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Effects of Postbiotic and Organic Selenium supplementation on Immunity, Antioxidant Status and Cost economics in Heat-Stressed Broiler chicken

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Heat stress is a major constraint to broiler productivity, impairing immunity, antioxidant status and overall performance. The present study sought to elucidate the individual and combined effects of a *Saccharomyces cerevisiae*–derived postbiotic and organic selenium on humoral immunity, serum biochemical profile, antioxidant enzymes, cortisol and cost economics in broiler chickens reared during summer conditions. A total of 288 day-old broiler chicks (45.13 ± 3 g) were equally and randomly distributed into six dietary regimens with eight replicates of six birds each for 35 days: T_1 (basal diet), T_2 (basal diet + 0.3 mg organic selenium/kg), T_3 (basal diet + 500 mg postbiotic/kg), T_4 (basal diet + 1000 mg postbiotic/kg), T_5 (basal diet + 0.3 mg organic selenium + 500 mg postbiotic/kg) and T_6 (basal diet + 0.3 mg organic selenium + 1000 mg postbiotic/kg). Humoral immunity was assessed by Newcastle disease hemagglutination inhibition titres, while serum biochemical parameters (total protein, albumin, globulin, (AG) ratio and cholesterol levels), antioxidant indices (Glutathione peroxidase, Glutathione reductase, Superoxide dismutase, Malondialdehyde) and cortisol were evaluated on days 21 and 35.Dietary supplementation significantly ($P < 0.05$) enhanced ND antibody titres, increased serum total protein and albumin, reduced cholesterol levels, improved antioxidant enzyme activities, decreased lipid peroxidation and lowered cortisol levels compared with the control. Combined supplementation (T5 and T6) produced the most pronounced improvements. Economic analysis revealed higher net profit per bird in supplemented groups, with the greatest return observed in T6, followed by T5.In conclusion, dietary inclusion of postbiotic and organic selenium, particularly in combination, effectively improved immune response, antioxidant status, stress resilience and profitability in broiler chickens during heat stress, indicating their potential as practical nutritional strategies for enhancing productivity during hot climatic conditions.

Keywords : Postbiotic, Organic selenium, Humoral immunity, Antioxidant status, Cost economics

Efficient poultry production depends on the combined influence of high-quality genetics, optimal housing conditions and precisely balanced nutrition. In practical farming systems, broiler chickens are routinely subjected to multiple environmental challenges, among which heat stress (HS) has become one of the most serious concerns, particularly with the ongoing impacts of climate change (Abdel-Moneim *et al.,* 2021). Exposure to elevated temperatures compromises growth performance, physiological functions and metabolic processes in broilers by impairing gut integrity, inducing oxidative stress and promoting epithelial injury and inflammatory responses (Lian *et al.,* 2020). To counteract these adverse effects, several dietary interventions have been explored to improve bird adaptability and productivity under stressful conditions. Recently, postbiotics and organic selenium have attracted increasing interest owing to their enhanced bioavailability, strong antioxidant potential and ability to support birds during thermal stress.

The International Scientific Association of Probiotics and Prebiotics characterizes postbiotics as preparations comprising non-living microbial cells and/or their components that promote beneficial physiological effects in the host. (Salminen *et al.,* 2021). These compounds demonstrate diverse functional properties, such as antimicrobial, antioxidant, anti-inflammatory and immunomodulatory actions, along with hypocholesterolemic, antiproliferative, hepatoprotective and growth-enhancing effects, thereby supporting overall host wellbeing (Aguilar-Toala *et al.,* 2018).

Selenium (Se) is a vital micronutrient necessary for maintaining animal health and productivity, mainly through its role in antioxidant defense mechanisms that safeguard cells against free-radical-induced damage (Prasad *et al.,* 2023). Compared with inorganic forms, organic selenium exhibits superior absorption, higher tissue deposition and reduced toxicity (Liu *et al.,* 2022). Therefore, the present investigation was undertaken to evaluate the individual and combined effects of postbiotic derived from *Saccharomyces cerevisiae* and organic selenium on immunity, biochemical constituents, antioxidant status, stress marker cortisol and cost economics in heat stressed broiler chickens.

Materials and Methods

The present trial was carried out, using 288-day-old broiler chicks initially weighing 45.13 ± 3g, were randomly distributed into 6 experimental groups. Each group was housed in 8 replicate cages, with 6 birds accommodated in each cage. The feeding trial was undertaken for five weeks, encompassing 3 distinct phases: phase1

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(d1-14), phase2 (d15-28) and phase3 (d29-35). Dietary treatments were formulated based on a basal diet, with supplementation levels of Postbiotic (Celmanax®, Arm and Hammer Co., Ltd (USA)) and Organic selenium (AJ Supplements Private Limited, HYD) *viz*.T_1- Control (Basal Diet), T_2 – BD + 0.3mg Organic selenium/kg diet, T_3– BD + 500mg Postbiotic/kg diet, T_4– BD + 1000mg Postbiotic/kg diet, T_5– BD + 0.3mg Organic selenium + 500mg Postbiotic/kg diet and T_6– BD + 0.3mg Organic selenium + 1000mg Postbiotic/kg diet. The experimental protocols and associated procedures were performed in accordance with established ethical guidelines and were reviewed and approved by the Institutional Animal Ethics Committee (17/30/C.V. Sc,Hyd, dated:11/06/2024) in accordance with the CPCSEA. All birds were housed in four-tier battery cages measuring 1.25 m × 0.80 m × 0.50 m (length × width × height). Throughout the experimental period, feed and fresh drinking water were provided *ad libitum*. The basal diets were formulated to meet the nutrient specifications recommended in the breeder management manual, thereby fulfilling the nutritional requirements of the birds. These diets were detailed in Table-1.

The research work was carried out in the Poultry Experimental Station, College of Veterinary Science, P. V. Narsimha Rao Telangana Veterinary University, Hyderabad, Telangana from 16th May 2025 to 20th June 2025. Throughout the study, the average temperature fluctuated between 23.2 to 38.2°C. Similarly, the relative humidity during the experiment ranged from 25 to 65.2%. The average Temperature Humidity Index (THI) noted was 78.53 during the experimental period.

Humoral Immunity: The influence of dietary supplementation with graded levels of postbiotic and organic selenium on the humoral immune response of broiler chickens was assessed by determining antibody titres against the Newcastle disease virus. Birds were immunized with the Lasota strain of Newcastle disease vaccine (ND Lasota Vac-1000; Ventri Biologicals, Pune, India) via the ocular route on days 7 and 28 of the experimental period. At 35 days of age, blood samples were collected, and serum was separated by centrifugation for immunological analysis. Serum antibody titres against NDV were quantified using the hemagglutination inhibition assay as described by Allan *et al.,* (1978), and the results were expressed as $\log_2$ HI titres.

Serum Analysis: Blood was aseptically collected from one bird per replicate on days 21 and 35 via the brachial vein. After clotting at room temperature, samples were centrifuged at 3000 rpm for 5 minutes, and serum was stored at -20°C for analysis of antioxidants (glutathione peroxidase (Cat. No. E0298Ch), glutathione reductase (Cat. No. E029Ch), superoxide dismutase (Cat. No. E0295Ch) Malondialdehyde (Cat. No. E0171Ch), and cortisol (Cat. No. E009cC) determined using a commercial Enzyme-Linked Immunosorbent Assay (ELISA) kit, Bioassay Technology Laboratory, Jiaxing, Zhejiang, China. The biochemical parameters (total protein, albumin, globulin and cholesterol) were analysed according to Erba Mannheim kit protocol (TransAsia Bio-Medicals Limited, India).

Cost Economics:

The economics of broiler production were evaluated using the following calculations:

Total feed cost per bird (Rs) = Total feed intake per bird (kg) × Feed cost (Rs/kg)

Total production cost per bird (Rs) = Total feed cost + Cost of day-old chick + Miscellaneous cost

Cost of production per kg live body weight (Rs/kg) = Total production cost per bird ÷ Final live body weight (kg)

Sale value per bird (Rs) = Final live body weight (kg) × Market price of live broiler (Rs/kg)

Net profit per bird (Rs) = Sale value per bird – Total production cost per bird

Net profit per kg live body weight (Rs/kg) = Net profit per bird ÷ Final live body weight (kg)

$$\text{Return on Investment \% (ROI\%)} = \frac{\text{Net Profit}}{\text{Total Cost of Production}} \times 100$$

$$\text{Benefit:Cost (B:C) ratio} = \frac{\text{Sale Value}}{\text{Total Cost of Production}}$$

Statistical Analysis: All experimental data were subjected to statistical analysis using the General Linear Model procedure of the Statistical Package for the Social Sciences (Version 27.0). Treatment means were compared using Duncan's Multiple Range Test (Duncan, 1955). Biochemical and antioxidant variables were further analysed by two-way univariate analysis of variance following the procedures described by Snedecor and Cochran (1980). Differences among treatments were considered statistically significant at P< 0.05.

Results

Dietary supplementation of postbiotic and organic selenium significantly (P<0.05) enhanced the humoral immune response in broiler chickens, as evidenced by higher Newcastle Disease (ND) hemagglutination inhibition (HI) titres (Table 2). The supplemented groups exhibited significantly higher antibody titres compared to the control group, indicating improved immune response following ND vaccination.

Dietary treatments significantly (P<0.05) affected serum total protein and cholesterol concentrations during the experimental period (Table 3), whereas the sampling period and diet × period interaction had no significant effect. Serum albumin concentration was significantly influenced (P<0.05) by dietary treatment and sampling period. However, serum globulin concentration and albumin:globulin (A/G) ratio were not significantly affected (P>0.05) at either 21 or 35 days, although numerically higher A/G ratios were observed in the supplemented groups.

Dietary supplementation with postbiotic and organic selenium significantly (P<0.05) influenced antioxidant enzyme activities in broiler chickens (Table 4). Glutathione peroxidase (GPx) activity was significantly affected by dietary treatment, sampling period, and their interaction (P<0.05). Glutathione reductase (GR) and superoxide dismutase (SOD) activities were significantly affected by dietary treatment and sampling period (P < 0.05), while their diet × period interactions were not significant (P>0.05). Malondialdehyde levels were significantly reduced (P<0.05) in supplemented groups, whereas the effects of sampling period and diet × period interaction were not significant.

Dietary supplementation with postbiotic and organic selenium significantly (P<0.05) reduced serum cortisol concentrations in broiler chickens (Table 5). Sampling period also had a significant effect (P<0.05), whereas the diet × period interaction was not significant (P>0.05).

The economics of broiler production during the overall experimental period (0–35 days) are presented in Table 6. Supplementation with postbiotic and organic selenium improved net profit per bird compared with the control. The highest net profit was recorded in T6 (₹39.17), followed by T5 (₹37.35), T3 (₹36.71), T4 (₹35.44), T2 (₹33.65), while the lowest profit was observed in T1 (₹29.14).

Discussion

Newcastle Disease (ND) HI titre is a reliable indicator of humoral immune response and reflects the antibody production following vaccination. The higher antibody titres observed in the supplemented groups indicate enhanced immune competence due to dietary postbiotic and organic selenium supplementation.

These findings agree with those of Chang *et al.* (2022), Doski and Kareem (2023) and Soren *et al.* (2024) who also reported improved antibody responses following supplementation with postbiotics and organic selenium. The improvement may be attributed to enhanced immune cell function, improved intestinal health, and the antioxidant role of selenium, which protects immune cells against oxidative damage. However, Al-Sagheer *et al.* (2023) reported no significant effect of selenium, inactivated yeast, or their combination on immune function in heat-stressed rabbits, suggesting that responses may vary depending on animal species and experimental conditions.

The increased serum total protein and albumin concentrations observed in the supplemented groups suggest improved protein metabolism and liver function. The reduction in serum cholesterol may indicate improved lipid metabolism and enhanced physiological status. Similar observations were reported by Fang *et al.* (2024), Soren *et al.* (2024), and Monika *et al.* (2024), who found significant improvements in serum protein profile and reduced cholesterol concentrations following postbiotic supplementation. In contrast, Al-Sagheer *et al.* (2023) and Soren *et al.* (2024) observed no significant changes in serum total protein or albumin concentrations after supplementation with *Saccharomyces cerevisiae* fermentation products, indicating that responses may depend on dietary composition, environmental conditions, and supplementation level.

The improved GPx, GR, and SOD activities together with reduced lipid peroxidation demonstrate that dietary supplementation effectively enhanced the antioxidant defence system in broiler chickens. Organic selenium is an essential component of glutathione peroxidase, while postbiotics provide bioactive metabolites that enhance endogenous antioxidant capacity and reduce oxidative stress. These findings are consistent with those of Humam *et al.* (2021), Al-Sagheer *et al.* (2023), and Gul *et al.* (2023), who reported enhanced antioxidant enzyme activities in supplemented broilers exposed to heat stress. Conversely, Humam *et al.* (2020) reported no significant influence of postbiotic supplementation on SOD or GPx activity under heat stress, indicating that differences in postbiotic source, dosage, and environmental conditions may contribute to inconsistent responses.

The significant reduction in serum cortisol concentration observed in the supplemented groups indicates a lower physiological stress response. Selenium, through its antioxidant properties, and postbiotics, through modulation of gut health and immune function, likely reduced oxidative stress and activation of the hypothalamic-pituitary-adrenal axis during heat stress. Similar findings were reported by Sun *et al.* (2021) and Abbas *et al.* (2022), who demonstrated that selenium-enriched yeast supplementation significantly reduced cortisol levels in heat-stressed birds. In contrast, Forder *et al.* (2024) observed no effect of *Saccharomyces cerevisiae* extract supplementation on plasma cortisol concentration in breeder birds, suggesting that physiological responses may differ according to bird type, supplementation strategy, and production conditions.

The improved economic returns observed in the supplemented groups were primarily associated with enhanced growth performance, improved feed efficiency, better immune response, and reduced oxidative stress. The highest economic return recorded in the combined postbiotic and organic selenium treatment indicates that supplementation can be a cost-effective nutritional strategy for improving broiler productivity, particularly under heat stress conditions.

Conclusion

Dietary supplementation with postbiotic and organic selenium, particularly in combination, significantly enhanced immune response, antioxidant status and stress tolerance while improving economic returns in broiler chickens under heat stress, demonstrating their potential as effective nutritional strategies for sustainable broiler production.

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Competing Interests

The authors declare that they have no competing interests.

Authors' Contributions

Sagi Raju, J. Narasimha, Sarin. K. Kunnath and N. Nalini kumari contributed to the original idea and design of the study. Boini Sravanthi conducted the experiments and collected the data. All authors were involved in the manuscript preparation.

Data Availability Statement

The datasets generated during the current study are available from the corresponding author on request.

AI Policy

No generative AI tools were used in the experiment design, data collection, data analysis, interpretation of results or preparation of manuscript. All work presented is the original work of the authors.

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Table 1 - Diet ingredients and chemical composition of the basal control diet

Ingredient	Pre-Starter (1-14 days)	Starter (15-28 days)	Finisher (29-35 days)
Maize	53.1	53.79	58.43
Oil-veg	2.74	4.30	5.00
Deoiled soybean meal	40.24	38.00	32.55
Salt	0.35	0.30	0.30
Dicalcium phosphate	1.8	1.90	2.00
Lime stone powder	1.2	1.20	1.20
DL-Methionine	0.15	0.15	0.13
L-lysine Hydrochloride	0.06	0.00	0.03
Choline chloride,75%	0.06	0.06	0.06
Toxin binder[1]	0.05	0.05	0.05
Trace mineral mixture[2]	0.15	0.15	0.15
Vitamin premix[3]	0.05	0.05	0.05
Coccidiostat[4]	0.05	0.05	0.05
Total	100	100	100
Nutrient composition DMB(%)			
Me[b], MJ/kg	12.49	12.95	13.32
Protein[a], (% g)	23.01	22.03	20.00
Lysine[b], (%)	1.31	1.20	1.10
Methionine[b](%)	0.50	0.49	0.45
Calcium[a], (%)	0.97	1.00	1.02
Available phosphorous[a], (%)	0.44	0.45	0.46

1. Five gram of toxin binder provided per kg diet: Acetic acid 2mg, Formic acid 2mg, propionic acid 2mg, citric acid 2mg, Benzoic acid 1mg, Sorbic acid 0.25 mg, HSCAS 9.1mg.
2. Each gram of trace mineral mixture provided per kg diet: Manganese 1.1 mg, Zinc 1mg, Iron 110mg, Copper 20mg, Iodine 2.5mg, Cobalt 1mg, Chromium 0.4mg and Selenium 1.5mg
3. Vitamin pre-mix provided per kg diet: Riboflavin 25mg, Vitamin B1 1mg, Vitamin B6 2mg, Vitamin B12 40mg, Niacin 15mg, Vitamin A 20000 IU, Vitamin D3 3000 IU, Vitamin K 2mg
4. Five gram of coccidiostat provided per kg diet: Maduramicin 5 mg

DMB, dry matter basis [a]Analysed value, [b]calculated value

Table 2 -Individual and Combined Effects of dietary supplementation ofPostbiotic and Organic selenium on ND titration(log_2) in broiler chicken during summer.

Treatment	HI titre (log_2)
Standard diet	5.62^{b}
OS-0.3mg/kg	7.00^{a}
PB-500mg	6.50^{ab}
PB-1000mg	6.87^{a}
OS+500mg PB	7.13^{a}
OS+1000mg PB	7.25^{a}
N8SEM	0.15
P-value	0.02

^{a,b}Means with different superscript in a column differ significantly: (*P < 0.05)

P- value: probability value. N: number of replicates (6 birds in each replicate); SEM: Standard Error Mean

SD: Standard diet; OS-0.3mg/kg: standard diet + 0.3mg organic selenium/kg diet; PB-500mg: standard diet + 500mg postbiotic/kg diet; PB-1000mg: standard diet + 1000mg postbiotic/kg diet; OS+500mg PB: standard diet + 0.3mg organic selenium/kg diet +500mg postbiotic/kg diet; OS+1000mg PB: standard diet + 0.3mg organic selenium/kg diet +1000mg postbiotic/kg diet.

Table 3 - Individual and Combined Effects of dietary supplementation of Postbiotic and Organic selenium on Biochemical constituents in broiler chicken during summer.

Parameters	Total protein (g/dL)	Albumin (g/dL)	Globulin (g/dL)	AG ratio	Cholesterol (g/dL)
			Treatments		
Standard diet	4.29^{c}	2.18^{c}	2.11	1.04	141.00^{a}
OS-0.3mg/kg	4.49^{b}	2.27^{bc}	2.22	1.07	135.89^{ab}
PB-500mg/kg	4.46^{bc}	2.40^{ab}	2.06	1.18	130.62^{abc}
PB-1000mg/kg	4.50^{b}	2.42^{ab}	2.08	1.25	127.78^{bc}
OS+PB-500mg/kg	4.69^{a}	2.51^{a}	2.18	1.17	122.87^{c}
OS+PB-1000mg/kg	4.77^{a}	2.57^{a}	2.21	1.20	123.39^{c}
SEM	0.05	0.06	0.08	0.06	5.38
p- value	0.001	0.001	0.61	0.26	0.01
			Day		
21st day	4.51	2.31^{y}	2.19	1.07	130.77
35th day	4.57	2.40^{x}	2.09	1.23	130.05
SEM	0.07	0.09	0.11	0.07	2.32
p-value	0.29	0.001	0.09	0.09	0.77
Treatmentx Day	0.93	0.72	0.93	0.95	1.00

^{a,b,c,x,y}Means with different superscript in a column differ significantly: (*P < 0.05)

P- value: probability value. N: number of replicates (6 birds in each replicate); SEM: Standard Error Mean

SD: Standard diet; OS-0.3mg/kg: standard diet + 0.3mg organic selenium/kg diet; PB-500mg: standard diet + 500mg postbiotic/kg diet; PB-1000mg: standard diet + 1000mg postbiotic/kg diet; OS+500mg PB: standard diet + 0.3mg organic selenium/kg diet +500mg postbiotic/kg diet; OS+1000mg PB: standard diet + 0.3mg organic selenium/kg diet +1000mg postbiotic/kg diet

Table 4 - Individual and Combined Effects of dietary supplementation of Postbiotic and Organic selenium on Antioxidant status in broiler chicken during summer.

Parameters	Glutathione peroxidase (ng/mL)	Glutathione reductase (ng/mL)	Superoxide dismutase (ng/mL)	Malondialdehyde (nmol/mL)
		Treatments		
Standard diet	2.94^{c}	2.93^{c}	1.59^{c}	4.01^{a}
OS-0.3mg/kg	5.44^{ab}	3.91^{ab}	2.96^{ab}	2.29^{b}
PB-500mg	4.69^{b}	3.35^{bc}	2.49^{b}	2.52^{b}
PB-1000mg	4.99^{ab}	3.59^{bc}	2.99^{ab}	2.47^{b}
OS+500mg PB	5.53^{a}	4.15^{ab}	3.33^{a}	2.23^{b}
OS+1000mg PB	5.73^{a}	4.46^{a}	3.46^{a}	2.18^{b}

SEM	0.28	1.04	0.20	0.17
p- value	0.001	0.001	0.001	0.001
		Day		
21st day	4.63^{y}	3.49^{y}	2.45^{y}	2.803
5th day	5.15^{x}	4.29^{x}	3.16^{x}	1.92
SEM	0.21	0.15	0.14	0.22
p-value	0.02	0.001	0.001	0.06
TreatmentxDay	0.04	0.46	0.79	0.92

[a,b,c,x,y]Means with different superscript in a column differ significantly: (*P < 0.05)

P- value: probability value. N: number of replicates (6 birds in each replicate); SEM: Standard Error Mean

SD: Standard diet; OS-0.3mg/kg: standard diet + 0.3mg organic selenium/kg diet; PB-500mg: standard diet + 500mg postbiotic/kg diet; PB-1000mg: standard diet + 1000mg postbiotic/kg diet; OS+500mg PB: standard diet + 0.3mg organic selenium/kg diet +500mg postbiotic/kg diet; OS+1000mg PB: standard diet + 0.3mg organic selenium/kg diet +1000mg postbiotic/kg diet

Table 5 - Individual and Combined Effects of dietary supplementation of Postbiotic and Organic selenium on Cortisol levels in broiler chicken during summer.

Parameters	Cortisol(ng/mL)
Treatment	
Standard diet	8.25^{a}
OS-0.3mg/kg	4.04^{b}
PB-500mg	4.93^{b}
PB-1000mg	4.33^{b}
OS+500mg PB	3.83^{b}
OS+1000mg PB	3.46^{b}
SEM	0.48
p- value	0.001
Period	
21st day	5.25^{x}
35th day	4.36^{y}
SEM	0.37
p-value	0.04
TreatmentxDay	0.94

[a,b,c,x,y]Means with different superscript in a column differ significantly: (*P < 0.05)

P- value: probability value. N: number of replicates (6 birds in each replicate); SEM: Standard Error Mean

SD: Standard diet; OS-0.3mg/kg: standard diet + 0.3mg organic selenium/kg diet; PB-500mg: standard diet + 500mg postbiotic/kg diet; PB-1000mg: standard diet + 1000mg postbiotic/kg diet; OS+500mg PB: standard diet + 0.3mg organic selenium/kg diet +500mg postbiotic/kg diet; OS+1000mg PB: standard diet + 0.3mg organic selenium/kg diet +1000mg postbiotic/kg diet

Table 6 Cost of production during overall experimental period (0 – 35 days) of broiler chickens during summer.

Particulars	**Treatments**					
	Control	**0.3mg OS**	**500mg PB**	**1000mg PB**	**0.3mg OS + 500mg PB**	**0.3mg OS + 1000mg PB**
Live body weight (g)	1940	2076	2034	2057	2101	2127
Total FI/bird (g) (0-35 days)	2782	2909	2877	2875	2940	2944
Cost of feed/kg (Rs)	40	40.0001	40.15	40.30	40.1501	40.3301
Cost of day-old chick(Rs)	35	35	35	35	35	35
Miscellaneous cost/bird (Rs)	5	5	5	5	5	5
Total feed cost, Rs/bird	111.28	116.36	115.51	115.86	118.04	118.64
Total cost, Rs/bird	151.28	156.36	159.53	155.86	158.04	158.64
Total cost, Rs/Kg bird	77.97	75.317	76.46	75.77	75.22	74.59
Sale of each bird (Rs)	180.42	193.068	189.16	191.30	195.39	197.81
Net profit /bird (Rs)	29.14	36.708	33.65	35.44	37.35	39.17
Net profit/kg b. wt. (Rs)	15.02	17.68	16.54	17.23	17.78	18.41
ROI%	19.26	23.48	21.09	22.74	23.63	24.69
B:C Ratio	1.19	1.23	1.18	1.23	1.24	1.25

SD: Standard diet; OS-0.3mg/kg: standard diet + 0.3mg organic selenium/kg diet; PB-500mg: standard diet + 500mg postbiotic/kg diet; PB-1000mg: standard diet + 1000mg postbiotic/kg diet; OS+500mg PB: standard diet + 0.3mg organic selenium/kg diet +500mg postbiotic/kg diet; OS+1000mg PB: standard diet + 0.3mg organic selenium/kg diet +1000mg postbiotic/kg diet