study, experimental birds were evaluated for oxidative stability, fatty acid profile, cholesterol, HDL, LDL and triglycerides and found significant positive impact on poultry bird and its meat. Thus, fruit waste can be utilized as feed source of poultry animals to improve health and to reduce waste burden.

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INTRODUCTION

World's population reached around 8.16 billion in 2024 and is expected to approach 9.6 billion by 2050. With the increase in world's population the demand for food has also been increased. Globally, around 2.3 billion people suffer from food insecurity that is almost 28% of the whole population (He *et al.*, 2022). Food industry has been facing a continuous pressure to meet the demand of nutritious food. Balanced diet is a major concern these days, and it is nearly impossible to achieve it without adding meat in the diet. FDA has established the minimum quantity of meat consumption to be 0.8g/kg body weight. Meat is nutritionally enriched product, packed with good quality proteins, low lipid profile, essential B-vitamins and minerals including iron and selenium (Bishnoi *et al.*, 2025).

Food insecurity and agricultural wastes are prevailing problems that need to be addressed for sustainable world. Agriculture waste is nutritionally dense, yet become an unwanted burden on earth (Maji *et al.*, 2020). Fruit processing units generate 0.5 billion tons of agricultural wastes every year, and the availability and significant value

of this waste is untapped on a huge scale till date (Rakha *et al.*, 2025). Numerous databases have reported that different fruits and vegetable wastes can be efficient source for the processing of functional food and feed to improve its nutritional value at low cost (Hanif *et al.*, 2025;).

Indigenous fruit waste including apple pomace and peel, citrus peel, apricot kernels, pomegranate peel, blueberry, grapes, cranberry, olives, mulberry, strawberry and pineapple pomace has been solely or in combination used in poultry feed in Gilgit Baltistan, Pakistan. Fruits wastes own significance due to its nutritional value (Shahak *et al.*, 2025; Altarjami, 2025). Apple peels are rich source of polyphenols, minerals, vitamin C, pectin, and dietary fibers. Apple pomaces are enriched in polyphenols that depict antioxidant and anti-inflammatory properties. Dietary fibers are responsible for the improved gut health (Manrich, 2024). Evidence reported that pomegranate peel is a great source of antioxidants, but no research has been conducted on the inclusion of pomegranate peel in poultry feed. There is high concentration of polyphenols. tannins, flavonoids and anthocyanins in the pomegranate peel and rind. Fruits byproducts improve the cardiovascular health, lipid metabolism, gut health, immunity, and antioxidant level and reduce the oxidative stress (Santacroce *et al.*, 2024; Yiget *et al.*, 2024; Hafeez *et al.*, 2024). Formulating poultry feed by the inclusion of pomegranate peel can improve the overall nutritional value and quality of chicken meat. There are ample concentrations of easily digestible lipids with significant proportions of linoleic and oleic acids that provide energy and modify the fatty acid profile in poultry meat. The physiological functioning of chicken fed with apricot kernels was also improved due to presence of minerals including potassium, phosphorus, iron, magnesium and calcium. Reportedly, safe level of apricot kernels in poultry feed is recommended between 2 to 10% (Basyony *et al.*, 2023). Mulberry fruits and leaves are nutrient dense ingredients with exceptional bioactive profile are widely grown in Gilgit. Studies reported that adding mulberry in poultry feed had great impact on the growth performance, meat quality and health status of poultry. Studies revealed that broilers fed with mulberry leaves had better color stability, sensory properties and lower malondialdehyde levels (Ding *et al.*, 2021; Sajid *et al.*, 2025). Current study was designed to combine various waste sources from multiple fruits to get single dietary formulation with multiple nutritional and bioactive rich feed. This study aimed to focus on determining the potential of agro-industrial waste by-products though evaluating nutritional, mineral profile, antioxidant activities with the aim to utilize them in poultry feed for to add nutritional value, enhance production quality. The indicators of growth performance and bio evaluation was done to access health benefits to poultry bird and end users consume through their meat and other products.

MATERIALS AND METHODS

Agro-industrial waste (apple peel and pomace, pomegranate peel, mulberry leaves and apricot kernels) were collected from local fruits processing units of Gilgit Pakistan. Waste materials were dried in a tray dehydrator at 50°C for 4 hours, and ground to the fine particle size (1-2mm), suitable to be incorporated into broiler diets. For dietary formulation equal proportion (25%) of each fruit waste was weighed to prepare dietary-mix. For feed formulation mix was added to feed following treatment plan: (T_1:5%, T_2: 7.5%, T_3: 10%, T_4: 12.5%). Laboratory grade chemicals and reagents were procured from Sigma Aldrich (USA) to perform physicochemical, nutritional, antioxidant analysis and fatty profile.

Animals, Experimental Diets and Designs: Research protocols and animal care were in accordance with ethical guidelines for care and use of experimental animals. A total of 225 broiler chickens (1 day old) were procured from commercial hatchery and divided into 5 groups. Each group had 3 replicates of 15 chicks. Chicks were kept in properly disinfected pens under controlled conditions such as uniform temperature (28-30°C), proper ventilation, and 65 to 70% humidity with 24/7 lighting during entire experimental timeline. During first 21 days, commercial starter and grower diets from Asia Feed Ltd., were fed to the chicks. After 21 days, till the end of study period (42 days), the supplemented diets were provided to experimental groups, throughout the rearing period of 42 days, the water and feed supply were *ad libitum*.

Different dietary treatments (T_1-T_5) were designed to examine the impact of agro-industrial waste incorporation on quality and performance of broiler meat. Control group (T_0) was treated on regular feed, while treatment groups (T_1=5%, T_2=7.5%, T_3=10%, T_4 =12.5%) were fed on agriculture processed wastes to evaluate supplementation effect on meat quality parameters.

Growth Performance Evaluation: Body weight of chicks and their feed intake were recorded on every 7th day. Mortality was recorded on daily basis (Zhang *et al.*, 2023).

Chemical Analysis of Feed: Samples of experimental feed were analyzed for basic nutritional composition (Carbohydrates, crude fat, crude protein, crude fiber, moisture and ash), by following standard AOAC methods (AOAC, 2023). Supplemented groups were analyzed on Flame Photometer (Elico CL-378) for mineral estimation (Getachew, 2021).

Sample Collection: On 42nd day, the experimental chickens were slaughtered following Halal guidelines (PS 3733). EDTA vials were used to collect blood samples, centrifuged at 3000 rpm to separate plasma for hematological and biochemical assay. Chicken carcasses were de-feathered and eviscerated followed by storage at -40°C for further analysis.

Physicochemical Analysis of Meat: Drip loss method was used to determine water holding capacity, and AQUALAB chilled mirror for water activity of meat following method reported by Szmańko *et al.* (2021).

Estimation of Phenolic Content and Antioxidant Potential: Phenolic content and antioxidant potential of agricultural waste fed poultry meat was analyzed. For each test, three samples were taken from each group (n=3). A total of 15 samples for breast, 15 for leg and 15 for thigh were taken for each test. TPC for phenolic content analysis and ABTS, DPPH and TBARS were conducted to analyze the antioxidant potential of modified feed on poultry meat.

Folin-Ciocalteu reagent was used to determine TPC, by using GAE (Gallic acid equivalent) for standard calibration, as described by (George *et al.*, 2022; Siddiqa *et al.*, 2025). DPPH radical scavenging activity was determined according to the method described by (Gulcin & Alwasel, 2023). $ABTS^{+}$ radical cation de-colorization assay was performed to analyze the antioxidant capacity of agricultural waste fed broiler meat by following method of (Jin, 2020). FRAP assay of poultry meat samples were conducted by following the antioxidant measuring method (Qin *et al.*, 2026). The hydroxyl radical scavenging activity ($^{\bullet}OH$ RSA) assay based on the principle of the Fenton reaction (Negasa, 2024). TBARS assay was used to evaluate lipid oxidation level as described by Hanif *et al.* (2025).

Fatty Acid Profile: Fatty acid profile of treated chicken meat samples was determine using Gas chromatograph and observed peaks were identified against standard (Supelco FAME-Mix, Sigma, USA) peaks, followed by lipid extraction and methylation of fatty acids (Chirilă *et al.*, 2020).

Bio-evaluation: Bio-evaluation of serum bio-chemical parameters was conducted to analyze the total cholesterol, triglycerides, HDL and LDL enzymatic assay kits (Sigma Aldrich). The total cholesterol was measured (Shafiq *et al.*, 2022) to assess the effect of supplementation. Agro-industrial waste fed poultry groups (T_1-T_4, thigh, breast and leg muscles meat was analyzed for triglycerides by following lipid extraction and enzymatic colorimetric method described by (Saleh *et al.*, 2021). High-density lipoprotein and low density lipoproteins in experimental bird's meat were also analyzed in all samples (Saleh *et al.*, 2021).

Statistical Analysis: The data was processed in Microsoft excel and statistically analyzed by applying ANOVA and mean comparison via Tukey's honesty significant differences at $P \leq 0.05$ via software Statistix 8.1 and Minitab (22.4.0).

RESULTS AND DISCUSSION

Proximate Analysis Controlled and Supplemented Diet: The direct comparison of the commercial broiler feed and the agro-industrial waste incorporated diet revealed non-significant changes in nutritional composition, indicating natural properties of the fruit by-products, added at different ratios. While the commercial feed was characterized by a balanced formulation in accordance with the NRC guidelines, compositional changes in the supplemented feeds proposed nutritional and functional significance in regard to the performance of broilers. Table 3.1 has evidenced non-significant impact on crude protein, crude fat, crude fiber, carbohydrate, ash, and moisture content. Although a slight increase in concentration of all these physicochemical parameters was observed, yet it was not significantly higher enough to alter the nutritional composition of poultry feed. A non-significant increase in the crude protein was also reported when apple pomace was incorporated in poultry diet along with enzymes (Colombino *et al.*, 2020). In another study, Ghasemi-Sadabadi *et al.* (2022) reported non-significant impact on crude fat by incorporating 8% pomegranate peel in poultry feed. Total energy was observed significant with the increase in overall nutritional value among different supplemented diets. Results are supported by previous study reported an increase in the energy of poultry feed when dried fruit pomace was added in poultry diets (Sosnówka-Czajka *et al.*, 2023).

Table 1: Proximate Analysis for Broiler Feed Having agro-industrial waste (Apple Peel and Pomace, Mulberry Leaves and Fruits, Apricot Kernel and Pomegranate Peel)

Composition	Controlled	Supplementation			
	T_0	T_1	T_2	T_3	T_4
Crude Protein %	17.50	17.81	17.91	18.02	18.32
Crude Fat %	5.50	5.71	5.71	5.73	5.93
Crude Fiber %	7.20	8.40	8.70	9.10	9.61
Carbohydrates%	51.0	53.30	54.80	56.16	57.54
Ash %	2.50	2.60	2.620	2.66	2.70
Moisture %	9.30	10.42	10.67	11.32	12.03
Energy (kcal/kg)	2883	3051	3096	3167	3238

T_0 = Control diet (100% Commercial), T_1 = 5%, T_2 = 7.5%, T_3 = 10%, T_4 12.5% supplementation of agro-industrial waste

Mineral Analysis: Mineral analysis was performed to assess various minerals including calcium, potassium, iron, zinc etc. Results reported significant increase in supplemented diet groups (T_2, T_3, T_4). Fruits by-products have significantly raised the levels of potassium, calcium, magnesium, phosphorus, and zinc levels in poultry diet. In T_4, where potassium observed highest (133 mg/100g) followed by calcium (18 mg/100g) and magnesium (14.25 mg/100g). Potassium levels were found significant (Table 2) due to the high potassium content in apple pomace, mulberry leaves and pomegranate peel (Abbas *et al.*, 2025). Potassium and magnesium are also observed highest with supplemented feed. It helps to improve the physiological functionality that is one of the attributes of magnesium Numerous evidence confirmed that the supplemented diet are bio-available source of minerals that helps in improving poultry bird's growth and meat quality attributes (Mnisi *et al.*, 2022; Nastoh *et al.*, 2026). No significant impact was observed on the levels of iron, manganese and copper of the diet. Moreover, minerals also improves the hardness of eggshell, bone formation, muscle contraction, blood clotting, and enzyme activation (Kazaev *et al.*, 2024).

Table 2: Mineral Analysis for Broiler Feed with agro-industrial waste (Apple Peel and Pomace, Apricot Kernel, Mulberry Fruit and Leaf, Pomegranate Peel)

Minerals	Control	Levels of Supplementation			
	T_0	T_1	T_2	T_3	T_4
Potassium (mg/100g)	60.23	68.5	79.8	106.4	133.0
Magnesium (mg/100g)	5.301	7.54	8.55	11.40	14.25
Calcium (mg/100g)	1.923	9.85	11.1	14.93	18.66
Phosphorus (mg/100g)	2.890	4.80	5.58	7.460	9.33
Iron (mg/100g)	0.282	0.13	0.38	0.510	0.64
Copper (mg/100g)	0.005	0.02	0.03	0.040	0.05
Zinc (mg/100g)	0.002	0.04	0.07	0.090	0.11
Manganese (mg/100g)	0.026	0.04	0.05	0.070	0.09

T_0 =Control diet (100% Commercial), T_1=5%, T_2=7.5%, T_3=10%, T4=12.5% supplementation of agro-industrial waste

Physicochemical Analysis of Experimental Birds: Physicochemical analysis (Table 3) showed non-significant ($p>0.05$) impact observed on water activity (a_w)

in samples of leg, thigh and breast muscles at all levels of supplementation. Another study reported that apple, strawberry and blackcurrant pomace supplemented diet had no significant impact on physicochemical properties of meat quality (Colombino *et al.*, 2020). Water holding capacity (WHC) was also observed non-significant at all levels of supplementation (5%, 7.5%, 10%, 12.5%). Previous study also reported that with addition of sun dried tomatoes, it had no significant impact on water holding capacity and drip loss of broiler meat (Mohammed *et al.*, 2021). Results are also in line with previous investigation of Sosnówka-Czajka *et al.*, (2023), reported incorporation of 3% apple pomace and other fruits waste, does not impart any significant impact on water holding capacity of broiler meat. Current study results are supported by recent evidence confirmed that supplementation has no significant effect on meat quality including pH, color and water holding capacity in supplemented groups (Nastoh *et al.*, 2026).

Table 3: Effect of agro-industrial waste supplementation on Water Activity and Water Holding Capacity of Breast, Thigh and Leg muscles

Test	Treatment	Breast	Thigh	Leg
A_w	T_0	0.96±0.03^a	0.97 ±0.02^a	0.95 ±0.03^a
	T_1	0.97±0.02^a	0.96 ±0.03^a	0.94 ±0.04^a
	T_2	0.97±0.03^a	0.96 ±0.01^a	0.93 ±0.02^a
	T_3	0.97±0.02^a	0.95 ±0.03^a	0.94 ±0.03^a
	T_4	0.97±0.03^a	0.94 ±0.04^a	0.93 ±0.01^a
WHC (g H_2O/g DM)	T_0	65.33±0.01^a	70.04 ±0.07^a	67.99 ±0.02^a
	T_1	65.97±0.09^a	70.95 ±0.06^a	67.32 ±0.41^a
	T_2	66.01±0.03^a	71.06 ±0.04^a	67.83 ±0.06^a
	T_3	66.31±0.05^a	71.18 ±0.11^a	68.21 ±0.02^a
	T_4	66.79±0.02^a	71.20 ±0.01^a	69.55 ±0.07^a

A_w=Water Activity, WHC= Water Holding Capacity. T_0 =Control (100% Commercial), T_1=5%, T_2=7.5%, T_3=10%, T_4=12.5% supplementation of agro-industrial waste

Phenolics and Antioxidant Assays of Different Anatomical Sites of Experimental Birds: Phenolics and antioxidant assays were performed (Table 4) showed that supplemented diet groups exhibited significant impact on all anatomical sites (leg, breast and thigh muscles). Total phenolic content (TPC) was found to be the highest in T_4 (0.52-0.70 mg GAE/g) group samples. As fruits and their byproducts of apple pomace, pomegranate peel, apricot kernel and mulberry leaves rare rich source of phenolic acids, anthocyanins and flavonoids which ultimately leads to higher TPC content in treated groups (Suleria *et al.*, 2020; (Oleszek *et al.*, 2023). The dietary supplementation had a significant impact on condensed tannins in all treatment groups. Results (Table 4) showed a significant decreasing trend in condensed tannins from T_0 to T_4. Fruits byproducts added in supplementation are reported to have high levels of dietary fibers, polyphenols and pectin, thus capable to reduce the bioavailability of TCT in body (Efimtseva and Chelpanova, 2020). Recent research study by Zhang *et al.* (2025), reported similar findings where polyphenols enriched agricultural wastes were fed to animals that bound the mycotoxins and reduced the bioavailability of TCT in body. Table 4 showed a significant impact of supplemented diet on antioxidant activities and radical scavenging activities. The highest DPPH and OH was observed in T_4 (2.46 AAE mg/g d_w and 3.33 TE mg/g d_w) samples of breast sample, respectively. A significant impact of diet supplementation on ABTS assay of poultry birds at different muscles. The controlled group in leg and breast muscles exhibited lowest mean ABTS value, indicating the lower antioxidant potential in lean poultry meat. A significantly higher ABTS assay was observed with the increase in level of supplementation in leg muscles (T_4 =2.72 AAE mg/g d_w), indicating an efficient transmission and absorption of dietary antioxidants into the muscles. However, in thigh muscles a completely opposite trend was observed among all the treatments. Lengkidworraphiphat *et al.* (2020) has reported genotype-dependent differences in antioxidant potential between thigh and breast muscles due to the different intrinsic tissues affecting results of radical scavenging assays. The results showed that in controlled group of all muscles (leg, thigh and breast) the OH^- was minimum and it was observed to be increasing with the increase in level of supplementation. The maximum level of OH^- value was observed in breast muscle, while the minimum level of OH^- was observed in controlled treatment of thigh muscles. Studies have reported similar outcomes when dietary apple pomace and pomegranate peel extracts were fed to poultry birds and it reduced that TBARS clause and improved the antioxidant potential in meat (Sosnówka-Czajka *et al.,* 2023).

Table 4: Effect of agro-industrial waste (Apple Peel and Pomace, Mulberry Leave and Fruits, Apricot Kernel and Pomegranate Peel) Supplemented Diet on Phenolic Acid and Antioxidant Assay of Chicken

Treatments		TPC (mg GAE/g)	TCT (CE mg/g)	DPPH (AEE mg/g)	$ABTS^+$ (AEE mg/g)	OH^- (TE mg/g)
Leg Muscle	T_0	0.25±0.07^c	1.61±0.08^a	1.64±0.11^a	1.41±0.072^b	1.84±0.07^b
	T_1	0.42±0.04^{bc}	0.87±0.04^b	1.76±0.08^a	2.45±0.155^a	1.87±0.08^b
	T_2	0.51±0.05^{ab}	0.36±0.03^d	1.83±0.36^a	2.62±0.121^a	2.14±0.11^a
	T_3	0.52±0.10^{ab}	0.45±0.06^d	2.06±0.04^a	2.65±0.104^a	2.24±0.07^a
	T_4	0.67±0.04^a	0.65±0.05^c	2.17±0.11^a	2.72±0.117^a	2.35±0.04^a
Thigh muscle	T_0	0.43±0.02^b	1.12±0.01^a	2.23±0.01^a	3.30±0.03^a	0.91±0.05^c
	T_1	0.45±0.07^b	0.83±0.13^b	2.21±0.12^a	3.25±0.18^a	1.55±0.08^b
	T_2	0.53±0.04^b	0.37±0.05^c	2.12±0.19^{ab}	2.74±0.22^a	2.15±0.15^a
	T_3	0.54±0.07^b	0.17±0.04^d	2.08±0.05^{ab}	2.53±0.28^b	2.25±0.04^a
	T_4	0.70±0.04^a	0.16±0.04^d	1.73±0.27^b	2.50±0.26^b	2.30±0.09^a
Breast Muscle	T_0	0.28±0.05^c	1.27±0.20^a	2.00±0.16^b	1.25±0.03^b	2.69±0.32^b
	T_1	0.39±0.02^{bc}	1.09±0.08^a	2.12±0.08^{ab}	1.47±0.09^{ab}	2.70±0.27^b
	T_2	0.48±0.04^{ab}	0.59±0.15^b	2.14±0.10^{ab}	1.59±0.08^a	3.13±0.10^{ab}
	T_3	0.50±0.06^{ab}	0.32±0.26^b	2.24±0.16^{ab}	1.64±0.20^a	3.24±0.07^a
	T_4	0.52±0.03^a	0.21±0.03^b	2.46±0.19^a	1.65±0.18^a	3.33±0.04^a

T_0 = Control diet (100% Commercial), T_1 = 5%, T_2 = 7.5%, T_3 = 10%, T_4 =12.5%. GAE: Gallic acid equivalent; CE: Catechin equivalent; AEE=Ascorbic acid equivalent, TE; Trolox equivalent.

Weight of Experimental Birds: Table 5 shows a significant increase in the overall weight of poultry birds fed with supplemented diets. In controlled group T_0, the body weight was 2226 grams which significantly increased in treatment groups T_1 (2336 g), followed by T_2, T_3 and T_4 (Table 4). The increase in body weight is attributed to the enhanced nutritional value in supplemented diets. Results have been strongly evidenced by multiple studies conducted on poultry birds fed with fruits and vegetable wastes, resulting in increased body weight (Nisar *et al.*, 2023; Nastoh *et al.*, 2026).

Effect of Supplemented diets on Thiobarbituric Acid Substances of Experimental Birds: Table 6 showed non-significant impact on thiobarbituric Acid Substances (TBARS) values of breast, thigh and leg muscles of experimental birds. The highest TBARS value (1.65

MDA/kg) was observed in T_4 of leg muscles. The results suggest a gradual increase in TBARS value in leg muscles while a slight decrease in breast and thigh muscles, due to muscular specific response to oxidative stress from dietary interventions. The slight reduction is TBARS value in breast and thigh muscle evidence the presence of antioxidants from agricultural waste products. (Wereńska *et al.*, 2022) reported that leg muscles had higher TBARS value than breast muscles, which are in accordance with our findings.

Table 5: Weight of broiler chicken fed on agro-industrial waste (Apple peels & pomace, apricot waste, mulberry fruit & leaves and pomegranate peel)

Treatments	Body weight (g)
T_0	2226.6[a]
T_1	2336.3[b]
T_2	2396.0[ab]
T_3	2466.6[a]
T_4	2494.3[a]

T_0 =Control diet (100% Commercial), T_1 =5% agricultural-waste supplementation, T_2 =7.5% agricultural-waste supplementation, T_3 =10% agricultural-waste supplementation, T_4 =12.5% agricultural-waste supplementation

Table 6: TBARS activity of Breast Thigh and Leg muscles of Experimental Birds

Treatment	Breast MDA/kg	Thigh MDA/kg	Leg MDA/kg
T_0	1.05±0.28[a]	1.25±0.49[a]	1.00±0.18[a]
T_1	1.00±0.04[a]	1.09±0.19[a]	1.20±0.05[a]
T_2	0.96±0.05[a]	1.00±0.23[a]	1.25±0.02[a]
T_3	0.89±0.21[a]	0.94±0.13[a]	1.55±0.17[a]
T_4	0.83±0.18[a]	0.85±0.98[a]	1.65±0.21[a]

T_0 = Control diet (100% Commercial), T_1 = 5%, T_2 = 7.5%, T_3 = 10%, T_4 =12.5% supplementation of agro-industrial waste

Effect of agro-industrial waste Supplementation on Fatty Acid Profile of Leg, Thigh and Breast Muscles of Experimental Birds: Fatty acid profile of chicken meat fed with controlled diet and different levels of supplemented diets indicated a different impact on various anatomical sites of meat (Table 7). Overall a significant impact was observed on *omega*-3 and *omega* 6- fatty acids on all anatomical sites in group T_3 and T_4. In leg muscles, a non-significant impact of supplemented diet was observed. A significant ($P \leq 0.05$) increase was observed on absorbance of oleic acid and linoleic acid in leg muscles with the increase in level of supplementation in diet. Agro-industrial waste supplementation had non-significant impact on eicosenic acid, and total saturated fatty acid. Similar findings have been reported by (Basyony *et al.*, 2023b) who evidenced a significant increase in linoleic acid levels by incorporating apricot kernels in poultry feed. On pamitoleic and stearic acid a non-significant impact was observed among all groups. There was non-significant impact on total saturated fatty acids, and monounsaturated fatty acids of thigh muscles when supplemented diet was fed to them. Apple peel and pomace contain moderate levels of omega-3 and omega-6 fatty acids, while apricot kernels contain 18 to 40% of *omega*-6 fatty acids and traces of *omega*-3 fatty acids (Alajil *et al.*, 2022).

Effect of Agro-industrial Waste Supplementation on Cholesterol Level of Different Anatomical Sites of Experimental Birds: The results show that fruits-byproducts supplementation in poultry diet had a significant impact ($P \leq 0.05$) on lipid profile of experimental birds including HDL content in broiler meat. HDL increased with the increase in level of supplementation, until T_4 where 12.5% of fruits waste was added, a sudden increase in HDL level was observed from 34.33 mg/dL in T_3 to 51.33mg/dL T_4 in breast muscles. Similar trend was observed in thigh and leg muscles. A gradual increase was observed from T_0 to T_1, followed by T_2 and T_3, while a major increase in T_4 (38mg/dL in thigh and 48.67mg/dL in leg muscles). The incorporation of apple pomace and other fruits byproducts in poultry diets have reported a potential increase in HDL cholesterol and reduction in LDL cholesterol without having a negative impact on meat quality (Malenica *et al.*, 2022; Rasheed *et al.*, 2025).

The results reported significant reduction in LDL of breast, thigh and leg muscles of experimental birds. The controlled groups of each anatomical sites had slightly higher values for LDL, while a significant reduction was observed with the increase in level of supplementation. The least values for LDL were observed in T_4 of leg muscles (22.05 mg/dL). The results were found to be in accordance with (Chaib Eddour *et al.*, 2023), who reported that incorporating 5% and 10% apple peel in poultry diet significantly increases the HDL levels while reducing the LDL and MDA levels in poultry meat.

Table 7: Fatty Acid Composition (%) of Broiler Leg, Thigh and Breast Muscles Fed on the Agro-Waste (Apple Peel and Pomace, Apricot Waste, Mulberry Waste and Pomegranate Peels) Supplemented Diets

Treatment		Palmitic acid (16:00)	Palmitoleic acid (16:01)	Stearic acid (18:00)	Oleic acid (18:010	Linoleic acid (18:2n-6)	MUFA (20:01)	DHA (22:6n-3)	Total SFA	Total MUFA	Total Omega 6	Total Omega 3
Leg muscle	T_0	11.02	0.305	1.64	21.61	29.45	1.50	0.61	16.03	22.64	28.60	0.51
	T_1	11.05	0.405	1.67	27.31	30.99	5.08	1.50	16.25	29.31	31.46	2.47
	T_2	11.31	0.411	1.82	42.085	31.41	5.12	1.61	16.99	48.04	31.47	2.55
	T_3	15.45	0.441	2.04	43.22	33.21	5.42	1.69	17.03	48.91	33.69	2.66
	T_4	16.07	0.451	8.94	43.91	48.78	8.87	8.02	17.16	49.05	51.04	8.16
Thigh muscle	T_0	11.04	0.331	1.59	27.33	29.47	1.51	0.31	16.24	29.01	28.61	0.23
	T_1	11.09	0.350	1.64	27.64	30.96	1.62	0.54	16.30	29.45	31.45	0.52
	T_2	11.39	0.384	1.67	42.06	31.43	5.08	1.50	17.02	48.06	31.49	2.49
	T_3	15.51	0.395	1.82	43.22	48.79	5.10	1.60	17.04	48.91	51.03	2.56
	T_4	16.08	0.461	2.03	44.01	50.72	5.43	1.69	18.40	48.99	51.19	2.61
Breast muscle	T_0	0.51	0.421	1.61	17.07	20.98	0.25	0.73	16.27	1.660	0.32	0.22
	T_1	11.04	0.425	1.69	27.625	29.46	1.55	1.53	16.31	29.02	28.61	2.50
	T_2	11.11	0.451	1.83	42.11	31.01	5.06	1.63	17.06	48.06	31.48	2.58
	T_3	11.41	0.471	1.66	43.25	31.45	5.12	1.71	18.44	48.945	31.50	2.70
	T_4	16.09	0.551	2.04	44.05	50.74	5.44	8.79	27.63	49.04	51.215	5.53

T_0 = Control diet (100% Commercial), T_1 = 5%, T_2 = 7.5%, T_3 = 10%, T_4 12.5% supplementation of agro-industrial waste

Table 8: Lipid Profiling of Experimental Birds fed on Agro-industrial Waste Supplemented diet on poultry birds

Test	Treatment	HDL mg/dL	LDL mg/dL	Cholesterol mg/dL	Triglycerides mg/dL
Breast	T_0	26.00±0.01^{c}	36.73±0.01^{a}	55.67±0.06^{a}	102.67±0.16^{b}
	T_1	28.33±0.03^{bc}	32.89±0.36^{b}	50.00±0.07^{ab}	108.00±0.26^{ab}
	T_2	34.33±0.04^{bc}	30.43±0.33^{c}	47.67±0.03^{ab}	112.00±0.03^{a}
	T_3	36.33±0.02^{b}	29.72±0.13^{d}	46.00±0.02^{b}	112.33±0.04^{a}
	T_4	51.33±0.02^{a}	26.31±0.21^{e}	43.67±0.09^{c}	115.00±0.02^{c}
Thigh	T_0	21.67±0.06^{d}	29.57±0.01^{a}	79.33±0.03^{a}	118.00±0.01^{a}
	T_1	25.30±0.03^{cd}	27.02±0.02^{b}	66.00±0.07^{b}	119.00±0.05^{a}
	T_2	28.05±0.16^{bc}	25.19±0.04^{c}	63.00±0.03^{b}	122.67±0.46^{a}
	T_3	32.65±0.02^{ab}	24.91±0.14^{d}	54.33±0.01^{c}	123.09±0.36^{a}
	T_4	38.47±0.05^{a}	23.04±0.60^{e}	54.33±0.46^{c}	124.35±0.02^{a}
Leg	T_0	22.00±0.01^{a}	27.71±0.16^{a}	71.67±0.03^{a}	122.67±0.14^{a}
	T_1	23.45±0.02^{b}	26.91±0.36^{b}	64.00±0.01^{ab}	124.33±0.03^{a}
	T_2	25.21±0.04^{b}	25.13±0.04^{c}	64.33±0.02^{ab}	129.00±0.02^{a}
	T_3	26.96±0.07^{b}	23.12±0.19^{d}	55.00±0.03^{bc}	129.33±0.06^{a}
	T_4	48.65±0.01^{b}	22.05±0.06^{e}	47.33±0.06^{c}	131.67±0.36^{a}

T_0 = Control diet (100% Commercial), T_1=5%, T_2=7.5%, T_3=10%, T_4 12.5% supplementation of agro-industrial waste

The supplementation of agricultural waste in poultry feed had imparted a significant impact ($p \leq 0.05$) on triglycerides levels on breast muscles, while thigh and leg muscles depicted a non-significant impact. The lowest level of triglycerides was observed in controlled group of breast muscle i.e. 102.67 mg/dL, while the highest level of triglycerides was observed in T_4 of Leg muscles i.e. 131.67 mg/dL. In breast muscles, the increase in triglycerides is mainly attributed to the pattern of lipid deposition within muscles as well as the different metabolic response towards bioactive compounds in diet. Moreover, the process of triglyceride deposition showed a muscle-specific distribution whereby, breast muscle had the highest level, indicating disparate lipid storage and usage in the type of muscle fibers. Graph (Fig. 1) represents an increase in level of HDL with the increase in dietary supplementation at all anatomical sites.

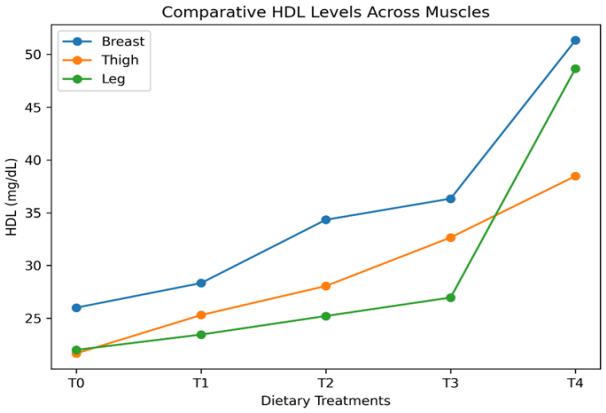

Fig. 1: Comparative Analysis of HDL at Breast, Thigh and Leg Muscles.

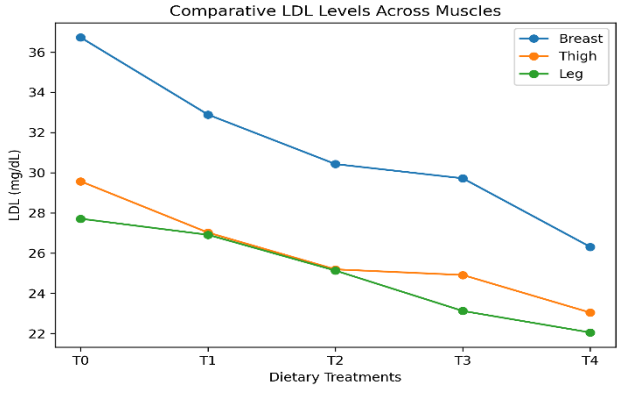

Fig. 2: Comparative Analysis of LDL at Breast, Thigh and Leg Muscles.

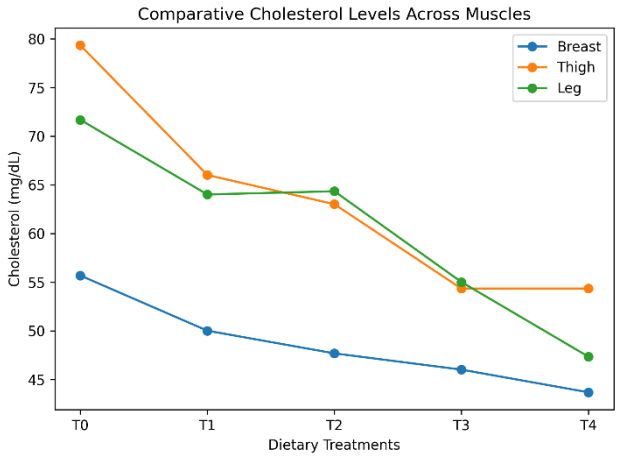

Fig. 3: Comparative Analysis of Cholesterol at Breast, Thigh and Leg Muscles.

Conclusions: The comparative analysis demonstrates that the feeds supplemented with agro-industrial waste with different inclusion levels ($T_0 \rightarrow T_4$) have a better nutrition profile and functional properties. Significant proteins, minerals, dietary fiber and antioxidants activities from supplemented feed resulted in optimal gut health, oxidative stability efficiently modulated the lipid metabolism and meat quality in samples of experimental birds. Supplemented feed significantly increased the oleic acid, linoleic acid, omega-3 and omega-6 fatty acids, hence improving the overall fatty acid profile of meat. The results evident positive impact on PUFA profile of poultry meat. Moreover, a significant increase in HDL (51 mg/dL) and triglycerides (131 mg/dL) was observed with a significant reduction in levels of LDL at all anatomical sites (breast, thigh and leg muscles) was observed, indicating an improved lipid metabolism. Thus, the agro-industrial waste (by-products) can be effectively used as functional feed supplements without negatively impacting the meat quality. Oxidative stability tests demonstrated that it had muscle specific activity with minor decrement in TBARS values in both the breast and thigh muscles. Overall, the results indicate the potential of agricultural by-products of fruits but still limited to quantify functional bioactive compounds and *in-vitro* bioaccessibilty. In Gilgit Baltistan, these fruit wastes are generated in large amounts during seasonal fruit drying and processing. Agro-industrial wastes are inexpensive, readily available, and often underutilized, making them a cost-effective alternative feed ingredient in such far areas for circular economy. The strategic use of these wastes could help to increase the

quality of meat, as well as grey burden on the environment and make the production systems of poultry more sustainable.

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