

# Effect of Different Levels of Citrus Waste (*Kinnow* sp.) on Growth Performance and Nutrient Digestibility of Broiler Birds without and with Cocktail of Enzymes

Devi Prasad Behera, A. P. S. Sethi, Udeybir Singh\* and M. Wadhwa

Department of Animal Nutrition, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, Punjab, INDIA

\*Corresponding Author: [udeybirchahal@gmail.com](mailto:udeybirchahal@gmail.com)

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## Abstract

*This experiment was conducted to study the effect of citrus waste (CW) and cocktail enzyme supplementation on performance of broilers. Three-hundred-day-old broiler birds were divided into eight groups having four replicates of eight birds. Birds of control (T1) were fed a standard ration to meet their requirements; diets of the treatment groups T2, T3 and T4 were supplemented with citrus waste at 2.5%, 5% and 7.5%, respectively. Diet of group T5 was same as T1 but also contained cocktail of enzymes. Diet of groups T6 to T8 were similar to those of groups T2- T4, but were additionally supplemented with cocktail of enzyme at 100g/100kg of the feed. During starter phase, the group fed 5% citrus waste without addition of enzyme showed best response ( $P<0.05$ ) with respect to various growth parameters. During grower and finisher phase final body weight, body weight gain and feed conversion ratio (FCR) was best ( $P<0.05$ ) in the group where no CW was added followed by 5% CW supplemented group. Feed intake reduced with increased level of CW in the diet. For overall period of 42 days, the growth performance of broilers was best in groups fed no CW, the 5% CW supplemented group was best amongst different citrus waste supplemented groups. It was concluded that 5% citrus waste can be supplemented in broiler starter ration.*

**Keywords:** Broilers, Citrus Waste, Cocktail of Enzyme, Growth Performance, Nutrient Digestibility

## Introduction

In poultry industry, feed alone costs approximately 60-70 % of the total cost of production (Thirumalaisamy *et al.*, 2016). Increase in the price of feed ingredients have direct impact on the broiler industry both in terms of economics and demand. In order to meet the increased demand for poultry feed, search for novel feed resources, particularly those not competing with human food, is the key for sustainable development of the poultry industry. The food processing sector generate approximately 1.81 million tonnes of fruit and vegetable wastes in India which are either composted or dumped in landfills or rivers, causing environmental hazards (Wadhwa and Bakshi, 2013). These wastes need immediate attention which will not only help in decreasing environmental hazard but will also lead to improved economical production of livestock products by their use as feed and feed ingredients. Such an approach will convert “wastes to opportunities for development” in addition to contributing to sustainable intensification of livestock industry. These wastes left after processing is rich in essential nutrients that have the potency to be supplemented in animal diets as by-products.

Citrus waste of the citrus processing industry is available in huge quantities in India which includes 60–65% peel, 30–35% internal tissues and up to 10% seeds which constitutes 50% of processed citrus (Crawshaw, 2004). The term citrus covers oranges, sweet lemon/lime, lemon, kinnow, grapefruit, tangerine, etc. The major by-products of processed citrus are dried pulp, molasses, washed pulp solids and essential oils. Dried citrus pulp contains about 5–10% CP, 6.2% EE, 10–40% soluble fibre (pectins), 54% water-soluble sugars, 1–2% calcium and 0.1% phosphorus (Wadhwa and Bakshi, 2013).

Citrus (Kinnow sp.) production in Punjab is 1,140.31 thousand tonnes and it stands first in India (<http://agriexchange.apeda.gov.in>) and generates huge amount of kinnow waste from its processing. Punjab Agro Juices Ltd. is leading processor of fruit juices in Punjab state. The waste left after extracting juice is one of the major hurdles to manage. This can be used as a good alternate feed ingredient for broilers. Use of citrus waste will not only help in preventing environmental pollution but will be a cost-effective alternative feed ingredient for economical broiler production. The present investigation was conducted to assess the impact on performance of broilers fed different levels of citrus waste without and with cocktail of enzymes.

## Materials and Methods

The present investigation was carried out on a synthetic stock used by crossing broiler parent line (IBL-80) and RIR birds with the expectation of improving the growth performance of broiler parents in the poultry nutrition laboratory and at the poultry farms of the department of Animal Nutrition, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana. Citrus waste was procured from Punjab Agro juices Ltd, and the wet material obtained from the firm was sun dried and grounded to obtain powdered citrus waste. Three-hundred-day old broilers chicks were procured from university hatchery. Each bird was weighed on arrival and randomly assigned to eight different dietary treatments using completely randomized design. Each dietary treatment had four replicates having eight broiler birds in each replicate. All the experimental groups of birds were reared in the pens on the deep litter from day one to 42nd day of age. Daily feed intake, weekly body weight gain and mortality was recorded following standard management practices and vaccination schedule.

The feeding was done in three phases i.e., starter (0-14 days), grower (15-21 days) and finisher (22-42 days) phase. For each phase, eight iso-caloric and iso-nitrogenous (T1-T8) diets were formulated as per ICAR (2013) specification (Table 1). Diet T1 served as control while diet T5 served as positive control and was supplemented with cocktail of enzymes ( $\beta$ -glucanase, xylanase, pectinase, cellulase, acid protease, natural protease, mannanase,  $\alpha$ -glucosidase, amylase, lipase, phytase and  $\alpha$ -Galactosidase) @100 g/q feed. Diets T2 to T4 were supplemented with citrus waste @ 2.5, 5 and 7.5 % level without cocktail of enzymes. Similarly, diets T5 to T8 were fed with citrus waste @ 2.5, 5 and 7.5 % level with cocktail of enzymes. Weighed amount of respective diet was offered daily to all groups to ensure ad lib feeding. All the experimental diets were analysed for proximate principles, phosphorus (AOAC, 2000) and calcium (Talpatra *et al.*, 1940).

To assess the nutrient digestibility four birds from each treatment of comparable body weight were selected and divided into two replicates of treatment for conducting metabolic trial in the cages. After five days of adaptation period, weighed amount of fresh feed was offered to each group, for three consecutive days. The feed residue was collected on the fourth day to calculate actual feed consumption for each group. Faeces were collected daily,

weighed, dried at 80°C in hot air oven. Dried faeces of each group for three consecutive days was pooled and grounded. Chemical analysis of feed, faeces and residue was done to evaluate the nutrient digestibility. The collected data were analysed by 2 X 4 factorial design using software package for social sciences (SPSS Version 24.0) at 95% significant level using Duncan's multiple range test (Duncan, 1955).

**Table 1:** Ingredient composition of starter, grower and finisher feed

Ingredients	Starter							
	T1	T2	T3	T4	T5	T6	T7	T8
(%)								
Maize	58.5	56.6	55.5	53.5	58.4	56.5	55.4	53.4
DORP	2.1	1.8	1	0	2.1	1.8	1	0
SBM	28.1	29.1	29.4	27.4	28.1	29.1	29.4	27.4
MGM	0.6	0.8	1.2	1.2	0.6	0.8	1.2	1.2
GNE	4.8	3.2	2	4.3	4.8	3.2	2	4.3
CITRUS	0	2.5	5	7.5	0	2.5	5	7.5
OIL	2.3	2.5	2.5	2.8	2.3	2.5	2.5	2.8
DCP	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
LSP	1.4	1.3	1.2	1.1	1.4	1.3	1.2	1.1
Methionine	0.16	0.16	0.16	0.17	0.16	0.16	0.16	0.17
Enzyme (g)	---	---	----	----	100	100	100	100
Additives*	+	+	+	+	+	+	+	+
Grower								
(%)	T1	T2	T3	T4	T5	T6	T7	T8
Maize	61.2	59.1	57	55.15	61.1	59	57	55.05
DORP	0	0	0	0	0	0	0	0
SBM	22.9	24.3	25	26.6	22.9	24.3	25.1	26.6
MGM	1.2	1.3	1.5	1.9	1.2	1.3	1.5	1.9
GNE	8.8	6.8	5.4	2.65	8.8	6.8	5.2	2.65
CITRUS	0	2.5	5	7.5	0	2.5	5	7.5
OIL	2.5	2.7	2.9	3.1	2.5	2.7	2.9	3.1
DCP	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45
LSP	1.45	1.35	1.25	1.15	1.45	1.35	1.25	1.15
Methionine	0.12	0.13	0.13	0.14	0.12	0.13	0.13	0.14
Enzyme (g)	---	---	----	----	100	100	100	100
Additives*	+	+	+	+	+	+	+	+
Finisher								
(%)	T1	T2	T3	T4	T5	T6	T7	T8
Maize	63.9	61.8	61.5	60	63.8	61.7	61.4	59.9
RP	1.8	1.8	0.5	0	1.8	1.8	0.5	0
SBM	19.4	19.4	20.9	21.1	19.4	19.4	20.9	21.1
MGM	0.3	0.7	1.3	1.7	0.3	0.7	1.3	1.7
GNE	8.7	7.8	4.9	3.8	8.7	7.8	4.9	3.8
CITRUS	0	2.5	5	7.5	0	2.5	5	7.5
OIL	2.8	3	3	3.1	2.8	3	3	3.1
DCP	1.35	1.4	1.35	1.4	1.35	1.45	1.35	1.4
LSP	1.25	1.1	1.05	0.9	1.25	1.1	1.05	0.9
Methionine	0.08	0.08	0.08	0.09	0.08	0.08	0.08	0.09
Enzyme (g)	---	---	----	----	100	100	100	100
Additives*	+	+	+	+	+	+	+	+

\*Additives: Per 100 kg Ration: vitamin A 8,25,000 IU; vitamin D3 1,20,000 IU; riboflavin 500 mg; Vitamin K 100mg; Vitamin E 800 mg; thiamin 80 mg; pyridoxine 160 mg; Cynacobalamin 800 mg; Niacin 1200 mg; calcium pantothenate 800 mg; manganese sulphate 25g; znc Sulphate 25g; ferrous sulphate 10g; copper sulphate 500 mg; potassium iodide 100 mg; coccidiostat 60 g; toxin binder 50 g; salt 300 g.

## Results and Discussion

Data pertaining to performance of synthetic stock of broiler parents during starter phase are presented in Table 2. Highest ( $p < 0.05$ ) final body weight (94.09g) and BWG (58.50g) were observed in the group fed 5% CW; however,

non-significant differences were observed in group where no CW was included in the diet. The FBW and BWG in the two other groups where 2.5% and 7.5% citrus waste was supplemented were less ( $p < 0.05$ ). There was a significant ( $p < 0.05$ ) difference among the entire groups in case of feed intake during starter phase. Feed intake decreased ( $p < 0.05$ ) with increase in the inclusion of citrus level in the diet. Oluremi *et al.* (2006) fed citrus peel in starter diets of broiler as substitute to corn also found decreased feed intake as the level of citrus peel was increased in the diet (0-20%). The decrease in FI can be attributed to the bitter taste and presence of appetite depressing factor i.e., D-limonene in the citrus by-products (Jong-kyu *et al.*, 1996). Less FI and higher BWG in the group fed 5 percent citrus waste irrespective of enzyme level was reflected in the best ( $p < 0.05$ ) FCR, PER and CCR. Poorest ( $p < 0.05$ ) FCR, PER and CCR was observed in the group where no citrus waste was included in the diet.

**Table 2:** Effect of feeding different levels of citrus waste with and without enzyme on growth performance during Starter phase (0 - 14<sup>th</sup> day)

Treatment	Citrus (%)	Enzyme (g/q)	Initial BW (g)	FBW (g)	BWG (g)	FI (g)	FCR	PER	CCR
<b>Effect of citrus waste</b>									
-	0	-	35.6	93.37 <sup>a</sup>	57.78 <sup>a</sup>	225.07 <sup>a</sup>	3.91 <sup>a</sup>	1.09 <sup>d</sup>	0.09 <sup>d</sup>
-	2.5	-	35.6	87.19 <sup>b</sup>	51.61 <sup>b</sup>	175.60 <sup>b</sup>	3.42 <sup>b</sup>	1.24 <sup>c</sup>	0.10 <sup>c</sup>
-	5	-	35.6	94.09 <sup>a</sup>	58.52 <sup>a</sup>	167.96 <sup>c</sup>	2.90 <sup>c</sup>	1.47 <sup>a</sup>	0.12 <sup>a</sup>
-	7.5	-	35.5	86.45 <sup>b</sup>	50.98 <sup>b</sup>	157.19 <sup>d</sup>	3.10 <sup>c</sup>	1.36 <sup>b</sup>	0.11 <sup>b</sup>
-	Pooled SE		0.025	1.175	1.182	1.293	0.081	0.032	0.003
<b>Effect of enzyme</b>									
-	-	0	35.6	92.40 <sup>a</sup>	56.80 <sup>a</sup>	184.07 <sup>a</sup>	3.26	1.32 <sup>a</sup>	0.11 <sup>a</sup>
-	-	100	35.5	88.15 <sup>b</sup>	52.65 <sup>b</sup>	178.84 <sup>b</sup>	3.4	1.25 <sup>b</sup>	0.10 <sup>b</sup>
-	Pooled SE		0.018	0.831	0.835	0.914	0.058	0.022	0.002
<b>Citrus waste × enzyme</b>									
T <sub>1</sub>	0	0	35.7	92.82 <sup>bc</sup>	57.11 <sup>bc</sup>	233.17 <sup>a</sup>	4.10 <sup>a</sup>	1.04 <sup>c</sup>	0.08 <sup>c</sup>
T <sub>2</sub>	2.5	0	35.6	89.45 <sup>bcd</sup>	53.82 <sup>bcd</sup>	171.52 <sup>d</sup>	3.19 <sup>c</sup>	1.32 <sup>b</sup>	0.10 <sup>b</sup>
T <sub>3</sub>	5	0	35.6	99.26 <sup>a</sup>	63.64 <sup>a</sup>	172.48 <sup>d</sup>	2.72 <sup>d</sup>	1.56 <sup>a</sup>	0.12 <sup>a</sup>
T <sub>4</sub>	7.5	0	35.4	88.06 <sup>cd</sup>	52.62 <sup>bcd</sup>	159.11 <sup>ef</sup>	3.03 <sup>cd</sup>	1.39 <sup>b</sup>	0.11 <sup>b</sup>
T <sub>5</sub>	0	100	35.5	93.92 <sup>b</sup>	58.44 <sup>b</sup>	216.98 <sup>e</sup>	3.72 <sup>b</sup>	1.14 <sup>c</sup>	0.09 <sup>c</sup>
T <sub>6</sub>	2.5	100	35.5	84.92 <sup>d</sup>	49.41 <sup>d</sup>	179.69 <sup>c</sup>	3.64 <sup>b</sup>	1.16 <sup>c</sup>	0.09 <sup>c</sup>
T <sub>7</sub>	5.0	100	35.5	88.92 <sup>cd</sup>	53.41 <sup>bcd</sup>	163.43 <sup>e</sup>	3.08 <sup>c</sup>	1.38 <sup>b</sup>	0.11 <sup>b</sup>
T <sub>8</sub>	7.5	100	35.5	84.84 <sup>d</sup>	49.33 <sup>d</sup>	155.27 <sup>f</sup>	3.17 <sup>c</sup>	1.33 <sup>b</sup>	0.11 <sup>b</sup>
-	Pooled SE		0.036	1.662	1.671	1.828	0.115	0.045	0.004

*a, b, = Means bearing different superscripts in a column differ significantly ( $P \leq 0.05$ )*

Feed intake, final body weight, final body weight gain and FCR were significantly ( $p < 0.05$ ) better in the non-enzyme supplemented groups. It showed that supplementation of enzyme had no effect on different growth parameters rather the performance deteriorated by adding enzyme. The observations recorded were in contradiction with that of Abdel-Moneim *et al.* (2014) who reported that replacing the yellow corn with orange waste in broilers diet did not cause any significant change in performance at all dietary treatments with and without enzyme addition in starter phase. No specific reason could be ascertained.

Highest ( $p < 0.05$ ) FBW and BWG were obtained where 5 percent citrus waste without enzyme was fed to the commercial broilers (Table 2). FBW and BWG decreased with increase in citrus level in the diet. Similarly, as the citrus level was increased the FI decreased significantly. Best ( $p < 0.05$ ) FCR, PER and CCR was observed when 5 percent citrus waste without enzyme was fed to the commercial broilers due to best ( $p < 0.05$ ) BWG observed in this treatment during this phase. The observed results were in agreement with Ebrahimi *et al.* (2013) wherein they used dried sweet orange peel @ 1.5% in the starter diets of broilers and reported higher FBW, BWG and better FCR in broilers when compared with control group.

Higher (39.26 g) BWG was achieved in control groups during grower phase which differs significantly ( $p < 0.05$ ) from other groups showing growth depression with increase in level of citrus waste (Table 3). FI had no significant effect amongst control and 5% citrus fed groups. Lowest (129.72 g) feed intake was observed at 2.5% citrus waste inclusion level. Highest ( $p < 0.05$ ) BWG reflected the FCR. Best FCR (4.29) was observed in control group followed by 5% citrus fed group irrespective of enzymes ( $p < 0.05$ ). The observed results were in congruence with Faiz *et al.* (2017) who also reported reduced BWG as the level of citrus waste in the feed increased significantly ( $p < 0.05$ ).

FBW, BWG and FI were higher ( $p < 0.05$ ) in the groups where no enzyme was added in the diet irrespective of citrus waste inclusion level (Table 3) similar trend of better PER and CCR was attained in the non-enzyme supplemented groups ( $p < 0.05$ ). But the results obtained were in conflict with the results obtained by Alefzadeh *et al.* (2016) which reported no effect of enzyme supplementation in the performance of chicks i.e., neither increased nor decreased the growth performance.

**Table 3:** Effect of feeding different levels of citrus waste with and without enzyme on the growth performance during Grower phase (15<sup>th</sup> – 21<sup>st</sup> day)

Treatment	Citrus (%)	Enzyme (g/q)	FBW (g)	BWG (g)	FI (g)	FCR	PER	CCR
<b>Effect of citrus waste</b>								
-	0	-	132.63 <sup>a</sup>	39.26 <sup>a</sup>	145.93 <sup>a</sup>	4.29 <sup>c</sup>	1.17 <sup>a</sup>	0.09 <sup>a</sup>
-	2.5	-	102.25 <sup>c</sup>	15.07 <sup>d</sup>	129.72 <sup>c</sup>	8.65 <sup>a</sup>	0.52 <sup>d</sup>	0.04 <sup>c</sup>
-	5	-	118.16 <sup>b</sup>	24.07 <sup>b</sup>	143.86 <sup>a</sup>	6.48 <sup>b</sup>	0.74 <sup>b</sup>	0.05 <sup>b</sup>
-	7.5	-	106.77 <sup>c</sup>	20.32 <sup>c</sup>	135.91 <sup>b</sup>	6.81 <sup>b</sup>	0.68 <sup>c</sup>	0.05 <sup>b</sup>
-	Pooled SE	-	2.086	1.186	1.889	0.273	0.035	0.002
<b>Effect of enzyme</b>								
-	-	0	122.64 <sup>a</sup>	30.24 <sup>a</sup>	142.26 <sup>b</sup>	5.70 <sup>b</sup>	0.91 <sup>a</sup>	0.07 <sup>a</sup>
-	-	100	107.27 <sup>b</sup>	19.12 <sup>b</sup>	135.45 <sup>a</sup>	7.42 <sup>a</sup>	0.64 <sup>b</sup>	0.05 <sup>b</sup>
-	Pooled SE	-	1.475	0.839	1.336	0.193	0.024	0.003
<b>Citrus waste × enzyme</b>								
T <sub>1</sub>	0	0	148.40 <sup>a</sup>	55.58 <sup>a</sup>	165.62 <sup>a</sup>	2.99 <sup>f</sup>	1.52 <sup>a</sup>	0.11 <sup>a</sup>
T <sub>2</sub>	2.5	0	104.60 <sup>d</sup>	15.16 <sup>e</sup>	121.85 <sup>f</sup>	8.06 <sup>b</sup>	0.55 <sup>d</sup>	0.04 <sup>de</sup>
T <sub>3</sub>	5	0	130.03 <sup>b</sup>	30.77 <sup>b</sup>	151.10 <sup>b</sup>	4.99 <sup>e</sup>	0.90 <sup>b</sup>	0.07 <sup>b</sup>
T <sub>4</sub>	7.5	0	107.53 <sup>d</sup>	19.47 <sup>cde</sup>	130.48 <sup>de</sup>	6.74 <sup>d</sup>	0.68 <sup>cd</sup>	0.05 <sup>cd</sup>
T <sub>5</sub>	0	100	116.87 <sup>c</sup>	22.95 <sup>c</sup>	126.23 <sup>ef</sup>	5.59 <sup>e</sup>	0.82 <sup>bc</sup>	0.06 <sup>bc</sup>
T <sub>6</sub>	2.5	100	99.90 <sup>d</sup>	14.98 <sup>e</sup>	137.60 <sup>cd</sup>	9.25 <sup>a</sup>	0.48 <sup>e</sup>	0.04 <sup>e</sup>
T <sub>7</sub>	5	100	106.28 <sup>d</sup>	17.36 <sup>de</sup>	136.62 <sup>cd</sup>	7.96 <sup>bc</sup>	0.57 <sup>d</sup>	0.04 <sup>de</sup>
T <sub>8</sub>	7.5	100	106.01 <sup>d</sup>	21.18 <sup>cd</sup>	141.35 <sup>c</sup>	6.87 <sup>cd</sup>	0.68 <sup>cd</sup>	0.05 <sup>cd</sup>
-	Pooled SE	-	2.951	1.678	2.672	0.386	0.049	0.004

*a, b, = Means bearing different superscripts in a column differ significantly ( $P \leq 0.05$ )*

Inclusion of citrus waste affected significantly ( $p < 0.05$ ) with respect to FBW, BWG and FCR with lowest (15.16 g) BWG obtained where 2.5% citrus waste was added (Table 3). Amongst the citrus waste fed groups maximum (30.77 g) BWG was observed where 5% citrus waste was added in the diet but it was less ( $p < 0.05$ ) than the control group. Feed intake was observed in different treatments. Similar trend with higher (165.62 g) FI was reported in control group ( $p < 0.05$ ) and lower (121.85g) FI was seen in 2.5% citrus waste supplemented group. Higher ( $p < 0.05$ ) BWG and FI in control gave best (2.99) FCR in this group. The poorest FCR was observed in 2.5% citrus waste with enzyme supplemented groups. Similar trend was observed for PER and CCR. Kalim *et al.* (2015) also reported decreased growth performance ( $p < 0.05$ ) at higher (10%) Citrus sinensis linn (Musambi) inclusion in the diet.

During finisher phase effect of citrus waste irrespective of enzyme on FBW, BWG and FI showed significant ( $p < 0.05$ ) difference (Table 4). Highest ( $p < 0.05$ ) values of these parameters were observed in the group where no citrus waste was incorporated. The lowest ( $p < 0.05$ ) values were for highest inclusion level of citrus waste. Best ( $p < 0.05$ ) FCR was obtained in the control group which was significantly ( $p < 0.05$ ) better than all the groups. There was no significant difference for FCR among 2.5% and 5% citrus fed groups but was poorer than the control group. The highest inclusion level of citrus waste had poorest ( $p < 0.05$ ) FCR. The results were in correlation with Ahaotu *et al.* (2017), who also reported high level of supplementation of sweet orange peel in broiler diets lead to reduced ( $p < 0.05$ ) weight gain and poorest FCR. However; the result obtained in this study was in paradox with the results obtained by Akbarian *et al.* (2013) and Lee *et al.* (2003) who found no difference in FI, BWG and FCR of broiler chickens.

Addition of enzyme in the experimental diets failed to show any significant ( $p < 0.05$ ) improvement in various growth parameters (Table 4). The body weight gain was better ( $p < 0.05$ ) in groups fed without enzyme during this phase of meat type birds irrespective of citrus waste supplementation. There was no significant ( $p < 0.05$ ) difference for feed intake among non-enzyme supplemented and enzyme supplemented groups. The highest ( $p < 0.05$ ) BWG and almost same FI showed best ( $p < 0.05$ ) FCR where no enzyme was added as compared to supplemented group. Abdel-

Moneim *et al.* (2014) also reported no effect of enzyme supplementation in the growth performance of chicks.

Different level of citrus waste inclusion affected significantly ( $p < 0.05$ ) the FBW and BWG (Table 4). Maximum ( $p < 0.05$ ) BWG was in the T<sub>1</sub> group where no citrus waste was added. Addition of citrus waste at different levels reduced the BWG. FI reduced with increase in the citrus waste inclusion. There was no significant ( $p < 0.05$ ) difference in FI between T<sub>1</sub> and T<sub>5</sub> treatment groups where no citrus waste was added without and with enzyme supplementation. Lower BWG and higher FI in the citrus waste-based diets lead to poor performance in terms of FCR, PER, and CCR. The best ( $p < 0.05$ ) FCR, PER and CCR was in the T<sub>1</sub> group where no citrus waste was added. However, the poorest FCR, PER and CCR was observed in T<sub>8</sub> group. Kalim *et al.* (2015) also observed negative results on the growth performance at higher (10%) inclusion level of citrus waste in the diet as compared to control. The presence of anti-nutritional factor (oxalates, saponins, tannins, and phytates) in peel contributed to the negative performance of the broilers (Ebrahimi *et al.* 2013).

**Table 4:** Effect of feeding different levels of citrus waste with and without enzyme on the growth performance during Finisher phase (22<sup>nd</sup> – 42<sup>nd</sup> day)

Treatment	Citrus (%)	Enzyme (g/q)	FBW (g)	BWG (g)	FI (g)	FCR	PER	CCR
<b>Effect of Citrus waste</b>								
-	0	-	583.39 <sup>a</sup>	450.76 <sup>a</sup>	1034.33 <sup>a</sup>	2.35 <sup>c</sup>	2.17 <sup>a</sup>	0.14 <sup>a</sup>
-	2.5	-	431.30 <sup>c</sup>	329.04 <sup>c</sup>	851.97 <sup>c</sup>	2.62 <sup>b</sup>	1.93 <sup>c</sup>	0.13 <sup>b</sup>
-	5	-	477.51 <sup>b</sup>	359.35 <sup>b</sup>	912.05 <sup>b</sup>	2.58 <sup>b</sup>	1.98 <sup>b</sup>	0.13 <sup>b</sup>
-	7.5	-	366.90 <sup>d</sup>	260.13 <sup>d</sup>	715.59 <sup>d</sup>	2.79 <sup>a</sup>	1.83 <sup>d</sup>	0.12 <sup>c</sup>
-	Pooled SE	-	3.997	5.29	13.467	0.015	0.014	0.001
<b>Effect of enzyme</b>								
-	-	0	505.84 <sup>a</sup>	383.20 <sup>a</sup>	877.75	2.32 <sup>b</sup>	2.17 <sup>a</sup>	0.14 <sup>a</sup>
-	-	100	423.71 <sup>b</sup>	316.44 <sup>b</sup>	879.22	2.85 <sup>a</sup>	1.79 <sup>b</sup>	0.12 <sup>b</sup>
-	Pooled SE	-	5.653	3.741	9.523	0.021	0.01	0.001
<b>Citrus waste × enzyme</b>								
T <sub>1</sub>	0	0	646.18 <sup>a</sup>	497.78 <sup>a</sup>	1052.50 <sup>a</sup>	2.12 <sup>g</sup>	2.36 <sup>a</sup>	0.15 <sup>a</sup>
T <sub>2</sub>	2.5	0	457.30 <sup>c</sup>	352.70 <sup>c</sup>	812.82 <sup>c</sup>	2.31 <sup>f</sup>	2.16 <sup>b</sup>	0.14 <sup>b</sup>
T <sub>3</sub>	5	0	523.14 <sup>b</sup>	393.11 <sup>b</sup>	930.65 <sup>b</sup>	2.37 <sup>f</sup>	2.12 <sup>b</sup>	0.13 <sup>c</sup>
T <sub>4</sub>	7.5	0	396.75 <sup>e</sup>	289.22 <sup>e</sup>	715.03 <sup>d</sup>	2.47 <sup>e</sup>	2.03 <sup>c</sup>	0.13 <sup>d</sup>
T <sub>5</sub>	0	100	520.60 <sup>b</sup>	403.73 <sup>b</sup>	1016.17 <sup>a</sup>	2.59 <sup>d</sup>	1.98 <sup>c</sup>	0.13 <sup>d</sup>
T <sub>6</sub>	2.5	100	405.29 <sup>e</sup>	305.39 <sup>de</sup>	891.12 <sup>b</sup>	2.94 <sup>b</sup>	1.71 <sup>e</sup>	0.11 <sup>f</sup>
T <sub>7</sub>	5	100	431.88 <sup>d</sup>	325.60 <sup>d</sup>	893.45 <sup>b</sup>	2.78 <sup>e</sup>	1.83 <sup>d</sup>	0.12 <sup>e</sup>
T <sub>8</sub>	7.5	100	337.06 <sup>f</sup>	231.05 <sup>f</sup>	716.14 <sup>d</sup>	3.10 <sup>a</sup>	1.62 <sup>f</sup>	0.10 <sup>g</sup>
-	Pooled SE	-	7.995	7.481	19.045	0.029	0.02	0.001

*a, b, = Means bearing different superscripts in a column differ significantly ( $P \leq 0.05$ )*

The growth performance during overall period (0-42 days) of production is presented at Table 5. The results showed that the FBW, BWG and FI was best in the group where no citrus waste was fed irrespective of enzyme supplementation. Amongst the citrus waste fed groups, the performance of birds were best ( $p \leq 0.05$ ) in the group where 5% citrus waste was fed. Lowest ( $p < 0.05$ ) FBW, BWG and FI was obtained at the highest (7.5%) level of citrus waste supplementation. The maximum BWG reflected the performance of the birds in terms of FCR, PER and CCR. Best values of these parameters were obtained in non-citrus waste supplemented groups. These findings is in resemblance with Oluremi *et al.* (2017) who also reported decrease ( $p < 0.05$ ) in final body weight, feed intake, body weight gain and poorer FCR as the level of sweet orange fruit peel increased in the diets of broilers.

The FBW, BWG was significantly ( $p < 0.05$ ) better in the groups fed diets without enzymes irrespective of citrus levels (Table 5). Non-significant difference was observed in FI between enzyme supplemented and non-enzyme supplemented groups. Significantly higher BWG and non-significant difference in FI affected the FCR, PER and CCR. Better indices of these parameters were observed where no enzyme was supplemented in the diets irrespective of citrus wastes levels in the experimental rations. Alefzadeh *et al.* (2016) also reported no effect of enzyme supplementation in the performance of chicks. During overall period of growth up to 42<sup>nd</sup> day of age final body weight and body weight gain were maximum ( $p < 0.05$ ) in control group (Table 5). Among the different citrus waste supplemented groups the best ( $p < 0.05$ ) performance was observed in T<sub>3</sub> group where CW was added at the rate of 5% in the experimental rations. Feed intake reduced ( $p < 0.05$ ) as the level of citrus waste increased in the diet. Best

( $p < 0.05$ ) FCR and PER was observed in T<sub>1</sub> group. FCR in T<sub>2</sub> and T<sub>3</sub> group were significantly ( $p < 0.05$ ) better than the other CW supplemented groups. Poorest ( $p < 0.05$ ) FCR was observed in T<sub>8</sub> ration. Basir and Toghyani (2017) also reported decreased ( $p < 0.05$ ) body weight of chickens using graded levels of dried lemon pulp as compared to non-supplemented control group. The lower feed intake in citrus waste supplemented group could be due to the presence of pectin. Pectin is a kind of soluble fibre which increases the intestinal viscosity and enhanced retention time of the feed in GIT. This increase in retention time is negatively correlated with daily feed intake (Almirall and Esteve-Garcia 1994). Higher levels of anti-nutritional factor like tannins and oxalates present in the citrus might be the cause behind the negative growth performance of broilers. The results obtained in our study were in congruence with Ebrahimi *et al.* (2013) who also reported lower feed intake with increase in the level of dried sweet orange peel in the ration and decreased ( $p < 0.05$ ) growth performance.

**Table 5:** Effect of feeding different levels of citrus waste with and without enzyme on the growth performance during overall period (0 - 42<sup>nd</sup> day)

Treatment	Citrus (%)	Enzyme (g/q)	Initial BW (g)	FBW (g)	BWG (g)	FI (g)	FCR	PER	CCR
<b>Effect of citrus waste</b>									
-	0	-	35.6	583.39 <sup>a</sup>	547.79 <sup>a</sup>	1405.34 <sup>a</sup>	2.59 <sup>d</sup>	1.87 <sup>a</sup>	0.13 <sup>a</sup>
-	2.5	-	35.58	431.30 <sup>c</sup>	395.72 <sup>c</sup>	1157.30 <sup>c</sup>	2.95 <sup>b</sup>	1.64 <sup>c</sup>	0.11 <sup>c</sup>
-	5	-	35.57	477.51 <sup>b</sup>	441.95 <sup>b</sup>	1223.87 <sup>b</sup>	2.79 <sup>c</sup>	1.74 <sup>b</sup>	0.12 <sup>b</sup>
-	7.5	-	35.47	366.90 <sup>d</sup>	331.43 <sup>d</sup>	1008.69 <sup>d</sup>	3.07 <sup>a</sup>	1.58 <sup>d</sup>	0.10 <sup>d</sup>
-	Pooled SE	-	0.025	5.653	5.652	14.668	0.019	0.012	0.001
<b>Effect of enzyme</b>									
-	-	0	35.6	505.84 <sup>a</sup>	470.24 <sup>a</sup>	1204.08	2.59 <sup>b</sup>	1.86 <sup>a</sup>	0.13 <sup>a</sup>
-	-	100	35.5	423.71 <sup>b</sup>	388.21 <sup>b</sup>	1193.52	3.11 <sup>a</sup>	1.55 <sup>b</sup>	0.11 <sup>b</sup>
-	Pooled SE	-	0.018	3.997	3.997	10.372	0.013	0.008	0.001
<b>Citrus waste × enzyme</b>									
T <sub>1</sub>	0	0	35.72	646.18 <sup>a</sup>	610.47 <sup>a</sup>	1451.29 <sup>a</sup>	2.38 <sup>f</sup>	2.01 <sup>a</sup>	0.13 <sup>a</sup>
T <sub>2</sub>	2.5	0	35.63	457.30 <sup>c</sup>	421.67 <sup>c</sup>	1106.18 <sup>de</sup>	2.62 <sup>e</sup>	1.82 <sup>c</sup>	0.12 <sup>b</sup>
T <sub>3</sub>	5	0	35.62	523.14 <sup>b</sup>	487.52 <sup>b</sup>	1254.24 <sup>c</sup>	2.57 <sup>e</sup>	1.87 <sup>b</sup>	0.12 <sup>b</sup>
T <sub>4</sub>	7.5	0	35.44	396.74 <sup>e</sup>	361.30 <sup>e</sup>	1004.62 <sup>e</sup>	2.78 <sup>d</sup>	1.73 <sup>d</sup>	0.11 <sup>c</sup>
T <sub>5</sub>	0	100	35.48	520.60 <sup>b</sup>	485.12 <sup>b</sup>	1359.38 <sup>b</sup>	2.80 <sup>d</sup>	1.72 <sup>d</sup>	0.11 <sup>c</sup>
T <sub>6</sub>	2.5	100	35.52	405.29 <sup>e</sup>	369.77 <sup>e</sup>	1208.41 <sup>c</sup>	3.27 <sup>b</sup>	1.46 <sup>f</sup>	0.09 <sup>e</sup>
T <sub>7</sub>	5	100	35.51	431.88 <sup>d</sup>	396.37 <sup>d</sup>	1193.50 <sup>c</sup>	3.01 <sup>c</sup>	1.60 <sup>e</sup>	0.10 <sup>d</sup>
T <sub>8</sub>	7.5	100	35.5	337.06 <sup>f</sup>	301.56 <sup>f</sup>	1012.77 <sup>e</sup>	3.36 <sup>a</sup>	1.43 <sup>f</sup>	0.09 <sup>e</sup>
-	Pooled SE	-	0.036	7.995	7.993	20.743	0.027	0.017	0.001

*a, b, = Means bearing different superscripts in a column differ significantly ( $P \leq 0.05$ )*

The DM digestibility was maximum ( $p < 0.05$ ) at 2.5% citrus waste inclusion level followed by 5% citrus waste inclusion level which was significantly ( $p < 0.05$ ) lower than 2.5% citrus waste but was higher ( $p < 0.05$ ) than non-supplemented group and 7.5% inclusion level of citrus waste irrespective of enzyme supplementation (Table 6). The CP digestibility and OM digestibility was best ( $p < 0.05$ ) when no citrus waste was added in the experimental diets. However, CP digestibility at 2.5% and 5% citrus waste supplemented diets was better ( $p < 0.05$ ) than highest citrus waste supplemented ration. EE digestibility was best ( $p < 0.05$ ) at 5% citrus waste inclusion level, however, at 2.5% citrus waste inclusion level and at non-supplemented group the EE digestibility was equally good but was less ( $p < 0.05$ ) than 5% and better ( $p < 0.05$ ) than 7.5% citrus waste supplemented diet. CF digestibility was best ( $p < 0.05$ ) at 2.5% and 5% citrus waste supplemented group and lowest CF digestibility was at 7.5% citrus waste supplemented diet irrespective of enzyme supplementation. Data further revealed that the digestibility of Ca and P was maximum ( $p < 0.05$ ) at 5% citrus waste supplemented diets.

**Table 6:** Effect of feeding different levels of citrus waste with and without enzyme on the nutrient utilization in meat type birds.

Treatment	Citrus (%)	Enzyme (g/q)	% DMD	% CPD	% EE D	%CF D	%OM D	%Ca Av	%P Av
<b>Effect of citrus waste</b>									
-	0	-	83.89 <sup>c</sup>	57.12 <sup>a</sup>	82.91 <sup>b</sup>	25.56 <sup>b</sup>	73.83 <sup>a</sup>	31.85 <sup>b</sup>	30.18 <sup>c</sup>
-	2.5	-	86.49 <sup>a</sup>	52.82 <sup>b</sup>	82.34 <sup>b</sup>	30.26 <sup>a</sup>	72.33 <sup>b</sup>	31.41 <sup>b</sup>	42.25 <sup>a</sup>
-	5	-	84.93 <sup>b</sup>	52.95 <sup>b</sup>	84.36 <sup>a</sup>	30.39 <sup>a</sup>	71.58 <sup>b</sup>	35.85 <sup>a</sup>	43.76 <sup>a</sup>
-	7.5	-	83.94 <sup>c</sup>	50.17 <sup>c</sup>	80.53 <sup>c</sup>	23.93 <sup>c</sup>	69.55 <sup>c</sup>	35.07 <sup>a</sup>	35.20 <sup>b</sup>
-	<b>Pooled SE</b>		0.274	0.449	0.345	0.221	0.449	0.638	0.655
<b>Effect of enzyme</b>									
-	-	0	85.19 <sup>a</sup>	55.13 <sup>a</sup>	84.40 <sup>a</sup>	27.94	73.72 <sup>a</sup>	31.93 <sup>b</sup>	37.3
-	-	100	84.43 <sup>b</sup>	51.40 <sup>b</sup>	80.67 <sup>b</sup>	27.13	69.92 <sup>b</sup>	35.16 <sup>a</sup>	38.4
-	<b>Pooled SE</b>		0.193	0.318	0.244	0.156	0.317	0.451	0.463
<b>Citrus waste × enzyme</b>									
T <sub>1</sub>	0	0	84.96 <sup>cd</sup>	58.82 <sup>a</sup>	85.92 <sup>a</sup>	31.91 <sup>ab</sup>	74.95 <sup>a</sup>	31.40 <sup>cd</sup>	27.95 <sup>e</sup>
T <sub>2</sub>	2.5	0	86.29 <sup>ab</sup>	56.14 <sup>b</sup>	83.32 <sup>b</sup>	28.04 <sup>d</sup>	74.38 <sup>ab</sup>	29.01 <sup>e</sup>	41.20 <sup>b</sup>
T <sub>3</sub>	5	0	85.28 <sup>bc</sup>	55.62 <sup>b</sup>	86.68 <sup>a</sup>	31.19 <sup>b</sup>	73.80 <sup>abc</sup>	34.61 <sup>ab</sup>	46.72 <sup>a</sup>
T <sub>4</sub>	7.5	0	84.23 <sup>cd</sup>	49.95 <sup>c</sup>	81.69 <sup>bc</sup>	20.62 <sup>e</sup>	71.76 <sup>cd</sup>	32.69 <sup>bc</sup>	33.32 <sup>d</sup>
T <sub>5</sub>	0	100	82.82 <sup>c</sup>	55.41 <sup>b</sup>	79.91 <sup>de</sup>	19.20 <sup>f</sup>	72.72 <sup>bc</sup>	32.30 <sup>bc</sup>	32.42 <sup>d</sup>
T <sub>6</sub>	2.5	100	86.69 <sup>a</sup>	49.51 <sup>c</sup>	81.35 <sup>cd</sup>	32.48 <sup>a</sup>	70.27 <sup>de</sup>	33.81 <sup>bc</sup>	43.30 <sup>b</sup>
T <sub>7</sub>	5	100	84.57 <sup>cd</sup>	50.28 <sup>c</sup>	82.04 <sup>bc</sup>	29.60 <sup>c</sup>	69.35 <sup>ef</sup>	37.09 <sup>b</sup>	40.81 <sup>b</sup>
T <sub>8</sub>	7.5	100	83.65 <sup>de</sup>	50.39 <sup>c</sup>	79.37 <sup>e</sup>	27.24 <sup>d</sup>	67.34 <sup>f</sup>	37.44 <sup>a</sup>	37.09 <sup>c</sup>
-	<b>Pooled SE</b>		0.387	0.635	0.488	0.312	0.635	0.902	0.926

*a, b, = Means bearing different superscripts in a column differ significantly (P<0.05)*

However, the calcium digestibility at 2.5% and at non-supplemented citrus waste diets was statistically ( $p<0.05$ ) similar but was less than 5% and more ( $p<0.05$ ) than 7.5% citrus waste supplemented group. But in case of P availability, was statistically ( $p<0.05$ ) similar at 2.5% and 5% citrus waste supplemented group and lowest ( $p<0.05$ ) P availability was obtained at non-supplemented group irrespective of enzyme supplementation. The result found were in correlation with the findings of Nobakht (2013) who found decrease in digestibility of nutrients as the inclusion of dried lemon pulp was increased. The reduced nutrient digestibility might be due to insoluble fibres diluting the nutrient concentration and increasing digesta passage rate (Hetland *et al.* 2004). Nutrient digestibility with respect to DM, CP, EE, OM and availability of Ca was better ( $p<0.05$ ) in the non-supplemented group than the enzyme supplemented groups irrespective of citrus level (**Table 8 NOT FOUND**). However, non-significant ( $p<0.05$ ) difference were observed in CF and P digestibility between the non-supplemented and enzyme supplemented groups.

The supplementation of citrus waste at different levels with or without cocktail of enzyme in the broilers had significant effect ( $p<0.05$ ) on dry matter digestibility (%DMD), Crude protein digestibility (%CP), fat digestibility (%EE), Crude fibre digestibility (%CF), organic matter digestibility (%OM), Calcium availability (%Ca Av) and phosphorus availability (%P Av). Highest ( $p<0.05$ ) DMD (86.29%) was observed in T<sub>6</sub> diet fed with citrus waste at 2.5% along with enzyme supplementation which was statistically comparable with T<sub>2</sub> diet fed groups (Table 8). The DMD of T<sub>3</sub> diet fed groups where 5% citrus waste was supplemented was comparable with T<sub>2</sub> diet fed groups. Lowest ( $p<0.05$ ) DMD was obtained in T<sub>5</sub> diet fed groups where no citrus waste was supplemented but enzyme was added in that diet. The crude protein digestibility linearly decreased ( $p<0.05$ ) with increase in citrus waste in the diets of broilers. Highest ( $p<0.05$ ) CP digestibility was in T<sub>1</sub> diet where no citrus waste was added and lowest ( $p<0.05$ ) CP digestibility was at highest level of citrus waste supplemented groups. EE digestibility was maximum ( $p<0.05$ ) at T<sub>1</sub> and T<sub>3</sub> fed diets where either no citrus waste was added or 5% citrus waste was supplemented. Lowest EE digestibility was at highest level of citrus waste supplementation group (T<sub>8</sub>). CF and OMD deteriorated with increase in citrus waste supplementation except at 5% citrus waste fed groups where CF digestibility was maximum ( $p<0.05$ ) and was comparable with (T<sub>1</sub>) non citrus waste supplemented groups. Lower CF digestibility and OM digestibility was at higher level of citrus waste supplemented group. Ca availability was maximum ( $p<0.05$ ) at highest (T<sub>8</sub>) level of citrus waste supplemented group and lowest at (T<sub>2</sub>) 2.5% citrus waste supplemented group. The P availability was maximum ( $p<0.05$ ) at (T<sub>3</sub>) 5% supplemented group. The lowest P-availability was obtained with T<sub>1</sub> group where no citrus waste was added. Enzyme supplementation at no citrus supplemented (T<sub>5</sub>) group showed better ( $p<0.05$ ) digestibility then the non-enzymatic citrus waste supplemented group (T<sub>1</sub>). The results obtained by

Langhout *et al.* (2010) showed inclusion of high methylated citrus and low methylated citrus treated birds reduced digestibility of dry matter, organic matter, crude fat, nitrogen-retention of the diet. Oluremi *et al.* (2017) results were also in agreement with present finding where inclusion of graded level of fermented sweet orange showed variability in digestibility among the treatments. The lower levels of citrus supplementation showed non-significant change in the digestibility of diet whereas higher level of citrus waste supplementation in broilers decreased the digestibility significantly.

## Conclusion

Although the growth parameters for citrus waste supplemented group were no better than non-supplemented group but at 5% citrus waste inclusion levels without enzyme the growth parameters were better during starter phase and was best among all the levels studied in overall productive period. Moreover, the 5% CW inclusion is economical compared to non-supplemented group. It is also pertinent to mention that 5% citrus waste supplementation showed better digestibility compared to other groups besides more economical. It was concluded that citrus waste up to 5% can be supplemented in the broiler starter ration without any detrimental effect on growth parameters.

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## Conflict of Interests

There is no conflict of interest.

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