



## Effect of pomegranate (*Punica granatum*) peel powder supplementation on performance, carcass characteristics and haemato-biochemical parameters of broiler chickens

A S GOSAI<sup>1</sup>, M M PAWAR<sup>2✉</sup>, S S PATIL<sup>2</sup>, K J ANKUYA<sup>2</sup>, A K SRIVASTAVA<sup>2</sup> and B K ASHWAR<sup>2</sup>

*Kamdhenu University, Sardarkrushinagar, Gujarat 385 506 India*

Received: 10 August 2022; Accepted: 3 April 2023

### ABSTRACT

The present study was conducted to evaluate the effect of pomegranate peel powder (PPP) supplementation on growth performance, carcass characteristics, haemato-biochemical parameters and return over feed cost in broiler chickens. A total of 240 unsexed day-old broiler chicks were randomly allocated into four treatment groups with four replicates in each. The control group (T<sub>1</sub>) was fed with a standard basal diet as per BIS (2007). Groups T<sub>2</sub>, T<sub>3</sub>, and T<sub>4</sub> were fed the basal diet with 0.25, 0.5 and 1.0 % level of PPP, respectively for six weeks. Results revealed that the mean final body weight and body weight gain were significantly higher in T<sub>4</sub> as compared to the other dietary treatments. The feed conversion ratio was better in T<sub>4</sub> and T<sub>3</sub> groups as compared to the T<sub>1</sub> and T<sub>2</sub> groups. There were no differences in carcass characteristics among the dietary treatments. The serum concentration of triglycerides and cholesterol were significantly reduced in T<sub>4</sub> and T<sub>3</sub> groups as compared to the control. The return over feed cost was higher T<sub>3</sub> and T<sub>4</sub> groups than the control group. Thus, it can be concluded that dietary supplementation of 1% pomegranate peel powder improved growth performance, production efficiency, blood lipid profile and return over feed cost in broiler chickens.

**Keywords:** Blood variables, Broiler, Carcass characteristics, Growth, Pomegranate peel, ROFC

The use of antibiotic growth promoters as feed additive in poultry nutrition for improving the growth performance and protection from diseases has become a public health concern because of the risk of antibiotic carry-over through meat and eggs along with the emergence of antibiotic resistance and environmental pollution (Anee *et al.* 2021). Globally, poultry nutritionists are attempting the use of natural phyto-additives as eco-friendly and safe antibiotic replacers for improving health and production of poultry. Recently, phyto-additives have attracted the attention of scientists as useful resource for improving poultry productivity without any side effects (Chavan *et al.* 2022, Gurram *et al.* 2022). Among the various phyto-additives, pomegranate peel could be explored as feed additives in broiler chickens.

Pomegranate (*Punica granatum*) is an important fruit crop grown in India. India ranked first in the world with 31.86 lakh tonne pomegranate production during the year 2019-2020 (Anonymous 2021). The pomegranate fruit has three major parts: the outside peel, the inside peel and the edible arils. Pomegranate peels are the waste product of pomegranate fruit that constitutes about half of the total

weight of fruit (Tozzi *et al.* 2022). Pomegranate peel is rich source of various nutrients as well as bioactive compounds such as flavonoids and proanthocyanidin, which have growth promoting, immune-modulatory, antioxidant and anti-inflammatory activities (Tozzi *et al.* 2022). Recent studies have shown that pomegranate peel powder (PPP) supplementation improved the growth performance, feed conversion ratio and carcass traits in broilers (Akuru *et al.* 2021, Abdel Baset *et al.* 2022). However, influence of PPP supplementation in broiler chickens under Indian condition has not been studied widely. Therefore, the present study was conducted to evaluate the effect of PPP supplementation on growth performance, carcass characteristics, haemato-biochemical parameters and return over feed cost in broiler chickens.

### MATERIALS AND METHODS

The experimental protocol followed in this experiment was approved (No. VETCOLL/IAEC/2022/19/PROTOCOL-01) by the Institutional Animal Ethics Committee. This study was carried out at College of Veterinary Science and Animal Husbandry, Sardarkrushinagar which is located in semi-arid region of North Gujarat having latitude of 24.32°North and longitude of 72.31°East and at an elevation of 189 meters above the mean sea level. A total of 240 day-old broiler (Vencobb 400) straight run chicks on arrival were weighed and

Present address: <sup>1</sup>Hester Biosciences Ltd., Mehsana, Gujarat.  
<sup>2</sup>College of Veterinary Science and Animal Husbandry, Kamdhenu University, Sardarkrushinagar, Gujarat. ✉Corresponding author email: mahespawar@gmail.com

uniformly distributed into four treatment groups having 60 birds per treatment with four replicates of 15 chicks in each treatment for a period of 42 days. The dietary treatments were T<sub>1</sub>: Basal diet as per BIS (2007), T<sub>2</sub>: Basal diet + 0.25 % PPP, T<sub>3</sub>: Basal diet + 0.5% PPP and T<sub>4</sub>: Basal diet + 1.0% PPP. The pomegranate peels were manually removed from pomegranate fruits, dried and ground to a fine powder. The content of dry matter, crude protein, ether extract, crude fibre, total ash and nitrogen free extract in PPP was 90.22, 3.95, 2.42, 12.61, 8.49 and 72.53%, respectively. The ingredient and nutrient composition of basal diet fed to experimental birds is given in Supplementary Table 1.

The body weight and feed intake were recorded at weekly intervals. The body weight gain (g) and feed conversion ratio (FCR=feed intake/weight gain) was calculated at weekly intervals. Mortality, if any in experimental birds was recorded throughout the experimental period. Protein intake was calculated by multiplying amount of feed intake (g) and percentage of the protein in the feed.

Protein efficiency ratio (PER) was determined as amount of protein intake (g) that is converted into the weight gain (g). Production efficiency factor (PEF) was calculated as:

$$\text{PEF} = \frac{[\text{Final body weight (kg)} \times \text{Livability (\%)} \times 100]}{[\text{Age in days} \times \text{FCR}]}$$

The carcass traits such as carcass and dressed weight, dressing percentage, yields of breast, back, thigh, neck, wing and weights of spleen, liver, heart and gizzard were studied at the end of the experiment on eight birds from each treatment. On 42<sup>nd</sup> day, the blood samples were collected from experimental birds. The fresh blood samples were analyzed for the concentrations of haemoglobin, haematocrit, red blood cells (RBC) and white blood cells (WBC) using automatic analyzer. The serum was harvested from the blood collected in vial without anti-coagulant. The samples were analyzed for glucose, total proteins, albumin, triglycerides, cholesterol, high density lipoprotein (HDL), low density lipoprotein (LDL), serum glutamic pyruvic

Table 1. Effect of pomegranate peel powder supplementation on growth performance of broiler chickens at weekly intervals

Age in weeks	Treatments				Significance
	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>	T <sub>4</sub>	
<i>Body weight (g/bird)</i>					
Initial	46.37±0.72	46.77±0.38	46.58±0.88	46.10±0.27	NS
I	162.77±2.02	163.52±2.10	162.29±3.26	165.98±2.75	NS
II	421.64±10.18	421.33±6.75	432.48±7.20	448.38±9.52	NS
III	802.14 <sup>a</sup> ±12.74	821.30 <sup>ab</sup> ±8.13	850.51 <sup>bc</sup> ±11.49	870.89 <sup>c</sup> ±20.23	*
IV	1204.02 <sup>a</sup> ±30.53	1249.92 <sup>ab</sup> ±15.56	1298.94 <sup>b</sup> ±21.15	1319.85 <sup>b</sup> ±36.26	*
V	1606.52±37.26	1679.05±28.53	1728.94±25.40	1725.65±48.72	NS
VI	2121.47 <sup>a</sup> ±16.85	2165.40 <sup>a</sup> ±23.75	2174.59 <sup>ab</sup> ±42.09	2252.68 <sup>b</sup> ±16.59	*
<i>Body weight gain (g/bird)</i>					
I	116.40±2.12	116.75±1.82	115.71±3.73	119.88±3.02	NS
II	258.87±11.15	257.81±5.17	270.19±9.14	282.40±9.11	NS
III	380.50±19.19	399.97±9.85	418.02±15.88	422.50±11.64	NS
IV	401.89±21.33	428.62±10.96	448.44±14.59	448.96±17.83	NS
V	402.50±6.96	429.12±22.25	430.00±9.46	405.81±35.17	NS
VI	514.95±31.24	486.35±24.81	445.65±28.94	527.02±43.20	NS
Overall	2075.11 <sup>a</sup> ±16.28	2118.63 <sup>a</sup> ±23.72	2128.01 <sup>ab</sup> ±42.64	2206.58 <sup>b</sup> ±16.69	*
<i>Feed intake (g/bird)</i>					
I	120.35±1.98	120.88±1.86	118.97±1.62	121.43±1.22	NS
II	421.12±3.79	402.77±23.68	394.44±5.77	395.37±8.38	NS
III	727.85±29.65	747.69±33.44	719.39±3.64	795.06±2.70	NS
IV	738.77±41.09	785.11±21.05	724.48±4.46	761.56±7.91	NS
V	844.31±20.62	877.87±30.31	870.08±9.92	829.94±14.35	NS
VI	934.96±21.27	919.40±5.79	959.79±18.51	962.00±19.37	NS
Overall	3787.35±74.11	3853.72±77.41	3787.15±23.79	3865.35±24.72	NS
<i>Feed conversion ratio</i>					
I	1.03±0.02	1.04±0.02	1.03±0.04	1.01±0.03	NS
II	1.64±0.06	1.56±0.07	1.46±0.03	1.41±0.06	NS
III	1.92±0.02	1.88±0.12	1.73±0.06	1.89±0.05	NS
IV	1.84±0.02	1.83±0.02	1.62±0.05	1.71±0.08	NS
V	2.10±0.04	2.07±0.16	2.03±0.04	2.09±0.19	NS
VI	1.84±0.11	1.90±0.08	2.18±0.15	1.86±0.14	NS
Overall	1.73±0.02	1.71±0.05	1.67±0.04	1.66±0.02	NS

<sup>abc</sup>Means in a row with different superscripts differ significantly (\*P<0.05; NS: not-significant).

transaminase (SGPT) and serum glutamic oxaloacetic transaminase (SGOT) concentrations using commercial diagnostic kits. The return over feed cost (ROFC) was calculated as difference between income generated through sale of birds and the expenditure on feed during experimental period. The data obtained were subjected to analysis of variance (ANOVA) using the statistical package of SPSS software v.20 (SPSS Inc./IBM Corp., Armonk, New York, NY, USA). Differences between treatment means were statistically compared using Duncan's post-hoc test procedure, when significant ( $P < 0.05$ ) treatment effects were detected.

## RESULTS AND DISCUSSION

The mean final body weight and gain in weight (g/bird) were significantly ( $P < 0.05$ ) higher in  $T_4$  group, followed by  $T_3$  group than the  $T_2$  and  $T_1$  groups (Table 1). Dietary inclusion of 1% PPP improved growth performance in broiler chickens as compared to other dietary treatments.

The enhanced growth performance of broilers may be attributed to bioactive compound proanthocyanidin present in pomegranate peel, which enhances gut health, nutrient absorption and feed efficiency (Kupnik *et al.* 2022). Also, proanthocyanidin improves pancreatic function, digestive enzyme secretion in the small intestine and intestinal cell proliferation (Chen *et al.* 2022). Moreover, pomegranate

peel has anti-microbial activity which prevents subclinical infections; while antioxidant activity protects from free radicals (Gosset-Erard *et al.* 2021). Similar to the our findings, improvement in the growth performance of broiler supplemented with PPP were reported by Al-Shammari *et al.* (2019) at 0.5% level; Abdel Baset *et al.* (2022) at 2 and 4% level and Akuru *et al.* (2021) at 0.4% level than the control. In contrast, at lower supplementation levels (0.05 and 0.1%) of PPP there was no effect on growth performance of broilers (Ahmadipour *et al.* 2021); while higher supplemental levels (6 and 8%) lead to reduced body weight gain in broilers (Ghasemi-Sadabadi *et al.* 2021).

The total feed intake during experimental period in broiler chickens was without any significant ( $P > 0.05$ ) differences among the treatment groups (Table 1). It indicates that there was no adverse effect of PPP supplementation on palatability of feed. In line with the present findings, earlier studies reported that there was no effect on feed intake of broilers fed PPP (Akuru *et al.* 2021, Abdel Baset *et al.* 2022). The overall FCR in broiler chickens showed no significant ( $P > 0.05$ ) differences among the treatments (Table 1). However, the FCR was better in  $T_4$  and  $T_3$  groups as compared to the  $T_1$  and  $T_2$  groups. Better FCR in  $T_4$  and  $T_3$  groups may be contributed by the higher body weight gain with similar feed intake. Improved FCR in PPP fed broilers were also observed in earlier studies (Al-Shammari

Table 2. Effect of pomegranate peel powder supplementation on protein intake, efficiency and production efficiency factor at weekly intervals in broiler chickens

Age in weeks	Treatments				Significance
	$T_1$	$T_2$	$T_3$	$T_4$	
<i>Protein intake (g/bird)</i>					
I	27.90±0.46	28.03±0.43	27.60±0.38	28.20±0.28	NS
II	93.02±0.84	89.01±5.23	87.21±1.28	87.49±1.85	NS
III	160.78±6.55	165.24±7.39	159.06±0.81	175.94±0.60	NS
IV	152.34±8.47	161.97±4.34	149.53±0.92	157.33±1.63	NS
V	174.10±4.25	181.10±6.25	179.58±2.05	171.46±2.97	NS
VI	192.79±4.39	189.67±1.20	198.10±3.82	198.75±4.00	NS
Overall	800.92±15.64	815.02±16.71	801.08±4.96	819.17±5.20	NS
<i>Protein efficiency ratio</i>					
I	4.17±0.07	4.17±0.07	4.20±0.18	4.25±0.13	NS
II	2.78±0.10	2.92±0.12	3.10±0.07	3.24±0.14	NS
III	2.36±0.03	2.44±0.16	2.63±0.09	2.40±0.06	NS
IV	2.64±0.03	2.65±0.03	3.00±0.09	2.86±0.14	NS
V	2.31±0.05	2.38±0.18	2.39±0.05	2.37±0.20	NS
VI	2.67±0.16	2.56±0.12	2.26±0.17	2.64±0.17	NS
Overall	2.82±0.02	2.85±0.07	2.93±0.05	2.96±0.03	NS
<i>Production efficiency factor</i>					
I	472.65±11.77	481.70±11.42	487.25±20.33	512.26±16.49	NS
II	299.73±8.75	321.61±15.39	342.53±8.49	371.33±18.36	NS
III	255.02±4.29	269.27±19.27	291.05±13.91	275.63±8.85	NS
IV	265.78±3.20	272.26±5.81	310.17±14.69	306.30±16.37	NS
V	233.02±5.07	245.58±20.63	247.66±9.86	253.25±20.41	NS
VI	269.19±16.21	263.58±13.03	233.84±21.85	282.94±18.23	NS
Overall	299.23 <sup>a</sup> ±3.27	309.00 <sup>ab</sup> ±10.19	318.75 <sup>bc</sup> ±11.26	333.62 <sup>c</sup> ±5.39	*

<sup>abc</sup>Means in a row with different superscripts differ significantly (\* $P < 0.05$ ; NS: not-significant).

Table 3. Effect of pomegranate peel powder supplementation on carcass characteristics of broiler chickens

Age in weeks	Treatments				Significance
	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>	T <sub>4</sub>	
Pre-slaughter weight (g)	2335.63±26.48	2390.75±64.87	2361.63±37.50	2390.75±64.87	NS
Carcass weight (g)	2192.50±25.51	2217.00±58.89	2233.50±33.24	2216.13±21.17	NS
Dressed weight (g)	1716.63±21.49	1746.50±37.78	1754.88±28.38	1719.63±16.18	NS
Dressing percentage % of live weight	73.52±0.80	73.15±0.77	74.32±0.53	73.46±0.21	NS
Breast	30.96±0.43	30.49±0.92	31.10±0.52	31.03±0.55	NS
Back	5.69±0.41	5.84±0.30	4.78±0.16	5.62±0.19	NS
Thigh	21.25±0.40	20.79±0.29	21.72±0.32	21.24±0.29	NS
Neck	2.68±0.06	2.68±0.21	2.79±0.10	2.70±0.06	NS
Wing	8.26±0.23	8.11±0.33	8.84±0.24	8.15±0.28	NS
Spleen	0.11±0.01	0.09±0.01	0.09±0.01	0.07±0.01	NS
Liver	2.09±0.15	1.94±0.15	2.11±0.07	2.05±0.11	NS
Heart	0.45±0.03	0.38±0.02	0.45±0.03	0.49±0.04	NS
Gizzard	2.15±0.14	2.21±0.14	2.40±0.11	2.02±0.12	NS

NS: not-significant.

*et al.* 2019, Kishawy *et al.* 2019, Ahmadipour *et al.* 2021).

There were no differences in protein intake and protein efficiency ratio among the dietary treatments (Table 2). As the feed intake was comparable among the treatment groups and levels of protein in the diets were similar across the treatment group. Hence, the protein intake was at par among the treatment groups. The mean production efficiency factor was significantly ( $P<0.05$ ) greater in T<sub>4</sub> followed by T<sub>3</sub> and T<sub>2</sub> groups as compared to the T<sub>1</sub>. The higher production efficiency in 1% PPP supplemented group was directly attributed by greater body weight gain and better FCR. Similarly, Al-Shammari *et al.* (2019) reported that supplementation of PPP resulted in higher production efficiency than the control. The livability was similar (96.67%) among the various dietary treatment groups.

The carcass weight (g/bird) and dressing percentage (%) in broiler chickens did not influenced by the dietary treatments. Moreover, the yields of breast, back, thigh, neck and wing as well as weights of spleen, liver, heart and gizzard were not affected ( $P>0.05$ ) by the dietary inclusion of PPP (Table 3). Lack of alterations in organ indices like spleen, liver, heart and gizzard point out that supplementation of PPP up to 1% in the present study did not have any harmful effect on these organs. In agreement with the present findings, Al-Shammari *et al.* (2019), Kishawy *et al.* (2019) and Ahmadipour *et al.* (2021) found that dietary inclusion of PPP did not affect carcass characteristics in broiler chickens.

The concentrations of blood haemoglobin, haematocrit, red blood cells and while blood cells did not change

Table 4. Effect of pomegranate peel powder supplementation on haemato-biochemical parameters of broiler chickens

Parameter	Treatments				Significance
	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>	T <sub>4</sub>	
<i>Haematological parameters</i>					
Haemoglobin (g/dL)	11.63±0.07	11.59±0.15	11.49±0.39	11.30±0.42	NS
Haematocrit (%)	33.30±0.31	33.37±0.45	33.25±0.30	33.49±0.39	NS
RBC (10 <sup>6</sup> /μL)	2.63±0.02	2.60±0.03	2.54±0.04	2.56±0.04	NS
WBC (10 <sup>3</sup> /μL)	23.68±0.21	23.56±0.11	23.45±0.26	23.49±0.48	NS
<i>Blood biochemical parameters</i>					
Glucose (mg/dL)	215.87±1.72	216.37±1.76	214.50±3.54	215.95±2.75	NS
Total protein (mg/dL)	4.55±0.18	4.46±0.24	4.59±0.30	4.54±0.25	NS
Albumin (mg/dL)	2.18±0.03	2.16±0.02	2.15±0.02	2.14±0.04	NS
Triglycerides (mg/dL)	97.77 <sup>b</sup> ±1.55	96.38 <sup>b</sup> ±1.55	89.97 <sup>a</sup> ±2.48	88.26 <sup>a</sup> ±1.49	**
Cholesterol (mg/dL)	143.91 <sup>b</sup> ±2.48	136.08 <sup>a</sup> ±1.30	134.74 <sup>a</sup> ±2.83	132.95 <sup>a</sup> ±3.30	*
HDL (mg/dL)	91.10±2.12	88.45±1.57	90.73±2.21	89.49±1.95	NS
LDL (mg/dL)	42.30 <sup>b</sup> ±2.24	38.72 <sup>ab</sup> ±0.92	34.42 <sup>a</sup> ±1.20	33.94 <sup>a</sup> ±1.75	*
SGPT (U/L)	27.82±2.50	27.13±1.51	28.09±1.32	27.79±1.65	NS
SGOT (U/L)	155.37±7.79	152.99±3.23	154.11±3.06	153.08±4.34	NS

<sup>ab</sup>Means in a row with different superscripts differ significantly (\* $P<0.05$ ; \*\* $P<0.01$ ; NS: not-significant). HDL, high density lipoprotein; LDL, low density lipoprotein; SGPT, serum glutamic pyruvic transaminase; SGOT, serum glutamic oxaloacetic transaminase.

( $P > 0.05$ ) due to supplementation of PPP (Table 4). Thus, PPP supplementation does not have adverse effect on haematological parameters of broiler chickens. The mean serum triglycerides concentration (mg/dL) was significantly ( $P < 0.05$ ) reduced in  $T_4$  and  $T_3$  groups as compared to the  $T_1$  and  $T_2$  groups. The mean serum cholesterol level (mg/dL) was significantly ( $P < 0.05$ ) decreased in PPP supplemented groups than the control. The serum concentrations of glucose, total protein, albumin, HDL, LDL, SGPT and SGOT in broiler chickens did not differ among the treatment groups (Table 4). The serum triglycerides and cholesterol lowering effect of PPP was attributed to its anti-hyperlipidemic properties, which is achieved through up-regulation of PPAR- $\alpha$ , a major regulator of lipid metabolism in the liver (Ahmadipour *et al.* 2021). Haghghian *et al.* (2021) reported that there was reduction in the concentration of serum total cholesterol due to pomegranate extract supplementation by modulating the activity of HMGCoA reductase. These findings are in line with previous reports of Kishawy *et al.* (2019), Ahmadipour *et al.* (2021) and Abdel Baset *et al.* (2022) who found that broilers fed PPP had significantly ( $P < 0.05$ ) lower concentrations of total cholesterol and triglycerides than the control.

The return over feed cost was highest in  $T_4$  followed by  $T_3$  group as compared  $T_1$  and  $T_2$  groups (Supplementary Table 2). Higher return over feed cost in broiler chickens supplemented with 0.5 and 1% of PPP was attributed to the improved final body weights and production efficiency as compared to the other dietary treatment groups. This is in agreement with the findings of Kamel *et al.* (2021) who also reported that the net return was higher in 3, 6 and 9% PPP supplemented groups than the control.

From the findings of the present study, it could be concluded that dietary supplementation of 1% pomegranate peel powder improved growth performance, production efficiency, return over feed cost and reduced serum concentrations of triglycerides and cholesterol in broiler chickens. There were no effects of pomegranate peel powder supplementation on feed intake, haematological parameters and carcass characteristics of broiler chickens.

#### ACKNOWLEDGEMENTS

Authors are grateful to the Director of Research, Kamdhenu University and Dean, College of Veterinary Science and Animal Husbandry, Kamdhenu University, Sardarkrushinagar, Gujarat for providing the necessary facilities to carry out this research work.

#### REFERENCES

- Abdel Baset S, Ashour E A, Abd El-Hack M E and El-Mekkawy M M. 2022. Effect of different levels of pomegranate peel powder and probiotic supplementation on growth, carcass traits, blood serum metabolites, antioxidant status and meat quality of broilers. *Animal Biotechnology* **33**(4): 690–700.
- Ahmadipour B, Pat S, Abaszadeh S, Hassanpour H and Khajali F. 2021. Pomegranate peel as a phytogetic in broiler chickens: Influence upon antioxidant, lipogenesis and hypotensive response. *Veterinary Medicine and Science* **7**(5): 1907–13.
- Akuru E A, Mpendulo C T, Oyeagu C E and Nantapo C W T. 2021. Pomegranate (*Punica granatum L.*) peel powder meal supplementation in broilers: effect on growth performance, digestibility, carcass and organ weights, serum and some meat antioxidant enzyme biomarkers. *Italian Journal of Animal Science* **20**(1): 119–31.
- Al-Shammari K I A, Batkowska J and Zamil S J. 2019. Role of pomegranate peels and black pepper powder and their mixture in alleviating the oxidative stress in broiler chickens. *International Journal of Poultry Science* **18**: 122–28.
- Anee I J, Alam S, Begum R A, Shahjahan R M and Khandaker A M. 2021. The role of probiotics on animal health and nutrition. *Journal of Basic and Applied Zoology* **82**(1): 1–16.
- Anonymous. 2021. Area and Production of Horticulture Crops for 2020-21 (Second Advance Estimates), Horticulture Area Production Statistics, Department of Agriculture & Farmers Welfare, Government of India. <https://static.pib.gov.in/WriteReadData/userfiles/Second%20Adv%20Est%20of%202020-21%20of%20Horticulture%20Crops%20-%20Copy%201.pdf>
- BIS. 2007. *Nutrient Requirements for Poultry* IS:9883. Bureau of Indian Standards, New Delhi, India.
- Chavan V, Kulkarni R C, Awandkar S P, Chavhan S G, Gaikwad N Z, Suryawanshi R D, Kulkarni M B and Satapathy S. 2022. Effect of dietary supplementation of brown seaweed on performance of broiler chicken. *Indian Journal of Animal Sciences* **92**(8): 999–1005.
- Chen Y, Wang J, Zou L, Cao H, Ni X and Xiao J. 2022. Dietary proanthocyanidins on gastrointestinal health and the interactions with gut microbiota. *Critical Reviews in Food Science and Nutrition* **2**: 1–24.
- Ghasemi-Sadabadi M, Ebrahimnezhad Y, Maheri-Sis N, Ghalehkandi J G and Shaddel-Teli A. 2021. Immune response and antioxidant status of broilers as influenced by oxidized vegetable oil and pomegranate peel. *Journal of Animal Science and Technology* **63**(5): 1034–63.
- Gosset-Erard C, Zhao M, Lordel-Madeleine S and Ennahar S. 2021. Identification of punicalagin as the bioactive compound behind the antimicrobial activity of pomegranate (*Punica granatum L.*) peels. *Food Chemistry* **352**: 129396.
- Gurram S, Chinni Preetam V, Vijaya Lakshmi K, Raju M V L N and Venkateswarlu M. 2022. Effect of different combinations of probiotic, chicory root powder and coriander seed powder on growth, carcass, immunity, serum parameters and economics of broilers. *Indian Journal of Animal Sciences* **92**(11): 1337–42.
- Haghghian M K, Rafrat M, Hemmati S, Haghravan S and Asghari-Jafarabadi M. 2021. Effects of pomegranate (*Punica granatum L.*) peel extract supplementation on serum lipid profile and oxidative stress in obese women with knee osteoarthritis: A double blind, randomized, placebo controlled study. *Advances in Integrative Medicine* **8**(2): 107–13.
- Kamel E R, Shafik B M, Mamdouh M, Elrafaay S and Abdelfattah F A I. 2021. Effect of dietary pomegranate peel powder on productive traits, blood chemistry, economic efficiency and the expression of FSHR and LH- $\beta$  genes in two strains of laying Japanese quail. *Tropical Animal Health and Production* **53**(3): 1–11.
- Kishawy A T, Amer S A, Abd El-Hack M E, Saadeldin I M and Swelum A A. 2019. The impact of dietary linseed oil and

- pomegranate peel extract on broiler growth, carcass traits, serum lipid profile, and meat fatty acid, phenol, and flavonoid contents. *Asian-Australasian Journal of Animal Sciences* **32**(8): 1161–71.
- Kupnik K, Leitgeb M, Primožič M, Postružnik V, Kotnik P, Kučuk N, Knez Ž and Marevc M K. 2022. Supercritical fluid and conventional extractions of high value-added compounds from pomegranate peels waste: production, quantification and antimicrobial activity of bioactive constituents. *Plants* **11**(7): 928.
- Tozzi F, Núñez-Gómez D, Legua P, Del Bubba M, Giordani E and Melgarejo P. 2022. Qualitative and varietal characterization of pomegranate peel: High-value co-product or waste of production? *Scientia Horticulturae* **291**: 110601.