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ORIGINAL ARTICLE

Growth performance, economic efficiency, meat quality, and gene expression in two broiler breeds fed different levels of tomato pomace

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Abstract

Male broiler chicks (135 Indian River chicks (IR) and 135 Cobb chicks; n = 270) were weighed, wing banded, and distributed randomly into three iso-energetic and iso-nitrogenous diet groups for each breed (triplicate design, 45 bird/group, 15 bird/replicate). The chicks were fed the diets with levels of 0, 4, or 6% sun-dried tomato pomace (SDTP), respectively, for 42 consecutive days to determine the effect of consuming different levels of SDTP on growth performance, economic efficiency, meat quality, and gene expression in IR and Cobb broiler chickens. The inclusion of up to 6% SDTP in the diet of IR or Cobb chickens had no negative impact on growth performance parameters. Chickens from both the IR and Cobb breeds fed a diet containing 4% or 6% SDTP consumed more feed than those fed a diet containing 0% SDTP. Concomitantly, the groups fed a 6% SDTP diet of IR breed incurred a significantly higher feed cost, total variable cost (TVC), and total cost (TC). The inclusion of up to 6% SDTP in the feed of both breeds resulted in a non-significant increase in return parameters. The ultimate pH decreased as the SDTP concentration increased, with no significant differences in water holding capacity (WHC) or drip loss (48 h). No alteration in the mRNA expression of hepatic growth hormone receptor gene (GHR) or insulin like growth factor-1 (IGF-1) was found among the treatments for either the IR or Cobb breeds. Thus, up to 6% SDTP can be added to the diet of IR and Cobb broiler chickens without any adverse effects on the examined parameters.

Keywords Growth · Return parameters · Poultry meat quality · Growth hormone receptor gene · Insulin like growth factor-1 · Tomato pomace

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Introduction

In the poultry sector, which is considered the fastest growing and most flexible of all livestock sectors, the Egyptian poultry industry has greatly improved and moved into position as one of the most successful regional livestock businesses. Breeding and selling poultry is characterized by rapid monetary turnover, a short capital cycle, and a higher return on investment (FAO, 2006). Unfortunately, the cost of producing broiler meat increases and remains high due to continuous increases in the cost of feed. Feed costs represent a considerable percentage of livestock production costs, particularly in poultry production, where it reaches up to 75–80%. Therefore, in the last few years, alternative feed sources have been studied, such as various pomaces from food industry by-products (Kannan et al. 2007; Borycka, 2017).

Tomato pomace (TP) is a significant source of protein, vitamins, and minerals, but its high fiber content reduces its energy value. On a dry matter basis, the amount of crude protein in TP ranges between 15 and 25%, and the amount of neutral detergent fibers reaches 50% (Del Valle et al. 2006). TP is considered an essential source of functional food components such as β-carotene, lycopene, and phenolic acids (Borycka, 2017; Nour et al. 2018). Lycopene stimulates the liver to increase insulin-like growth factors, which increases the production of protein in cells, resulting in improved broiler productivity and performance (Vrieling et al. 2007; Englmaierová et al. 2011). The supplementation ratio of the TP-to-broiler diet reflected the increases in the live body weight and feed consumption in broilers fed a TP-supplemented diet for periods up to 21 days of continuous feeding (Persia et al. 2003). Also, broilers supplemented with TP (up to 5%) for their first 28 days of life demonstrated improved body weight and European broiler index (Hosseini-Vashan et al. 2016). Moreover, consumers prefer the meat of broilers fed from different vegetable sources, as they find it sweeter, juicier, and more tender. However, it should also be taken into account that vegetable sources include various anti-nutritional factors and can affect meat quality (Dublecz, 2003; Vieira et al. 2003). For instance, plants typically contain poisons and anti-nutrients derived from fertilizer and pesticides, as well as a variety of naturally occurring chemicals. Some of these compounds are known to obstruct metabolic processes, reducing growth and nutrient bioavailability (Sinha et al. 2017). Tomatine, a solanine-like alkaloid (saponin) found in unripe tomatoes and the green sections of mature tomatoes, is harmful to insects, dogs, and to a lesser degree to herbivores, causing diarrhea, vomiting, and intestinal discomfort. However, tomatine disappears as the tomato ripens and is not a concern in tomato peels (Milner et al. 2011). In addition, tomatine is thought to have medicinal properties (Milner et al. 2011).

Tomato pomace has been found to be devoid of anti-nutrient components (Sogi et al. 2002; Del Valle et al. 2006). Tomato pomace improves meat color stability and sensory attributes such as taste and aroma. It also improves the quality and texture of the meat, due to its high content of phenolic compounds, which act as antioxidants and improve the integrity of cell membranes, thereby inhibiting water loss from cells (Rossi et al. 2013; Pieszka et al. 2017). One of the critical factors that affects the quality of meat is the pH value, as it is directly linked to many other meat properties such as water-holding capacity, color, tenderness, and shelf-life (Hamoen et al. 2013; Glamoclija et al. 2015). The color of poultry meat is one of the most important factors influencing consumer preference, especially at the point of purchase (Font-i-Furnols and Guerrero, 2014).

The major differences in body weight, average daily gain, and average feed consumption between breeds may be due to genetic differences (Amao et al. 2011). The IR breed had higher expression levels of IGF-I and MyoG than the Cobb. It is possible that the IGF-I and MYO-G genes play a role in enhancing the IR breed's development. As a result, the IGF-1 gene is a promising marker (Jawasreh et al. 2019).

This study aimed to determine the effects of supplementing chicken feed with sun-dried tomato pomace (SDTP) on growth performance traits (body weight, body weight gain, daily body gain, feed consumption, feed conversion rate, and relative growth rate), percent mortality, meat quality (pH value, water holding capacity, drip loss, cooking loss, WBSF, and color), gene expression of hepatic growth hormone receptor (GHR) and insulin-like growth factor-1 (IGF-1) genes, and economic efficiency measures (different costs, different returns, partial and collective measures of efficiency) in the Indian River and Cobb broiler breeds.

Materials and methods

Birds and experimental diet design

The experiment was conducted from April 14th–May 26th, 2019, at the Center of Experimental Animal Research, Faculty of Veterinary Medicine, Benha University, Egypt. One-day-old chicks of the Indian River (IR; $n = 135$) and Cobb (135) breeds were obtained from local hatcheries. The broiler chicks received were weighed, wing banded, and distributed randomly into three iso-energetic and iso-nitrogenous diet groups, which were formulated for each breed (triplicate design, 45 bird/group, 15 bird/replicate). The chicks were kept in well-ventilated litter floor rooms and stocked at a density of 10 birds/m^2. All birds were subjected to the same managerial, hygienic, and housing conditions.

Tomato waste was obtained from the Qaha food processing plant, Qaha City, Qalubia Governorate. The tomato waste was sun-dried for several days and then ground into a meal in a grinding machine and mixed thoroughly. Ground tomato waste was analyzed chemically before being used in the diets to determine the dry matter, crude protein, crude fat, and crude fiber (AOAC 2005). The results are shown in Table 2. The feed diets, which were iso-energetic and iso-nutrient, were formulated to meet the nutritional requirements of both broiler chicken breeds according to the published nutritional requirements for Indian River (An Aviagen 2019) and Cobb 500 (Cobb500 broilers 2012) broiler chickens. The composition of diets used in the feeding trial is shown in Table 1, including the addition of sun-dried tomato pomace (SDTP) to the diet at levels of 0, 4 or 6%, respectively, for 42 days. The diets contain the following enzymes:

The energy enzyme Hamecozyme is a multienzyme that hydrolyses non-starch polysaccharides (NSP) in cereal grains by decreasing the viscosity of the gut content and promoting the utilization of nutrients, resulting in increased nutrient availability to the birds. Each gram contains beta-glucanase (400 units), xylanase (400 units), amylase (15

Table 1 Ingredient % and chemical composition of experimental diets

Items	Starter ration			Grower ration			Finisher ration		
	0% (Control)	4% SDTP	6% SDTP	0% (Control)	4% SDTP	6% SDTP	0% (Control)	4% SDTP	6% SDTP
Yellow corn	54.67	52.14	50.64	58.28	55.76	53.79	62.62	60.18	58.93
Soybean meal 46	36	35	35	33.8	32.7	32.2	28.9	27.8	27.2
SDTP	0	4	6	0	4	6	0	4	6
Vegetable oil	2.5	2.2	2.1	3.5	3.2	3.7	4.5	4.1	4
Corn gluten meal	2	1.9	1.55	0	0	0	0	0	0
Dicalcium phosphate	1.7	1.73	1.75	1.45	1.47	1.5	1.33	1.35	1.35
Lime stone	1.45	1.35	1.3	1.35	1.25	1.2	1.2	1.1	1.05
L_Lysine	0.33	0.29	0.25	0.29	0.24	0.22	0.23	0.18	0.16
Sodium chloride	0.32	0.32	0.32	0.3	0.3	0.3	0.3	0.3	0.3
Vitamins and mineral premix[1]	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
DL-Methionine	0.28	0.3	0.31	0.27	0.29	0.3	0.23	0.25	0.26
Sodium bicarbonate	0.19	0.18	0.18	0.17	0.17	0.17	0.17	0.17	0.17
Anti-coccidian	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Anti mycotoxin	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Anti-clostridia	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
L_Threonine	0.03	0.02	0.02	0.04	0.04	0.04	0	0	0
Energy enzyme	0.02	0.05	0.05	0.04	0.05	0.05	0.01	0.05	0.05
Lysomax	0.01	0.02	0.03	0.01	0.03	0.03	0.01	0.02	0.03
Phytase enzyme	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Protease B	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
choline chloride	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Chemical analysis									
Dry matter %	89.60	89.67	89.72	89.58	89.65	89.76	89.54	89.60	89.64
Crude protein%	23.02	23.00	23.01	21.03	21.03	21.00	19.02	19.03	19.01
MEn kcal/kg	3053.85	3039.08	3032.43	3152.05	3151.20	3149.49	3230.37	3224.10	3225.40
Crude fiber%	2.27	3.21	3.70	2.25	3.19	3.65	2.18	3.13	3.60
Crude fat %	4.97	5.03	5.10	5.98	6.05	6.69	7.06	7.03	7.12
Ash%	3.15	3.28	3.36	3.41	3.18	3.23	2.83	2.95	3.01
Sodium %	0.18	0.18	0.18	0.17	0.17	0.17	0.17	0.17	0.17
Lysine %	1.35	1.35	1.35	1.25	1.25	1.25	1.09	1.09	1.09
Methionine%	0.63	0.65	0.65	0.59	0.60	0.61	0.52	0.54	0.55
Methionine + cysteine%	1.02	1.02	1.02	0.95	0.95	0.95	0.86	0.86	0.86
Threonine %	0.94	0.94	0.94	0.88	0.88	0.88	0.77	0.77	0.77
Calcium %	1.05	1.05	1.06	0.95	0.95	0.95	0.85	0.85	0.85
Available phosphorus%	0.50	0.50	0.50	0.45	0.45	0.45	0.42	0.42	0.42

[1]Each 3 kg contain: Vit. A 12,000,000 IU, vit. D3 2,000,000 IU, vit. E 10,000 mg, vit.K3 2000 mg, vit B11000 mg, vit.B2 5000 mg, vit B6 1500 mg, vit. B12 10 mg, Biotin 50 mg, pantothenic acid 10,000 mg, Nicotinic acid 30,000 mg, Folic acid 1000 mg, Manganese 60,000 mg, Zinc 50,000 mg, Iron 30,000 mg, Copper 10,000 mg, Iodine 1000 mg, Selenium 100 mg, Cobalt 100 mg, carrier (CaCo3) add to 3 kg

Energy enzyme for non-starch poly saccharides, Phytase enzymes for utilization of phytate, Emulsifier (Lysomax) for metabolism of oil, Protease enzymes (Protease B) Improves protein digestion units), protease (14 units), cellulose (600 units), and a carrier (calcium carbonate up to 1 g); a 0.5 kg dose provides 85 kcal/kg diet. Phytase enzymes (Avemix P5000) contain molecule-coated phytase (5000 IU), which hydrolyses phytate by increasing cell wall permeability and breaking it down to release phosphorus in a form available for the animals; a 0.10 kg dose releases 0.09% available phosphorus. The emulsifier (Lysomax) is a lecithin component (lysophosphatidyle choline) that improves fat solubility and digestibility from feed ingredients as well as other fat sources. It has an energy sparing effect; inclusion of 1 g equals 1 kcal per kg of feed if the feed contains > 4% fat and a minimum of 2% added fat. A 0.25 kg dose liberates 45 kcal/kg. Protease enzymes (Protease B) improve protein digestion.

The nutritional matrix value of the energy enzymes and emulsifier were used to formulate the diets. The matrix was calculated according to the non-starch polysaccharide content for the energy enzyme and the phytate content for the phytase enzyme. The matrix content of the raw materials underwent local analysis in Egypt.

The feeding program was divided into three stages, each of which was 2 weeks long. During Stage One (1st and 2nd weeks of age), the chicks received Starter rations. During Stage Two (3rd and 4th weeks of age), the chicks received Grower rations. During Stage Three (5th and 6th weeks of age), the chicks received Finisher rations. The rations were provided ad libitum during the whole experimental period (42 days).

Evaluation of growth performance

The chicks were weighed individually at weekly intervals (on Days 7, 14, 21, 28, 35, and 42) during the experimental period. The average live body weights (BW) for each group were recorded and the average body weight gains (BWG) were calculated using the formula $BWG = BW_2 - BW_1$. The average daily gain (ADG) was calculated using the formula. $ADG = \frac{\mathrm{BWG}}{\mathrm{Number\ of\ days}}$ (Kamel et al. 2020). The relative growth rate (RGR) (expressed as a percentage) was calculated using the formula $RGR = \frac{\mathrm{BW_2 - BW_1}}{1\backslash 2(\mathrm{BW_2 + BW_1})} \times 100$ (Regassa et al. 2014), where BW_1 = live body weight at the beginning of the period and BW_2 = live body weight at the end of the period.

Percent mortality was checked daily and used to adjust the feed conversion ratio. Feed intake (FI) was measured weekly by weighing the feed that remained at the end of each period and subtracting it from the total quantity offered at the beginning of the period, taking into consideration the number of the dead chicks and the number of days they fed. The feed conversion ratio (FCR) was calculated using the formula

Table 2 Nutrient analysis of tomato waste

Items	Values %
Moisture	8.67
Dry matter	91.33
Crude protein	18.41
Neutral detergent fiber (NDF)	46.08
Crude fiber	25.79
Soluble carbohydrates	9.51
Crude fat	11.58
Ash	5.75
Metabolizable energy (ME) Mcal/ kg	1.84

$$FCR = \frac{\mathrm{FI(g/chick/week)}}{\mathrm{BWG\ (g/chick/week)}}$$

(Kamel et al. 2020).

Evaluation of economic efficiency

Economic efficiency includes the costs of production and returns parameters; costs of production include total costs (TC), which in turn consist of total variable cost (TVC) and total fixed cost (TFC). TVC included the cost of feed consumed, veterinary management, labor, chick price, water and electricity, and litter. This was estimated as an average value for each bird in each group per LE (1 USD ≈ 17 LE) during the experimental period. TFC (depreciation, building, and equipment) was as described by Rao (1987). The total return (TR) was calculated according to the methods of Omar (2014) as follows:

TR = average litter selling per each bird at the end of the experiment + the average bird selling return per gram.

The bird selling return = average final body weight per gram × market price per gram (Market price/g = 0.028 LE).

Net profit (NP) was estimated according to the methods of Tareen et al. (2017) using the following equation: NP = TR – TC.

Economic efficiency measures were calculated according to the methods of Ataallah (2004) and included:

Collective measures

- Benefit cost ratio (BCR) = TR (LE/chick/group) ÷ TC (LE/chick/group)
- TR (LE/chick/group) ÷ TVC (LE/chick/group)
- Net profit (NP) ÷ total cost (TC)
- Net profit (NP) ÷ total variable cost (TVC)

Partial measures of economic efficiency

- Feed cost ÷ body weight (which includes the cost of each kg broiler meat from the feed)
- Feed cost ÷ body weight gain (which includes the cost of each kg body weight gain from the feed)
- Relative Economic Efficiency (tested group) = [(NP/TC) (tested group) ÷ (NP/TC) (control group)] × 100

Evaluation of physicochemical analysis of chicken breast meat

The physicochemical analysis was conducted using the pectoral muscles from chicken carcasses (n = 5). The ultimate pH (pH_u) was measured directly on the pectoral muscle, after 24 h, using a digital pH meter (Thermo Orion 710A +, Cambridgeshire, UK). The water holding capacity (WHC) was estimated at 24 h after slaughter using the low-speed centrifugation method at 10,000 RPM at 5 °C for 20 min (Honikel and Hamm, 1994). The drip loss (at 24 and 48 h) and cooking loss were estimated according to the method described by Honikel (1998). Warner–Bratzler shear force (WBSF) was measured (3343 universal test system mono column, Instron, USA) according to previously described methods (AMSA, 2015). The color was measured using a Chroma meter (Konica Minolta, model CR 410, Japan). The color was expressed using the CIE L*, a*, and b* color system (Commission et al. 1977). These color scores were used to calculate the total color differences (ΔE*) using the following formula: $\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$ (Saricoban and Yilmaz, 2010).

Analysis of hepatic growth hormone receptor (GHR) and insulin like growth factor-1 (IGF-1) genes mRNA expression

For mRNA analysis, liver samples were taken, placed in sterile Eppendorf tubes, and stored in an RNA stabilization reagent (RNA Later solution; 10 µL per 1 mg of tissue) (Qiagen- GmbH, Germany) at -80 °C until required for total RNA extraction. Total RNA extraction was performed using a total RNA purification kit from Easy Red TM (Intron Biotechnology, Korea) following the manufacturer's instructions; ~ 100 mg tissue was placed in a microcentrifuge tube with 750 µL Trizol solution and homogenized using a Rotor Tissue Ruptor (Qiagen, GmbH, Germany). The concentration and purity of RNA were determined by measuring the absorbance in a Spectro Star Nano spectrophotometer (BMG Lab Tec, GmbH, Germany). An absorbance reading of 1.0 at 260 nm in a 1 cm detection path corresponds to an RNA concentration of 40 µg mL^{-1}. Pure RNA has an A260/A280 ratio of 1.8–2.0. cDNA synthesis was carried out following the manufacturer's instructions using a 2X Reverse Transcriptase Master Mix (Applied Biosystems, USA). Approximately 2 µg RNA in 10 µL was used with 10 µL reverse transcription mix for each sample.

Relative quantification of the mRNA expression for the respective genes was carried out using real-time PCR with SYBR green. Real-time PCR was performed in a 20 µL reaction mixture containing 10 µL SYBR Green qPCR Master Mix (TOPreal™ qPCR 2X PreMIX), 1 µM of each forward and reverse primer, 1 µL of 1 µg/µL cDNA, and nuclease-free water added to make a final volume of 20 µL. Reactions were then analyzed on an Applied Biosystem 7500 Fast Real-time PCR Detection System under the following conditions: 95 °C for 10 min followed by 40 cycles of 95 °C for 15 s then 60 °C for 1 min. The primer sequences of GHR, IGF-1,and β-actin (used as a housekeeping gene) were 5'-AACACAGATACCCAACAGCC-3' (5'-3' sequence forward) and 5'- AGAAGTCAGTGTTTGTCAGGG-3' (5'- 3' sequence reverse); 5'-CAC CTAAATCTGCACGCT-3' (5'-3' sequence forward) and 5'-CTTGTGGAT GGCATG ATCT-3'(5'-3' sequence reverse) and 5'-ACCCCAAAG CCAACAGA-3' (5'-3' sequence forward) and 5'-CCA GAGTCCATCACAATACC-3' (5'-3' sequence reverse), respectively (Gasparino et al. 2014). The PCR primers were synthesized by Invitrogen (Thermo Fisher Scientific, USA).

According to the RQ manager program ABI SDS software (ABI 7500 fast), the data are produced as sigmoid-shaped amplification plots in which the number of cycles is plotted against fluorescence (when using a linear scale). The threshold cycle (Ct) is defined as when the measured fluorescence rises above the background fluorescence and serves as a tool for calculating the starting template amount in each sample. Dissociation (melting) curve analysis was performed to verify PCR specificity using the real-time cycler software. Changes in gene expression were calculated from the cycle threshold (Ct) values obtained provided by real-time PCR instrumentation using the $2^{-\Delta\Delta Ct}$ calculation, where ΔCt indicates the changes in Ct in target genes in comparison to those in a reference (housekeeping) gene (Schmittgen and Livak, 2008).

Statistical analysis

The data were collected, arranged, summarized, and then analyzed statistically using SPSS statistical software (version 16 for Windows) (SPSS 2007) as follows:

The effects of experimental diets were tested using a two-way analysis of variance (ANOVA)

This statistical model was constructed to determine the consequence of the breed, treatment group, and breed × group interaction (Sallam et al. 2019).

$$V_{Io} = \mu + B_I + G_o + (Bx\,G)_{io}$$

where V_{Iop} = the studied and the target variable, μ = the overall mean of the population,

B_I = the effect of the Ith breed, G_o = the effect of oth group, and $(Bx\ G)_{io}$ = the effect of the interaction between the Ith breed type and the oth group.

Significance was calculated for breed, group, and interactions between groups and breeds. Differences were considered statistically significant when $p \leq 0.05$. Letters for means of interaction were performed using Tukey's test and the MSTAT program.

One-way analysis of variance (ANOVA)

This was carried out to determine the means of variables for genetic parameters among different treatment groups for each breed. Significance was calculated using Tukey's test and the SPSS program. The results are presented as mean ± SEM.

Cross-tabulation analysis

This was carried out to analyse the percent mortality among the different treatment groups.

Results

Nutritive value of SDTP

The average chemical composition of tomato pomace is presented in Table 2. SDTP contained 8.67% moisture, 18.41% crude protein (CP), 25.79% crude fiber (CF), 46.08% neutral detergent fiber (NDF), 5.75% ash, and 11.58% crude fat.

Growth performance during the rearing period

Growth performance results are presented in Tables 3, 4, and 5. With respect to live body weight on Day 42 (BW), cumulative body weight gain (BWG), and average daily gain (ADG), we found no significant difference among the treatment groups for either breed. The highest values were recorded for Cobb chicken fed the 6% SDTP diet (2162.2 g, 2114.2 g, and 50.34 g for BW on Day 42, cumulative BWG, and ADG, respectively). The highest cumulative feed intake and cumulative feed conversion rate were recorded for the IR chicken fed the 6% SDTP diet compared with the other treatment groups for both IR and Cobb breeds.

When assessing the treatments in each breed separately, during the entire rearing period, neither IR nor Cobb chickens showed any significant difference ($p \geq 0.05$) in BW or BWG between groups of the same breed fed diets with the different levels of SDTP (0, 4, and 6%). For both the IR and Cobb breeds, chickens fed the 6% SDTP diet had the highest numbers (not statistically significant) for BW on Day 42, cumulative BWG, and ADG compared to chickens of both breeds fed the diets with 0% or 4% SDTP. With respect to relative growth rate (RGR), IR chickens fed diets with different SDTP inclusion levels did not significantly differ in relative growth rate during the rearing period or for the cumulative RGR.

Concerning feed intake (FI) during the 1st week of the rearing period, it did not differ significantly between chickens fed diets with different SDTP inclusion levels for either the IR breed or the Cobb breed. IR chicken fed the 6% SDTP diet, and Cobb chicken fed the 4% SDTP diet, consumed more food than those of the same breed fed diets with 0% SDTP in the 2nd and 6th weeks; for both groups and breeds, the cumulative FI showed a significant difference ($p \leq 0.05$). The feed conversion rate (FCR) during the entire rearing period for either IR or Cobb chickens fed the diets with different levels of SDTP (0, 4, and 6%) did not differ significantly.

In terms of the difference in breeds between IR and Cobb, the IR showed a significant ($p \leq 0.05$) increase in BW and BWG in the 1st and 2nd weeks of the rearing period compared to the Cobb breed. While there was no significant difference in BW between the IR and the Cobb breeds during the remaining weeks of the rearing period, numerically the Cobb breed had better BW from the 21st till the 42nd day. In fact, the Cobb exceeded the numbers for the IR breed in BWG from Day 14 to Day 42. The Cobb breed had a significantly higher ($p \leq 0.05$) RGR than the IR breed even though the IR breed had a significantly higher ($p \leq 0.05$) cumulative feed intake and cumulative FCR than the Cobb breed. Regarding the mortality percent of the different groups (Fig. 1), there was no significant difference between different groups for either the IR or the Cobb breed.

Economic efficiency measures

The results of the economic efficiency measures are presented in Tables 6 and 7. Regarding the different feeding costs for the Grower (3rd and 4th weeks), and Finisher (5th and 6th weeks) diets, we did not find any significant differences for the different SDTP inclusion levels in the same breed. The Cobb chickens fed the 0% SDTP diet recorded a significantly lower value than the IR chicken fed the 6% SDTP diet; the latter group recorded a significantly higher value for Starter (1st and 2nd weeks), Grower, and Finisher feed costs (LE 3.4, 11.75, and 9.26 for Starter, Grower, and Finisher feed costs, respectively).

Concerning total feed cost, total variable cost (TVC), and total costs (TC), IR chicken fed the 6% SDTP diet recorded a higher total feed cost, TVC, and TC (LE 24.4,

Table 3 Effect of different SDTP inclusion levels on body weight (BW) and body weight gain (BWG) of Indian River and Cobb broiler chickens at different weeks

Items	Indian river				Cobb				P value		
	0% SDTP (Control)	4% SDTP	6% SDTP	Overall mean	0% SDTP (Control)	4% SDTP	6% SDTP	Overall mean	B	G	B*G
	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE			
Body weight g /bird											
Initial	$52.89^{a} \pm 0.87$	$52.89^{a} \pm 0.29$	$54.67^{a} \pm 0.69$	$53.48^{A} \pm 0.44$	$47.89^{b} \pm 0.80$	$48.89^{b} \pm 0.29$	$48.00^{b} \pm 0.88$	$48.26^{B} \pm 0.39$	.0.000	0.415	0.188
Day7	$182.89^{a} \pm 1.95$	$178.22^{ab} \pm 2.06$	$176.90^{ab} \pm 3.87$	$179.34^{A} \pm 1.66$	$153.00^{b} \pm 20.06$	$163.44^{ab} \pm 3.85$	$162.56^{ab} \pm 5.13$	$159.67^{B} \pm 6.30$	0.018	0.947	0.616
Day 14	$455.11^{a} \pm 8.83$	$448.22^{a} \pm 12.69$	$451.43^{a} \pm 9.72$	$451.59^{A} \pm 5.37$	$398.67^{a} \pm 36.05$	$434.00^{a} \pm 6.62$	$424.55^{a} \pm 10.87$	$419.07^{B} \pm 12.23$	0.04	0.696	0.478
Day 21	$819.63^{a} \pm 22.91$	$787.11^{a} \pm 25.87$	$797.14^{a} \pm 12.06$	$801.29^{A} \pm 11.61$	$755.33^{a} \pm 51.90$	$781.67^{a} \pm 22.62$	$770.93^{a} \pm 29.78$	$769.31^{A} \pm 18.86$	0.217	0.992	0.623
Day 28	$1313.70^{a} \pm 40.89$	$1279.20^{a} \pm 18.88$	$1279.10^{a} \pm 21.74$	$1290.70^{A} \pm 15.54$	$1329.00^{a} \pm 62.66$	$1307.00^{a} \pm 26.23$	$1250.30^{a} \pm 69.69$	$1295.40^{A} \pm 30.44$	0.899	0.47	0.804
Day 35	$1613.50^{a} \pm 93.81$	$1652.40^{a} \pm 9.97$	$1676.60^{a} \pm 44.47$	$1647.50^{A} \pm 31.48$	$1750.10^{a} \pm 66.15$	$1709.60^{a} \pm 56.55$	$1748.00^{a} \pm 41.86$	$1735.90^{A} \pm 28.64$	0.087	0.830	0.771
Day 42	$1953.90^{a} \pm 85.61$	$2036.50^{a} \pm 46.46$	$2093.70^{a} \pm 65.90$	$2028.00^{A} \pm 39.55$	$2110.60^{a} \pm 115.25$	$2134.70^{a} \pm 25.48$	$2162.20^{a} \pm 80.76$	$2135.80^{A} \pm 41.95$	0.106	0.47	0.841
Body weight gain (BWG) g/ bird											
0–7 day	$130.00^{a} \pm 2.22$	$125.33^{a} \pm 1.84$	$122.24^{a} \pm 3.25$	$125.86^{A} \pm 1.69$	$105.11^{a} \pm 20.41$	$114.55^{a} \pm 3.57$	$114.56^{a} \pm 4.62$	$111.4^{B} \pm 6.33$	0.049	0.963	0.597
7–14 day	$272.22^{a} \pm 7.75$	$270.00^{a} \pm 10.66$	$274.52^{a} \pm 6.54$	$272.25^{A} \pm 4.30$	$245.67^{a} \pm 16.00$	$270.56^{a} \pm 4.95$	$261.99^{a} \pm 5.97$	$259.40^{B} \pm 6.30$	0.052	0.462	0.385
14–21 day	$364.51^{a} \pm 22.69$	$338.89^{a} \pm 15.22$	$345.72^{a} \pm 8.67$	$349.71^{A} \pm 9.12$	$356.67^{a} \pm 22.90$	$347.67^{a} \pm 16.08$	$346.38^{a} \pm 19.12$	$350.24^{A} \pm 9.92$	0.972	0.604	0.901
21–28 day	$494.11^{a} \pm 51.11$	$492.12^{a} \pm 10.52$	$481.99^{a} \pm 16.79$	$489.41^{A} \pm 15.93$	$573.67^{a} \pm 12.01$	$525.33^{a} \pm 7.83$	$479.37^{a} \pm 39.92$	$526.12^{A} \pm 18.31$	0.138	0.212	0.377
28–35 day	$299.80^{b} \pm 69.49$	$373.12^{ab} \pm 28.78$	$397.45^{ab} \pm 35.21$	$356.79^{B} \pm 28.11$	$421.05^{ab} \pm 7.50$	$402.63^{ab} \pm 31.22$	$497.70^{a} \pm 43.95$	$440.46^{A} \pm 21.42$	0.027	0.131	0.514
35–42 day	$340.37^{a} \pm 147.69$	$384.18^{a} \pm 55.71$	$417.08^{a} \pm 23.81$	$380.54^{A} \pm 47.40$	$360.50^{a} \pm 124.58$	$425.06^{a} \pm 69.22$	$414.17^{a} \pm 90.83$	$399.91^{A} \pm 49.80$	0.807	0.768	0.974
Cumulative BWG	$1901.00^{a} \pm 84.89$	$1983.70^{a} \pm 46.18$	$2039.00^{a} \pm 66.12$	$1974.60^{A} \pm 39.30$	$2062.70^{a} \pm 115.95$	$2085.80^{a} \pm 25.75$	$2114.20^{a} \pm 79.93$	$2087.50^{A} \pm 41.99$	0.092	0.476	0.844
ADG	$45.26^{a} \pm 2.02$	$47.23^{a} \pm 1.10$	$48.55^{a} \pm 1.57$	$47.01^{A} \pm 0.94$	$49.11^{a} \pm 2.76$	$49.66^{a} \pm 0.61$	$50.34^{a} \pm 1.90$	$49.70^{A} \pm 1.00$	0.092	0.476	0.844

SDTP (sun dried tomato pomace), B (breed), G (group of treatment), ADG (average daily gain). Means carrying different superscripts $^{a-b-c}$ within the same row differ significantly at $P \leq 0.05$ among different SDTP inclusion levels of Indian River and Cobb while carrying different superscripts $^{A-B}$ Within the same row significantly ($P \leq 0.05$) differ among different treated breeds

Table 4 Effect of different SDTP inclusion levels on the relative growth rate of Indian River and Cobb broiler chickens at different weeks

Items	Indian river				Cobb				P value		
	0% SDTP (Control)	4% SDTP	6% SDTP	Overall mean	0%SDTP (Control)	4% SDTP	6% SDTP	Overall mean	B	G	B*G
	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE			
Relative growth rate at different weeks (RGR) %											
1st week	$110.27^{a} \pm 1.43$	$108.45^{a} \pm 0.56$	$105.54^{a} \pm 0.84$	$108.09^{A} \pm 0.85$	$102.44^{a} \pm 11.25$	$107.85^{a} \pm 1.26$	$108.75^{a} \pm 1.73$	$106.35^{A} \pm 3.45$	0.66	0.931	0.515
2nd week	$85.31^{a} \pm 1.22$	$86.14^{a} \pm 1.41$	$87.38^{a} \pm 0.82$	$86.27^{B} \pm 0.66$	$89.81^{a} \pm 3.70$	$90.59^{a} \pm 1.41$	$89.27^{a} \pm 0.68$	$89.89^{A} \pm 1.18$	0.03	0.887	0.726
3rd week	$57.13^{b} \pm 2.75$	$54.84^{b} \pm 1.23$	$55.39^{b} \pm 1.43$	$55.79^{A} \pm 1.02$	$62.13^{ab} \pm 3.58$	$57.14^{b} \pm 1.29$	$57.87^{ab} \pm 1.30$	$59.04^{A} \pm 1.40$	0.086	0.231	0.782
4th week	$46.26^{ab} \pm 4.39$	$47.71^{b} \pm 1.90$	$46.42^{ab} \pm 1.30$	$46.79^{B} \pm 1.45$	$55.26^{a} \pm 2.02$	$50.34^{ab} \pm 1.03$	$47.27^{ab} \pm 1.63$	$50.96^{A} \pm 1.42$	0.048	0.278	0.224
5th week	$20.21^{b} \pm 4.19$	$25.47^{ab} \pm 2.04$	$26.85^{ab} \pm 2.00$	$24.18^{B} \pm 1.78$	$27.43^{ab} \pm 1.00$	$26.62^{ab} \pm 1.41$	$33.42^{a} \pm 3.77$	$29.16^{A} \pm 1.61$	0.042	0.096	0.482
6th week	$19.16^{a} \pm 8.60$	$20.77^{a} \pm 2.84$	$22.10^{a} \pm 0.74$	$20.68^{A} \pm 2.66$	$18.48^{a} \pm 6.37$	$22.19^{a} \pm 3.87$	$21.09^{a} \pm 4.41$	$20.59^{A} \pm 2.56$	0.983	0.831	0.967
Cumulative RGR	$189.43^{b} \pm 0.33$	$189.87^{b} \pm 0.18$	$189.80^{b} \pm 0.37$	$189.70^{B} \pm 0.17$	$191.06^{a} \pm 0.62$	$191.04^{a} \pm 0.15$	$191.30^{a} \pm 0.17$	$191.13^{A} \pm 0.20$	0.000	0.674	0.799

SDTP (sun dried tomato pomace), B (breed), G (group of treatment). Means carrying different superscripts $^{a-b-c}$ within the same row differ significantly at $P \leq 0.05$ among different SDTP inclusion levels of Indian River and Cobb while means carrying different superscripts $^{A-B}$ Within the same row significantly ($P \leq 0.05$) differ among different treated breeds

39.50, and 41.60, respectively) than those fed diets with 0 and 4% SDTP. Moreover, the Cobb chicken fed the 0% SDTP diet recorded significantly lower ($p \leq 0.05$) values (LE 20.74, 35.84, and 37.94 for total feed cost, TVC, and TC, respectively).

Generally, the inclusion of up to 6% SDTP in both breeds resulted in a non-significant increase in return parameters, including return from bird selling and total return compared to consumption of the 0% SDTP diet in both chicken breeds. The Cobb chicken fed the 6% SDTP diet recorded the highest net profit, while the least profit was exhibited by the IR chicken fed the 0% SDTP diet.

Regarding economic efficiency measures calculated as a benefit–cost ratio (BCR (TR/TC)), TR/TVC, NP/TC, and NP/TVC showed non-significant differences ($p \geq 0.05$) between groups of the same breed fed diets with different SDTP inclusion levels (0, 4 and 6%) (Table 7). Among the different inclusion levels for both breeds, IR chicken fed the 0% SDTP diet recorded the lowest values (1.36, 1.44, 0.38, and 0.36 for TR/TC, TR/TVC, NP/TC, and NP/TVC, respectively). The addition of 4% or 6% SDTP resulted in a non-significant difference in feed cost (LE) for each kg body weight and feed cost for each kg body weight gain (BWG) between groups of the same breed fed diets with different SDTP inclusion levels (0, 4 and 6%). IR chicken fed the 0% SDTP diet showed significantly high ($p \leq 0.05$) values (LE 11.92 and 12.25 for feed cost/BW and feed cost/BWG, respectively); the lowest values were recorded in Cobb chickens fed the 0% SDTP diet (LE 9.89 and 10.12, respectively). Additionally, the relative efficiency measures showed a non-significant difference between groups fed diets with different SDTP inclusion levels (0, 4, and 6%) in both Cobb and IR chickens.

With respect to the effect of breed, the IR chickens recorded a significant increase in cost parameters such as feed cost, TVC, and TC compared to the Cobb chickens (Table 6). Regarding net profit and economic efficiency (TR/TC, TR/TVC, NP/TC, and NP/TVC), the Cobb breed recorded a significantly higher value than the IR breed. Additionally, the Cobb breed recorded a significant decrease in feed cost for each kg body weight and body weight gain compared to the IR chickens.

Physicochemical properties of broiler meat (Indian River and Cobb breeds)

The consequence of dietary inclusion of SDTP in the diets of both chicken breeds (IR and Cobb) on the physicochemical character of the meat is shown in Table 8. For the ultimate pH (pH_u), there was a significant difference in IR chicken fed both the 4% and 6% SDTP diets compared to those fed the 0% SDTP diet, while in the Cobb breed, the pH_u showed a significant difference between chickens fed the 6% SDTP

Table 5 Effect of different SDTP inclusion levels on feed intake (FI) and feed conversion rate (FCR) of Indian River and Cobb broiler chickens at different weeks

Items	Indian river				Cobb				P value		
	0% SDTP (Control)	4% SDTP	6% SDTP	Overall mean	0% SDTP (Control)	4% SDTP	6% SDTP	Overall mean			
	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	B	G	B*G
Feed intake (FI) g /bird at different weeks											
1st week	164.00^{a} ± 2.78	154.44^{a} ± 3.07	156.67^{ab} ± 4.67	158.37^{A} ± 2.31	128.44^{b} ± 12.63	156.11^{ab} ± 2.19	145.33^{ab} ± 8.55	143.30^{B} ± 6.00	0.019	0.436	0.05
2nd week	408.62^{b} ± 7.00	421.78^{ab} ± 1.35	445.10^{a} ± 10.60	425.17^{A} ± 6.48	355.73^{c} ± 19.05	420.78^{ab} ± 7.89	409.60^{b} ± 7.49	395.37^{B} ± 11.87	0.004	0.002	0.075
3rd week	706.89^{ab} ± 15.64	710.13^{ab} ± 14.84	760.10^{a} ± 11.10	725.71^{A} ± 11.10	657.24^{b} ± 26.90	706.18^{ab} ± 15.25	726.87^{a} ± 17.23	696.77^{A} ± 14.52	0.066	0.014	0.443
4th week	1204.10^{ab} ± 60.22	1199.10^{ab} ± 12.70	1341.20^{a} ± 68.93	1248.10^{A} ± 35.40	1012.70^{c} ± 61.54	1167.20^{bc} ± 13.32	1139.30^{bc} ± 39.87	1106.40^{B} ± 32.06	0.004	0.055	0.187
5th week	764.54^{ab} ± 20.16	801.70^{ab} ± 76.98	883.94^{a} ± 28.88	816.73^{A} ± 30.14	683.70^{b} ± 7.65	761.89^{ab} ± 5.05	785.20^{abc} ± 78.01	743.59^{A} ± 27.38	0.082	0.054	0.817
6th week	795.00^{bc} ± 8.66	820.00^{ab} ± 0.58	830.00^{a} ± 11.55	815.00^{A} ± 6.67	774.00^{c} ± 9.24	837.00^{a} ± 7.51	794.00^{bc} ± 9.24	801.67^{A} ± 10.26	0.079	0.001	0.024
Cumulative FI	4043.20^{b} ± 68.51	4107.10^{b} ± 103.71	4417.00^{a} ± 78.91	4189.10^{A} ± 71.68	3611.80^{c} ± 126.44	4049.10^{b} ± 8.90	4000.30^{b} ± 87.36	3887.10^{B} ± 82.23	0.001	0.003	0.09
Feed conversion rate (FCR) at end of different weeks											
1st week	1.26^{a} ± 0.02	1.23^{a} ± 0.03	1.28^{a} ± 0.01	1.26^{A} ± 0.01	1.28^{a} ± 0.17	1.37^{a} ± 0.06	1.27^{a} ± 0.09	1.31^{A} ± 0.06	0.479	0.942	0.670
2nd week	1.50^{ab} ± 0.05	1.57^{ab} ± 0.07	1.62^{a} ± 0.04	1.56^{A} ± 0.03	1.45^{b} ± 0.02	1.56^{ab} ± 0.00	1.56^{ab} ± 0.03	1.52^{A} ± 0.02	0.223	0.035	0.825
3rd week	1.96^{ab} ± 0.16	2.10^{ab} ± 0.06	2.20^{a} ± 0.06	2.09^{A} ± 0.06	1.85^{b} ± 0.09	2.04^{ab} ± 0.06	2.11^{ab} ± 0.08	2.00^{A} ± 0.06	0.265	0.05	0.972
4th week	2.52^{a} ± 0.41	2.44^{ab} ± 0.08	2.78^{a} ± 0.06	2.58^{A} ± 0.13	1.76^{b} ± 0.07	2.22^{ab} ± 0.06	2.42^{ab} ± 0.26	2.13^{B} ± 0.13	0.022	0.129	0.425
5th week	2.88^{a} ± 0.74	2.20^{ab} ± 0.33	2.25^{ab} ± 0.16	2.44^{A} ± 0.26	1.62^{b} ± 0.01	1.92^{ab} ± 0.17	1.58^{b} ± 0.12	1.71^{B} ± 0.08	0.024	0.635	0.391
6th week	4.40^{a} ± 2.58	2.24^{a} ± 0.38	2.00^{a} ± 0.09	2.88^{A} ± 0.84	3.22^{a} ± 1.58	2.07^{a} ± 0.32	2.17^{a} ± 0.57	2.49^{A} ± 0.53	0.709	0.341	0.86
Cumulative FCR	2.13^{ab} ± 0.06	2.07^{ab} ± 0.01	2.17^{a} ± 0.07	2.12^{A} ± 0.03	1.76^{c} ± 0.13	1.94^{abc} ± 0.03	1.90^{bc} ± 0.08	1.87^{B} ± 0.05	0.001	0.50	0.282

SDTP (sun dried tomato pomace), B (breed), G (group of treatment). Means carrying different superscripts $^{a-b-c}$ within the same row differ significantly at $P \leq 0.05$ among different SDTP inclusion levels of Indian River and Cobb while carrying different superscripts $^{A-B}$ Within the same row significantly ($P \leq 0.05$) differ among different treated breeds

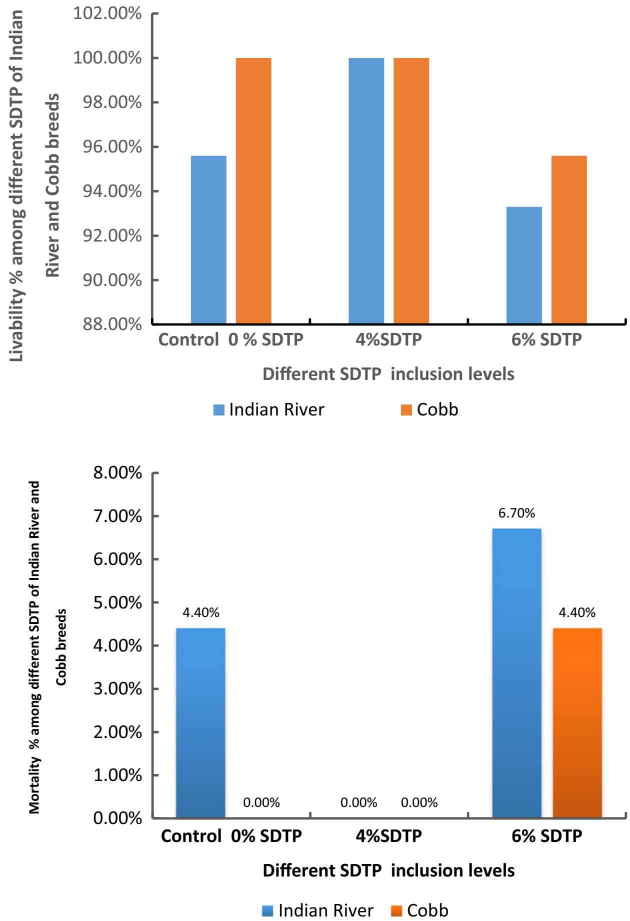

Fig. 1 Effect of different levels of SDTP on the percentage of survival and mortality in different breeds of broiler chicken

diet and those fed the 0% SDTP diet. We found that as the concentration of the tomato powder increased, the ultimate pH value decreased. Moreover, the Warner-Bratzler shear force showed a non-significant increase between chickens fed the 0% SDTP diet and those fed the 6% SDTP diet in the IR breed. Meat color parameters for Redness (a*) ($p \leq 0.05$) were affected significantly by SDTP supplementation, as IR chicken fed the 6% SDTP diet recorded a significantly higher value (11.17) while those fed the 0% SDTP diet recorded a significant decrease (8.58). However, the increase in a* value for Cobb chickens fed the 4% and 6% SDTP diets compared to those fed the 0% SDTP diet was not significant. Yellowness (b*) was affected significantly by SDTP supplementation with the lowest value found in Cobb chickens fed the 6% SDTP diet. The total color differences (Delta E*) between 0% SDTP and the 4% and 6% SDTP-supplemented groups increased with the increasing SDTP supplementation in the diet.

When we examined other study parameters for differences between the two breeds, we found non-significant differences between IR and Cobb for pH, water holding capacity (WHC), drip loss 24 h (DL_{24}), drip loss 48 h (DL_{48}), cooking loss (CL), and meat color. However, the Cobb breed did record a significantly higher Warner–Bratzler shear force (WBSF) value than the IR breed.

mRNA expression of hepatic growth hormone receptor (GHR) and insulin like growth factor-1 (IGF-1) genes

mRNA expression of hepatic GHR and IGF-1 in the IR and Cobb breeds (shown in Figs. 2 and 3) revealed that hepatic GHR expression was not significantly different in any of the groups in either the IR breed or the Cobb breed. However, the expression of hepatic IGF-1 showed significant changes ($p \leq 0.05$) between groups in the IR breed, while there were no significant changes between groups in the Cobb breed. These results confirm the correlation between gene expression and body weight gain in this genetic model.

Discussion

The steady increase in the population of our world shows no signs of stopping. One of the most critical priorities for nutrition experts and policymakers worldwide is easy access to affordable sources of food, so the demand for unconventional feed for stock animals has become more urgent. One of these unconventional feeds is tomato pomace (Asadollahi et al. 2014). The main factor controlling the rate of inclusion is the amount of crude fiber (so as not to exceed the permissible limits for each stage of growth). The high fiber content of dried tomato pomace makes it ideal for use as a low-inclusion alternative to cereal byproducts in poultry diets (Dotas et al. 1999)**.** Several authors who used varying amounts of tomato pomace in their studies (Lira et al. 2010; Rezaeipour et al. 2012) concluded that broiler diets could contain up to 20% DTP when fed to chicks between 29 and 42 days of age, and up to 50 g/kg for those 1–42 days of age, respectively, without affecting growth efficiency. We use two levels, 4% and 6%, to avoid increasing the crude fiber above permissible limits.

The results of the chemical composition analyses of SDTP used in this study (Table 2) show that they were within the range of the values obtained by Del Valle et al. (2006) but lower in crude protein (CP) and neutral detergent fiber (NDF) than those obtained by Mirzaei-Aghsaghali et al. (2011). The chemical composition of SDTP varies according to agriculture and processing practices, the degree of drying, removal of moisture, and cellulose separation.

Our study demonstrates that the inclusion of SDTP in the diets fed to IR and Cobb chickens had no adverse impact on growth performance. Similarly, Rahmatnejad et al. (2011) observed that up to 16% DTP could be added

Table 6 Effect of different SDTP inclusion levels on different costs and returns patterns (LE/bird) of Indian River and Cobb broiler chickens (LE/ bird)

Items	Indian river				Cobb				P value		
	0% SDTP (Control)	4% SDTP	6% SDTP	Overall mean	0% SDTP (Control)	4% SDTP	6% SDTP	Overall mean	B	G	B*G
	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE			
Chick price	10	10	10	10	10	10	10	10	–	–	–
Water and electricity	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	–	–	–
Labor	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	–	–	–
Litter cost	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	–	–	–
Drug	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	–	–	–
Vaccine	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	–	–	–
Disinfectant	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	–	–	–
TVM	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	–	–	–
Starter cost	$3.38^{a} \pm 0.03$	$3.31^{a} \pm 0.01$	$3.40^{a} \pm 0.07$	$3.36^{A} \pm 0.03$	$2.86^{b} \pm 0.19$	$3.31^{a} \pm 0.05$	$3.14^{ab} \pm 0.09$	$3.10^{B} \pm 0.09$	0.005	0.143	0.044
Grower cost	$11.05^{ab} \pm 0.29$	$10.73^{ab} \pm 0.15$	$11.75^{a} \pm 0.40$	$11.17^{A} \pm 0.21$	$9.65^{c} \pm 0.50$	$10.53^{bc} \pm 0.05$	$10.43^{bc} \pm 0.25$	$10.20^{B} \pm 0.21$	0.003	0.051	0.146
Finisher cost	$8.80^{ab} \pm 0.16$	$8.87^{ab} \pm 0.42$	$9.26^{a} \pm 0.20$	$8.97^{A} \pm 0.16$	$8.22^{b} \pm 0.05$	$8.75^{ab} \pm 0.04$	$8.53^{ab} \pm 0.41$	$8.50^{B} \pm 0.14$	0.048	0.347	0.516
Feed cost	$23.23^{ab} \pm 0.39$	$22.91^{ab} \pm 0.57$	$24.40^{a} \pm 0.44$	$23.51^{A} \pm 0.33$	$20.74^{c} \pm 0.73$	$22.59^{b} \pm 0.05$	$22.10^{c} \pm 0.47$	$21.81^{B} \pm 0.37$	0.001	0.047	0.087
TVC	$38.33^{ab} \pm 0.39$	$38.01^{ab} \pm 0.57$	$39.50^{a} \pm 0.44$	$38.61^{A} \pm 0.33$	$35.84^{c} \pm 0.73$	$37.69^{b} \pm 0.05$	$37.20^{bc} \pm 0.47$	$36.91^{B} \pm 0.37$	0.001	0.047	0.087
Building	2	2	2	2	2	2	2	2	–	–	–
Equipment	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	–	–	–
TFC	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	–	–	–
TC	$40.43^{ab} \pm 0.39$	$40.11^{ab} \pm 0.57$	$41.60^{a} \pm 0.44$	$40.71^{A} \pm 0.33$	$37.94^{c} \pm 0.73$	$39.79^{b} \pm 0.05$	$39.30^{bc} \pm 0.47$	$39.01^{B} \pm 0.37$	0.001	0.047	0.087
Return from bird selling	$54.71^{a} \pm 2.40$	$57.02^{a} \pm 1.30$	$58.62^{a} \pm 1.85$	$56.79^{A} \pm 1.11$	$59.10^{a} \pm 3.23$	$59.77^{a} \pm 0.71$	$60.54^{a} \pm 2.26$	$59.80^{A} \pm 1.17$	0.106	0.47	.841
Return from litter	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	–	–	–
TR	$55.21^{a} \pm 2.40$	$57.52^{a} \pm 1.30$	$59.12^{a} \pm 1.85$	$57.29^{A} \pm 1.11$	$59.60^{a} \pm 3.23$	$60.27^{a} \pm 0.71$	$61.04^{a} \pm 2.26$	$60.30^{A} \pm 1.17$	0.106	0.47	.841
Net profit	$14.78^{b} \pm 2.01$	$17.42^{ab} \pm 0.76$	$17.52^{ab} \pm 1.76$	$16.57^{B} \pm 0.92$	$21.66^{a} \pm 3.35$	$20.49^{ab} \pm 0.72$	$21.74^{a} \pm 2.27$	$21.30^{A} \pm 1.20$	0.014	0.789	0.639

SDTP (sun dried tomato pomace), B (breed), G (group of treatment), TVM (total veterinary management), TVC (Total variable cost), TFC (total fixed cost), TR (Total return). Means carrying different superscripts $^{a-b-c}$ within the same row differ significantly at $P \leq 0.05$ among different SDTP inclusion levels of Indian River and Cobb while carrying different superscripts $^{A-B}$ Within the same row significantly ($P \leq 0.05$) differ among different treated breeds

Table 7 Effect of different SDTP inclusion levels on different economic efficiency measures of Indian River and Cobb broiler chickens

Items	Indian river				Cobb				P value		
	0%SDTP (Control)	4% SDTP	6% SDTP	Overall mean	0%SDTP (Control)	4% SDTP	6% SDTP	Overall mean	B	G	B*G
	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE			
BCR(TR/TC)	1.36^{b} ± 0.05	1.43^{ab} ± 0.01	1.42^{ab} ± 0.04	1.41^{B} ± 0.02	1.57^{a} ± 0.09	1.51^{ab} ± 0.02	1.55^{a} ± 0.06	1.55^{A} ± 0.03	0.006	0.935	0.495
TR/ TVC	1.44^{b} ± 0.05	1.51^{ab} ± 0.01	1.50^{ab} ± 0.04	1.48^{B} ± 0.02	1.66^{a} ± 0.10	1.60^{ab} ± 0.02	1.64^{a} ± 0.06	1.64^{A} ± 0.04	0.006	0.951	0.473
Net profit / TVC	0.38^{b} ± 0.05	0.46^{ab} ± 0.01	0.44^{ab} ± 0.04	0.43^{B} ± 0.02	0.61^{a} ± 0.10	0.54^{ab} ± 0.02	0.58^{a} ± 0.06	0.58^{A} ± 0.04	0.006	0.941	0.488
Net profit/TC	0.36^{b} ± 0.05	0.43^{ab} ± 0.01	0.42^{ab} ± 0.04	0.41^{B} ± 0.02	0.57^{a} ± 0.09	0.51^{ab} ± 0.02	0.55^{a} ± 0.06	0.55^{A} ± 0.03	0.006	0.935	0.495
Relative efficiency %	100.00^{a} ± 12.78	118.94^{a} ± 3.79	115.43^{a} ± 11.46	111.46^{A} ± 5.85	100.00^{a} ± 15.99	89.96^{a} ± 3.20	96.71^{a} ± 10.33	95.56 ^{A} ± 5.76	0.093	0.841	0.414
Feed cost / BW(LE/kg)	11.92^{a} ± 0.34	11.25^{abc} ± 0.07	11.68^{ab} ± 0.36	11.61^{A} ± 0.17	9.89^{d} ± 0.70	10.58^{bcd} ± 0.13	10.25 ^{cd} ± 0.41	10.24^{B} ± 0.26	0.001	0.988	0.257
Feed cost / BWG (LE/kg)	12.25^{a} ± 0.36	11.55^{abc} ± 0.07	11.99^{ab} ± 0.38	11.93^{A} ± 0.18	10.12^{d} ± 0.73	10.83^{bcd} ± 0.14	10.48 ^{cd} ± 0.42	10.48^{B} ± 0.27	0.001	0.991	0.264

SDTP (sun dried tomato pomace),B (breed), G (group of treatment), BCR (benefit–cost ratio = TR/TC).TR (total return), TVC (Total variable cost), TC (total cost), BW (body weight), BWG (body weight gain). Means carrying different superscripts $^{a-b-c}$ Within the same row differ significantly at $P \leq 0.05$ among different SDTP inclusion levels of Indian River and Cobb while carrying different superscripts $^{A-B}$ Within the same row significantly ($P \leq 0.05$) differ among different treated breeds

Table 8 Effect of different SDTP inclusion levels on meat physicochemical properties of Indian River and Cobb broiler chickens

Items	Indian river				Cobb				P value		
	0% SDTP (Control)	4% SDTP	6% SDTP	Overall mean	0% SDTP (Control)	4% SDTP	6% SDTP	Overall mean	B	G	B*G
	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE			
PH_U	5.47^{a} ± 0.16	5.19^{bc} ± 0.03	5.17^{bc} ± 0.05	5.28^{A} ± 0.07	5.28^{ab} ± 0.07	5.26^{abc} ± 0.06	5.24^{c} ± 0.01	5.26^{A} ± 0.02	0.79	0.053	0.177
WHC%	82.66^{a} ± 1.55	81.22^{a} ± 0.73	81.84^{a} ± 0.19	81.91^{A} ± 0.54	83.12^{a} ± 0.64	83.03^{a} ± 2.70	83.15^{a} ± 3.37	83.10^{A} ± 1.26	0.461	0.924	0.939
DL24%	4.95^{a} ± 0.93	3.53^{a} ± 0.93	3.89^{a} ± 0.5	4.12^{A} ± 0.46	4.85^{a} ± 1.56	2.93^{a} ± 0.77	2.61^{a} ± 1.17	3.47^{A} ± 0.70	0.451	0.218	0.851
DL48%	6.24^{a} ± 2.54	8.68^{a} ± 1.00	8.10^{a} ± 1.12	7.67^{A} ± 0.93	8.88^{a} ± 2.06	6.86^{a} ± 1.13	6.75^{a} ± 1.01	7.50^{A} ± 0.82	0.895	0.976	0.34
Cooking loss %	9.11^{a} ± 3.65	9.48^{a} ± 1.25	11.87^{a} ± 1.52	10.15^{A} ± 1.27	8.75^{a} ± 1.48	9.34^{a} ± 0.0.51	7.41^{a} ± 0.50	8.44^{A} ± 0.55	0.992	0.811	0.393
WBSF	2.42^{a} ± 0.35	2.61^{a} ± 0.19	2.60^{a} ± 0.20	2.54^{B} ± 0.15	3.12^{a} ± 0.21	3.33^{a} ± 0.27	3.26^{a} ± 0.34	3.23^{A} ± 0.15	0.003	0.73	0.995
a*	8.58^{b} ± 0.50	9.60^{ab} ± 0.27	11.17^{a} ± 0.46	9.78^{A} ± 0.37	10.10^{ab} ± 0.01	9.65^{ab} ± 0.25	10.49^{a} ± 0. 75	10.08^{A} ± 0.29	0.443	0.011	0.088
b*	10.81^{a} ± 1.22	8.27^{ab} ± 0.42	8.39^{ab} ± 0.33	9.15^{A} ± 0.51	9.54^{ab} ± 1.39	8.99^{ab} ± 0.65	7.34^{b} ± 0.44	8.62^{A} ± 0.53	0.453	0.041	0.455
L*	57.04^{a} ± 0.44	55.98^{a} ± 0.32	55.56^{a} ± 0.88	56.19^{A} ± 0.35	55.85^{a} ± 1.79	57.84^{a} ± 0.99	55.19^{a} ± 1.87	56.29^{A} ± 0.86	0.922	0.443	0.441
Total color differences(ΔE*)	–	2.93	3.83	–	–	2.11	2.32	–			

SDTP (sun dried tomato pomace), B (breed), G (group of treatment), pH_u (Ultimate Ph), WHC (Water holding capacity), DL_{24} (Drip loss (24 h)), DL_{48} (Drip loss (48 h)), WBSF (Warner–Bratzler shear force), a* (redness), b* (yellowness), L* (lightness). Means carrying different superscripts $^{a-b-c}$ within the same row differ significantly at $P \leq 0.05$ among different SDTP inclusion levels of Indian River and Cobb while carrying different superscripts $^{A-B}$ Within the same row significantly ($P \leq 0.05$) differ among different treated breeds to diets without any adverse effect on the performance of the broiler chickens.

The data from our study also show that IR chicken fed the 6% SDTP diet and Cobb chicken fed the 4% SDTP diet presented significantly ($p \leq 0.05$) higher FI values than those of the same breed fed diets with 0% SDTP in the 2nd and 6th, weeks. Generally, chicken fed a diet with 4% or 6% SDTP, whether they were IR or Cobb chickens, consumed more feed than those chicken fed the 0% SDTP diet, probably because the large amount of fiber in the diets resulted in enlargement of the digestive tissue, due possibly to increased retention time for digestion of the diet, which led to higher feed intake (Colombino et al. 2020). Along the same lines, the IR group fed the 6% SDTP diet recorded significantly higher feed costs, TVC, and TC. Cobb chicken fed the 0% SDTP diet recorded significantly lower values. These results agree with those of Shehata et al. (2018), who concluded that incorporation of TP into poultry diets leads to more feed intake due to a higher fiber content to meet its needs for energy, which is reflected in both feed cost and TVC, as feed cost constitutes 70% of total production cost. Others have stated that the highest broiler feed intake belonged to birds supplemented with 150 g of DTP with enzyme supplementation (Rezaeipour et al. 2012). These results were consistent with findings showing higher feed consumption in the group fed a diet containing seed and TP than in the control group (King and Zeidler, 2004). This is advantageous for feed producers, as DTP is regarded as a waste material that can be purchased cheaply, thus reducing the production cost without affecting the feed consumption.

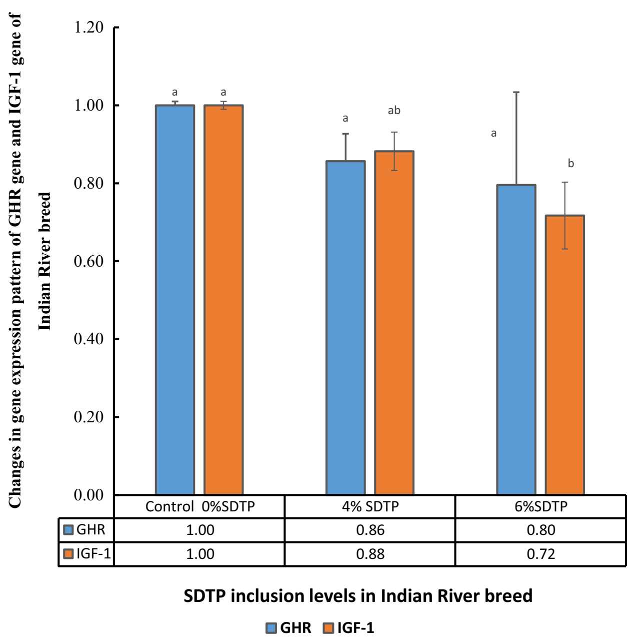

Fig. 2 Effect of different levels of SDTP on the GHR and IGF-1 in the Indian River breed. Samples were expressed for the changes in GHR and IGF-1 genes after normalization with the housekeeping gene (β-actin) for 5 different birds from each treatment. Values with the same letters are insignificant; those with different letters are significant at $p \leq 0.05$

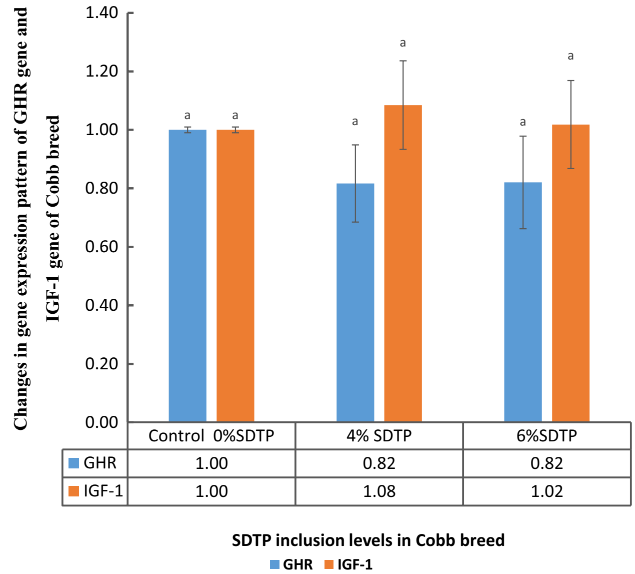

Fig. 3 Effect of different levels of SDTP on GHR and IGF-1 in the Cobb breed. Samples were expressed for the changes in GHR and IGF-1 genes after normalization with the housekeeping gene (β-actin) for 5 different birds from each treatment. Values with same letters are insignificant; those with different letters are significant at $p \leq 0.05$

The addition of up to 6% SDTP to the diets of both breeds resulted in a non-significant increase in return parameters, including return from bird selling and total return compared with the group fed the 0% SDTP diet in both breeds. Moreover, the Cobb chickens fed the 6% SDTP diet recorded the highest net profit, while the lowest value was noted in the IR chickens fed the 0% SDTP diet. This was reflected in the economic efficiency measures, as BCR (TR/TC), TR/TVC, NP/TC NP/TVC, feed cost for each kg body weight, and feed cost for each kg body weight gain showed a non-significant difference between groups of the same breed fed diets with different SDTP inclusion levels (0, 4 and 6%). The lowest values were recorded in IR chicken fed the 0% SDTP diet (TR/TC, TR/TVC, NP/TVC and NP/TC, respectively). IR chicken fed the 0% SDTP diet recorded the highest feed cost for each kg body weight and body weight gain. These results agree with those of Yitbarek, who reported that the addition of DTP at the level of 5% resulted in an increased net profit compared to the control group (Yitbarek, 2013). Similarly, other researchers (Rahmatnejad et al. 2011; Omar, 2014) have reported that SDTP could be added to poultry diets without any adverse effect on economic efficiency.

Our study demonstrated that the Cobb breed had higher overall BW from the third through the sixth weeks. The Cobb chickens also demonstrated a higher BWG (from 14 to 42 days) than the IR breed. Our result is in agreement with those in the study of Abo Ghanema, who demonstrated that Cobb 500 chickens had significantly ($p \leq 0.05$) higher final body weights and total body weight gain (2504.14 and 2461.14, respectively) than IR chickens (2417.27 and 2373.87, respectively) (Abo Ghanema, 2020). However, others (Jawasreh et al. 2019) have found that the IR breed had a significantly ($p < 0.0001$) heavier final body weight (1878.46 g) than the Cobb (1588.15 g). In our study, the IR breed had a significantly higher ($p \leq 0.05$) cumulative feed intake and cumulative FCR than the Cobb breed. Also, Abo Ghanema found that IR chickens had a significantly higher feed intake and recorded a higher FCR (4859.14 and 2.06, respectively) than Cobb 500 chickens (4812.67 and 1.96, respectively) (Abo Ghanema, 2020). This was reflected in the different economic efficiency measures as increasing values of different cost parameters in IR chicken and increased return parameters in Cobb chicken, which indicated that the Cobb chicken was more profitable than the IR chicken. These results are in agreement with those of Amao et al. (2015), who indicated that the Cobb breed was better and more profitable. Rudra et al. (2018) indicated that the Cobb had higher return parameters values than other broiler breeds.

Regarding the percent mortality, no significant difference was observed between the groups. Our results are similar to those of Rahmatnejad et al. (2011), who found that the addition of tomato pomace did not significantly affect mortality.

Generally, muscle pH values decrease during the immediate post-mortem period; the pH decline rate usually affects meat quality. The ultimate pH (pH_u) decreased and was concentration dependent as the concentration of the tomato powder increased. The influence of SDTP on the pH observed was in agreement with the results of others (Deda et al. 2007; Eyiler and Oztan, 2011; Kim and Chin, 2017). The low pH values of the groups fed the 4% and 6% SDTP diets is due to the low pH of tomatoes (pH 4.4–5.02) (Eyiler and Oztan, 2011). Moreover, the Warner–Bratzler shear force showed a non-significant increase between chickens fed the 0% SDTP diet and those fed the 6% SDTP diet ($p \geq 0.05$) in the IR breed, in agreement with the results of Chung et al. (2014). This could be attributed to the fiber content of DTP, which is mainly acid detergent fiber (cellulose and lignin) (299.4 g/kg of peel) (Knoblich et al. 2005), which could have an effect on the hardness, cohesiveness, and shear force of cooked meat samples. The Redness (a*) value increased with increased levels of SDTP in the diet, which is in agreement with the results of others (Nikolakakis et al. 2004; Eyiler and Oztan, 2011). This may be due to DTP, which contains a suitable amount of carotenoids (30 mg/kg) that could be responsible for desirable carcass pigmentation (Dotas et al. 1999). Lycopene is the principal pigment responsible for the characteristic deep-red color of ripe tomato fruits and tomato products (Shi and Le Maguer, 2000). The total color differences (Delta E*) between 0% SDTP and the SDTP-supplemented groups increased with increasing SDTP supplementation in the diet. These results agree with those of Peiretti et al. (2013). The use of ΔE^* values may be necessary for detection, as it unknown whether subtle changes in color are detectable by the human eye. According to Francis and Clydesdale (1975), when color differences (ΔE^*) exceed a value of 3, the color of meat is visually detectable.

Expression of hepatic GHR showed no significant changes between different groups in either the IR or Cobb breeds. However, hepatic IGF-1 showed significant changes in the IR breed between groups, while there were no significant changes between groups in the Cobb breed. These results confirm the correlation between gene expression and body weight gain in this genetic model and confirm those reported by others (Al-Betawi 2005; Ghazi and Drakhshan, 2006; Shamseborhan and Safamehr, 2012), who showed a non-significant difference between different levels of dried tomato pomace inclusion with respect to body weight and body weight gained in comparison with the control group.

Conclusion

This study concluded that the inclusion of up to 6% SDTP in the diet of IR or Cobb chickens had no adverse impact on growth performance parameters such as average body weight, average body weight gain, and relative growth rate; the highest values were recorded for Cobb chicken fed the 6% SDTP diet (2162.2 g, 2114.2 g, and 50.34 g for BW on Day 42, cumulative BWG, and ADG, respectively). Inclusion of up to 6% SDTP in the diets of both breeds resulted in a non-significant increase in return parameters as average return from bird selling and average total return. Moreover, Cobb chicken fed the 6% SDTP diet recorded the highest net profit (LE 21.74); the lowest value was for IR chicken fed the 0% SDTP diet (LE 14.78). The ultimate pH (pH_u) decreased with the increase in SDTP concentration in the feed of both breeds, consequently improving the meat quality and increasing its shelf life. In addition, the a* value increased so the desirable red color of the meat was improved. No alteration of genetic parameters was observed due to the diets, which were formulated to be iso-energetic and iso-nitrogenous.

When examining the differences between the breeds, we found that the IR showed a significant increase ($p \leq 0.05$) in BW and BWG during the 1st and 2nd weeks of the rearing period compared to the Cobb breed. The Cobb had a significantly higher ($p \leq 0.05$) RGR than the IR breed. The IR had a significantly higher ($p \leq 0.05$) cumulative feed intake and cumulative FCR than the Cobb breed, which resulted in a significant increase in cost parameters such as feed cost, TVC, and TC for the IR compared to the Cobb chickens. Cobb breed chickens outperformed IR chickens in terms of net profit and economic efficiency (TR/TC, TR/TVC, NP/TC, and NP/TVC) and the Cobb breed recorded a significantly higher Warner–Bratzler shear force (WBSF) value than the IR breed.

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Author contributions Conceptualization: LSM, EAS methodology: LSM, EAS, SNE, OAK, MMS, and SFS; investigation: LSM, EAS, SNE, OAK, MMS, and SFS; resources: LSM, EAS, SNE, OAK, MMS, and SFS; data curation: LSM, EAS, SFS, SNE; Writing—original draft preparation: LSM, EAS, SNS, OAK, and SFS; review and editing: LSM, EAS, SNE, OAK, MMS, and SFS; supervision: LSM, EAS, MMS, and SFS. All authors have read and agreed to the manuscript's current published version.

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Data Availability Data are available up on request.

Declarations

Conflict of interest The authors declare that there is no conflicts of interest.

Ethical Approval This study was approved by the Institutional Animal Care and Use Committee Research Ethics Board, Faculty of Veterinary Medicine, Benha University, under ethical number BUFVTM 02–09-20 and TURSP 2020–09.

Informed Consent All authors agree to the content of paper for publication.

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