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ORIGINAL ARTICLE

Supplementation of Mannan Oligosaccharide in Broiler Diets on Growth Performance and Nutrient Digestibility

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Abstract

This study evaluated the effects of mannan oligosaccharide (MOS) supplementation in broiler diets on growth performance and nutrient digestibility. A total of 200 vaccinated, day-old, broiler chicks were randomly assigned to five dietary treatments with four replicates each following a completely randomised design. The experimental diets included a control with no MOS supplementation (T1) and four treatment groups supplemented with MOS levels of 0.5 (T2), 1.0 (T3), 1.5 (T4) and 2.0 (T5) g kg^{-1} diet. Growth performances, dressing percentage, carcass quality, nutrient digestibility of feed and cost-benefit were evaluated. Results indicated that live weight of birds at 21 d of age was significantly higher ($p<0.05$) in T4 (1,220±88 g) and T5 (1,220±88 g) compared to T1, T2 and T3. However, there were no significant differences in feed conversion ratio, carcass weight and dressing percentage among the treatment groups ($p>0.05$). Additionally, the water holding capacity of meat was significantly higher ($p<0.05$) in T3 and T4 (78±17%) groups compared to T1 (72±17%). During the starter period, dry matter (77.2±1.6%) and crude fat (90.2±2.4%) digestibility were significantly higher in T4 compared to the control. However, no significant differences were observed during the finisher period. Crude fiber digestibility during both starter and finisher periods was significantly higher in birds fed with T4 (74.6±1.3% and 70.6±1.9%, respectively) compared to the control. Profit per bird was significantly higher ($p<0.05$) in T4 (LKR 1,157±52) compared to T1 (LKR 616±52). In conclusion, supplementation of MOS at 1.5 g kg^{-1} enhances the net profit while improving growth performances and feed digestibility, particularly during the early growth stage.

Keywords: *Carcass weight, dressing percentage, dry matter digestibility, water holding capacity*

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1. Introduction

Broilers are selectively bred chicken strains which developed specifically for rapid meat production within a short period (Bennett et al. 2018). Nowadays, the poultry sector runs on a large scale, basically focusing on profit. The profitability of farms depends on the proper nutrition, efficient feed manufacturing, and on flock health and hygiene (Rathnayake et al. 2024; Asif et al. 2024). Poor nutrient quality, less nutrient utilisation, high microbial load, stress conditions and sudden environmental changes significantly reduce gastrointestinal function, subsequently leading to poor birds' performance (Granstad et al. 2020). Gut microflora plays a vital role in improving intestinal wall function and immune condition, which directly influence the nutrient absorption and utilisation (Klasing, 2007), which enhances the overall broiler production (Chen et al. 2009; Gul et al. 2021).

The commercially available antibiotic growth promoters (AGPs) were used to enhance the growth and immune responses in broiler birds. Thus, the development of antibiotic-resistant bacteria, meat residue, and environmental contamination through manure, influences concerns about alternatives to improve broiler performance without relying on AGP. Prebiotics, probiotics, enzymes, organic acids, antimicrobial peptides, hyperimmune eggs, and bacteriophages are the identified alternatives (Kamran et al. 2013; Gadde et al. 2017). Among those, prebiotics are identified as a feed supplement which selectively stimulates beneficial gut bacterial growth without being digested (Patterson and Burkholder 2003; Rathnayake et al. 2024), by stimulating the gut microbiome by increasing beneficial bacterial population, while suppressing pathogenic bacterial growth (De Vrese and Schrezenmeir 2008; Yasmeen et al. 2021).

Currently, various oligosaccharides are used as prebiotics and mannan oligosaccharides (MOS) derived from yeast (*Saccharomyces cerevisiae*) are a promising avenue for poultry nutrition due to their capability to reduce pathogenic gut microbes and strengthen the intestinal mucosa. Mannan oligosaccharides improve intestinal health by triggering macrophages in the gut lymphoid tissues and cell immunity (Smith et al. 2020). Xu et al. (2017) demonstrated that MOS affects inhibiting pathogenic bacteria (*Escherichia coli* and *Salmonella pullorum*) while improving beneficial bacteria (*Bifidobacterium* Spp and *Lactobacillus* Spp), subsequently promoting gut health and growth performance of broilers. While considering these positive effects of MOS as an economical alternative to AGP, the primary objective of this study was to evaluate the effect of different levels of MOS supplementation on growth performance and nutrient digestibility of broiler birds in both starter and finisher phases.

2. Materials and Methods

2.1. Ethical Approval

All animal handling procedures were approved by the research ethics committee of the Uwa Wellassa University of Sri Lanka (Reference No: UWU/REC/2024/20).

2.2. Experimental Location

Feeding trial and field work were carried out at the Poultry Unit, Faculty Farm, Faculty of Agriculture, Rajarata University of Sri Lanka, located in the DL1b agro-ecological region with the annual mean minimum and maximum average temperature of 22.75±1.09°C and 31.9±0.91°C, respectively (meteobox 2025). Other laboratory analyses were carried out in the Animal Science laboratory, Department of Animal and Food Science, Faculty of Agriculture, Rajarata University of Sri Lanka.

2.3. Experimental Design and Treatment Diets

Two hundred vaccinated, Cobb-500 day-old broiler chicks (average body weight = 33.51±4.08 g) were purchased from a local commercial hatchery and randomly assigned to five treatment groups (T1 to T5), in a completely randomised design (CRD). There were four replicates per treatment, and for each replicate, ten birds were randomly assigned following two-phase feeding trials as a starter and the finisher phases. Commercially available broiler starter and finisher feeds were used as basal feeds. The control diet (T1) consisted basal diet without MOS, while T2, T3, T4, and T5 supplemented the same basal diet with MOS at the rate of 0.5 g, 1.0 g, 1.5 g, and 2.0 g kg^{-1}, respectively.

2.4. Broiler Management Practices

The broiler management protocols were followed for 35 days. Day-old broiler chicks were brooded for 10 days, and anti-stress supplements (Selvit-E® 1 mL L^{-1}, and Glucose with electrolyte solution 25 g L^{-1}) were provided during the brooding period with *ad libitum* feeding with the starter ration. The temperature and light requirement was provided by using a 60 W glass bulb for each treatment. During the post-brooding period, birds were housed in a naturally ventilated deep litter system, allocating 0.305 m^2 of space per bird. The control diet and treatment diets were also provided during the starter phase (11-22 days) and finisher phase (22-35 days) periods twice a day with *ad libitum* supply of drinking water. Digestibility trials were also conducted during the three days in the starter period (15 to 17 days) and in the finisher (31-33 days) period by birds kept in metabolic cages (50 × 50 × 55 cm). During the starter period, two randomly selected birds were housed in a metabolic cage, while in the finisher period, one randomly selected bird per metabolic cage represented each replicate. Feed intake, leftovers, and total faeces output were measured during the metabolic trial. The study ended up performing the standard Halal slaughter process on day 35th, followed by 12 h starvation, then ante-mortem inspection was done by the experienced animal scientist, and finally performing the slaughtering process with a quick, sharp incision made through the jugular vein by a practised slaughterman.

Carcass handling procedures were followed at the faculty meat processing unit, Faculty of Agriculture, Rajarata University of Sri Lanka. Standard food hygiene procedures were followed during the carcass handling. Then the evisceration process was done carefully to obtain giblets and offal for measurements without contamination. After harvesting necessary giblets and samples for the analysis, processed carcasses were immediately immersed in the 4^{O}C water to minimise the microbial contamination.

2.5. Sample Analysis

Collected feed and excreta samples were stored in cleaned and labelled bottles in -18°C. Those samples were analysed for proximate composition according to the Association of Official Analytical Chemists methods (AOAC, 2019). Samples were dried using a hot air oven (YCO-010, Germany) at 60°C until a constant weight. Prepared samples were burned at 550°C for 5 hours in a muffle furnace (DMF3514, Korea) to determine ash content. Ether extract (EE) and crude fibre (CF) contents were determined by a solvent extraction unit (VELP Scientifica-SER 148, Italy) and a fibre extraction unit (VELP Scientifica-FIWE 6, Italy), respectively. A Kjeldahl apparatus (VELP Scientifica-DK20, Italy) was used to determine the nitrogen content of samples, and then crude protein (CP) content was calculated.

2.6. Data Collection and Calculation

2.6.1. Growth Performance

The initial weight of one-day-old chicks was taken using an electronic scale (NMB072, Ceylon Weighing Machines LTD, Colombo, Sri Lanka). To measure the live weight and growth performances, birds were weighed weekly in the morning before feeding. Body weight gain was calculated for both starter and finisher periods. Given and leftover feeds were measured daily, and feed intake (FI) was calculated using Eq. 1. The Feed Conversion Ratio (FCR) was calculated using Eq. 2.

$$\textit{Feed intake} = \textit{Given feed (g)} - \textit{Remain feed (g)} \quad \text{------------} \quad \textit{Eq. 1}$$

$$\textit{Feed Conversion Ratio} = \frac{\textit{Feed intake (kg)}}{\textit{Live weight gain (kg)}} \quad \text{------------} \quad \textit{Eq. 2}$$

2.6.2. Carcass Characteristics

After slaughtering, carcass weight was measured using three randomly selected carcasses that represented each replicate. Dressing percentage was calculated using Eq. 3.

$$Dressing\ percentage\ (\%) = \frac{Carcas\ weight\ (g)}{Live\ weight\ (g)} \times 100 \text{ -- } Eq.\ 3$$

The weight of internal organs (gut, liver, gizzard, and heart) was measured and expressed as a percentage of the carcass weight (Eq. 4).

$$Weight\ of\ internal\ organs\ (\%) = \frac{Weight\ of\ the\ organ\ (kg)}{Carcas\ weight\ (kg)} \times 100 \text{ -------------------------------- } Eq.\ 4$$

2.6.3. Nutrient Digestibility

Apparent nutrient digestibility was calculated using Eq. 5.

$$Apparant\ ND = \frac{(\%\ N\ feed \times FI) - (\%\ N\ Faeces \times FO)}{(\%\ N\ feed \times FI)} \times 100 \text{ -- } Eq.\ 5$$

Where; ND = Nutrient digestibility, N = Nutrient, FI= feed intake and FO= faecal output

2.6.4. Cost Analysis

Total cost was calculated by summing all the expenses (e.g., feed cost, cost for day-old chicks, repairing of houses, labour cost, veterinary, transport, and Miscellaneous). Income Per Bird (IPB), Net Profit (NP) and Total Revenue (TR) were calculated using Eq. 6, Eq.7, and Eq. 8.

$IPB = Avarage\ C_{wb}\ (kg) \times Selling\ price\ (LKR,\ kg^{-1})$ --- *Eq. 6*

Where; C_{wb} *= Carcass weight per bird*

$NP = TR\ (LKR) \times Total\ cost\ (LKR)$ --- *Eq. 7*

$TR = TCW\ (kg) \times Selling\ price\ (LKR,\ kg^{-1})$ --- *Eq. 8*

Where; TCW= total carcass weight

2.6.5. Statistical Analysis

Data were analysed using a one-way analysis of variance (ANOVA) procedure in RStudio version 4.5.1. Means were compared by Turkey's standardised range test (TSRT). Differences among treatments were deemed to be significant only if the value of $p \leq 0.05$.

3. Results and Discussion

3.1. Growth Performances

Table 1 shows the effect of treatments on live weight, feed intake, weight gain, carcass weight and FCR of broilers fed with different levels of MOS. Accordingly, there was no significant difference (p>0.05) in feed intake among the birds fed different levels of MOS during the experimental period, aligning with previous studies on MOS supplementing poultry diets (Hassan et al. 2019; Liu et al. 2020). The numerically lowest feed intake was reported in the birds fed the control diet, while the highest feed intake was reported in the birds fed with 1.5 g MOS per kg of feed. Some existing studies showed that MOS supplementation typically maintains or reduces feed intake (Spring et al. 2000; Baurhoo et al. 2007).

Table 1: Growth performance of broilers fed with different levels of mannan oligosaccharide

Parameters	Treatments					MSE (±)	P value
	T1	T2	T3	T4	T5		
Feed intake (g/bird)							
Starter P*	928	984	991	1,028	1,034	31	0.105
Finisher P*	1,709	1,738	1,839	1,736	1,719	14	0.555
Total P*	2,637	2,721	2,831	3,003	2,753	77	0.447
Final body weight (g/bird)							
Starter P*	1,121^{bc}	1,097^{c}	1,138^{b}	1,220^{a}	1,230^{a}	88	<0.001
Finisher P*	2,023	2,171	2,048	2,129	2,092	28	0.727
Total P*	2,023	2,171	2,048	2,129	2,092	28	0.727
Weight gain (g/bird)							
Starter P*	1,057^{b}	1,125^{ab}	1,131^{ab}	1,207^{a}	1,140^{ab}	59	0.043
Finisher P*	965	1045	901	1185	951	32	0.096
Total P*	1,986^{b}	2,081^{ab}	1,998^{ab}	2,359^{a}	2,059^{ab}	84	0.038
FCR							
Starter P*	0.85	0.85	0.85	0.87	0.88	0.01	0.928
Finisher P*	1.88	1.76	2.11	1.83	1.92	0.10	0.641
Total P*	1.31	1.26	1.38	1.40	1.32	0.02	0.706

a, b, c, d: Means having different letters within the same row are significantly different (p<0.05).

MSE: Standard error of the mean

Treatments: T1 - Basal feed with no supplement (Control), T2 – Basal feed +MOS (0.5 g per kg), T3 – Basal feed + MOS (1.0 g per kg), T 4 – Basal feed + MOS (1.5 g per kg), T 5 – Basal feed + MOS (2.0 g per kg); P* - Period

According to Table 1, the significantly higher (p<0.05) live weights were observed in the birds fed with T4 and T5 diets compared with those fed T1, T2 and T3 during the starter period. However, no significant differences in body weights were observed among the tretments during the finisher period or over the total experimental period. These results were also similar to the findings reported by Fernandes et al. (2014). Further, the growth-promoting effect of MOS could be affected by several mechanisms, such as MOS functioning as a prebiotic, which selectively improves and activates beneficial bacteria in the digestive tract while reducing pathogenic bacterial load (Gurbuz et al. 2011; Dev et al. 2020; Aziz et al. 2024). These mechanisms of gut modulation facilitated more favourable conditions for nutrient absorption and utilisation, subsequently improving the liveweight. Moreover, Rahimi et al. (2024) revealed that the growth-promoting effect is regulated by enhancing gut health, strengthening nutrient digestion and boosting immune function. Moreover, the MOS shows competitive elimination of pathogenic bacteria, usually type-I fimbriae, which can bind mannose residues in MOS molecules. These binders prevent pathogenic bacteria from accumulating on the intestinal epithelium. Thereby the minimising the colonisation of pathogenic bacteria minimises their pathogenic effect, subsequently improving the broiler gut health, nutrient absorption and body weight (Sayed et al. 2024).

Additionally, the supplementation of MOS has shown improved efficiency of gene-related energy metabolism, protein synthesis, and lipid metabolism in broiler chickens, which directly contributed to the growth performances (Mayorga et al. 2024). The beneficial effect of the MOS, which is consistent with the existing findings of the supplementation of MOS, improves the prebiotic effect, a viable strategy for broiler growth performance.

According to Table 1, there were significant differences (p<0.05) in weight gain among birds fed different treatment diets during the starter period. A significantly higher (p<0.05) weight gain was reported in the birds fed 1.5 g MOS per kg ration (T4) compared with the birds fed the control feed (T1). The same trend was observed when considering the total study period. However, there were no significant differences (p>0.05) in the weight gain among the birds during the finisher period, though numerically the highest weight gain was reported in the birds fed with T4. Similarly, Shahir et al. (2014) observed significantly increased body weight gain in broiler chicks during 0-21 days of age when fed with a MOS-supplemented diet. Moreover, studies conducted by Shahir et al. (2014), Ahmed et al. (2020), Chen et al. (2021), Thompson et al. (2021), Williams et al. (2022) and Martinez and Davis (2023) consistently confirm that MOS supplementation significantly improves weight gain during the starter period (01–21 days). This early growth response is attributed to the age-specific sensitivity of younger birds, where MOS supports efficient development of the immune system and digestive tract (Hassan et al. 2019; Liu et al.

2020). Furthermore, the prebiotic effect of MOS continues to enhance weight gain during the finishing period, as evidenced by the same beneficial impact observed in the starter phase (Smith & Johnson 2022; Rodriguez et al. 2023).

There were no significant differences ($p>0.05$) in the FCR in birds fed with different treatment diets (Table 1). Based on existing studies, effect of MOS on FCR could be attributed to different prebiotic responses across different feeding phases (Hassan et al. 2019; Ahmed et al. 2020). Few studies showed that the different feeding stages may affect the FCR, and some studies show that MOS improves FCR during overall periods (Chen et al. 2021; Liu et al. 2022; Rodriguez et al. 2023).

Table 2. Carcass yield of broilers fed with different levels of mannan oligosaccharide

Parameters	Treatments					MSE (±)	P value
	T1	T2	T3	T4	T5		
CW (g/bird)	1,525	1,695	1,518	1,736	1,546	25	0.188
DP (%)	71	77	72	78	72	13	0.118
SIL (cm)	116^{ab}	121^{ab}	137^{a}	124^{ab}	110^{b}	13	0.037
Gizzard %	2.64	2.49	2.78	2.09	2.71	0.42	0.598
Heart %	0.62	0.64	0.66	0.53	0.55	0.01	0.234
Liver %	2.51^{ab}	2.81^{a}	2.91^{a}	1.99^{b}	2.37^{ab}	0.09	0.006

a, b, c, d: Means having different letters within the same row are significantly different ($p<0.05$).

MSE: Standard error of the mean.

Treatments: T1 - Basal feed with no supplement (Control), T2 – Basal feed +MOS (0.5 g per kg), T3 – Basal feed + MOS (1.0 g per kg), T 4 – Basal feed + MOS (1.5 g per kg), T 5 – Basal feed + MOS (2.0 g per kg); SIL-Small intestine length, CW-Carcass weight, DP-Dressing percentage.

There were no significant differences ($p>0.05$) in the carcass weight and dressing percentage (Table 2) among the birds fed with different levels of MOS. However, the numerically highest carcass weight and dressing percentages were observed in the birds fed with 1.5 g MOS per kg of diet compared to other treatments.

According to Table 2, significantly higher ($p<0.05$) small intestinal length was reported in the bird fed with 1.0 g MOS per kg of diet (T3) compared to the bird fed with 2 g MOS per kg of diet (T5). However, small intestinal lengths of birds fed with T2 , T3 and T4 were similar to the control. Based on the results, supplementation of different levels of MOS can be seen as the amount related to responses of intestinal growth; these results were supported by the studies of Hassan et al. (2019) and Ahmed et al. (2020). These developments could have happened through the support of prebiotic-mediated morphological adaptations (Liu et al. 2020; Chen et al. 2021). Based on the studies of Smith and Johnson (2022) and Rodriguez et al. (2023), the supplementation of MOS leads to improvement of intestinal morphological development. However, their findings further explained that there were no additional benefits of a higher MOS amount. This amount-dependent response shows that large MOS levels may negatively affect gut development. The enhanced intestinal length with proper MOS supplementation shows improved nutrient absorption and improved gut health (Thompson et al. 2021; Williams et al. 2022; Martinez and Davis, 2023). Therefore, this could be the reason for the enhanced intestinal length of supplementing 1.5 g MOS per kg of diet.

According to Table 2, significantly higher (p<0.05) liver percentage was observed in the birds fed with T2 and T3 compared to the T4, while no significant differences (p>0.05) in the other giblet weight percentages were observed among the birds supplemented with different levels of MOS in the broiler diets.

3.2. Meat Quality Parameters

Table 3 shows the meat quality parameters such as pH, colour, and WHC of the breast muscle of birds fed with different levels of MOS. The WHC of meat varied significantly (p<0.05) among birds fed different treatment diets (Table 3). The meat with significantly higher (p<0.05) WHC were found in birds fed with T3 and T4 compared to the birds fed with other treatment diets. These results were confirmed by studies conducted by Liu et al. (2020) and Chen et al. (2021), which observed the effect of MOS on WHC and meat quality parameters. The pH of the meat of broilers fed various levels of MOS was not significantly different (Table 3). Further, there was no significant difference in any meat colour values of the breast meat with MOS supplementation.

Table 3. Meat quality parameters of broilers fed with different levels of mannan oligosaccharide

Parameter	Treatments					MSE (±)	P value
	T1	T2	T3	T4	T5		
WHC	72^{b}	71^{b}	78^{a}	78^{a}	71^{b}	17	0.042
pH	6.09	6.12	6.14	6.21	6.27	0.02	0.348
Meat colour							
Average L	53.8	52.6	50.9	48.1	47.9	9.7	0.059
Average a*	1.6	1.6	2.4	2.2	2.1	1.2	0.784
Average b*	6.0	7.3	6.9	7.6	8.0	1.5	0.256

a, b: Means having different letters within the same row are significantly different (p<0.05). MSE: Standard error of the mean.

Treatments: T1 - Basal feed with no supplement (Control), T2 – Basal feed +MOS (0.5 g per kg), T3 – Basal feed + MOS (1.0 g per kg), T 4 – Basal feed + MOS (1.5 g per kg), T 5 – Basal feed + MOS (2.0 g per kg).

3.3. Digestibility of Nutrients

The impact of various treatments on nutrient digestibility is presented in Table 4 and Table ***5***. The digestibility of the majority of nutrients was significantly improved (p<0.05) by the supplementation of MOS in broiler diets. During the starter period, birds fed diets supplemented with MOS showed significant improvements (p<0.05) in the digestibility of dry matter, crude fat, crude fiber and ash. Dry matter digestibility was significantly (p<0.05) higher in T4 compared to the control and T5. Also, crude fat digestibility was significantly (p<0.05) higher in T3, T4 and T5 compared to the control, while crude fiber and ash digestibility were significantly (p<0.05) higher in T2, T3 and T4 compared to the control. However, crude protein digestibility did not show any difference among the treatments during the starter ration feeding period. Kumar et al. (2021) showed that the lower digestibility of crude protein in the starter period may age-dependent response to MOS, which could inhibit digestive enzyme activity in young broiler birds. This could be the reason why the digestibility of crude protein was not significant in this study. Apart from the protein digestibility, dry matter and crude fat digestibility have positively increased by supplementation of MOS, which supports the beneficial probiotic effect, subsequently improving the gut health and nutrient absorption (Zhang et al. 2020). While considering ash digestibility, a great indicator of mineral absorption, as well as improved prebiotic effect and gut health, MOS promotes efficient nutrient utilisation (Sohail et al. 2022). These findings support that MOS is an effective prebiotic supplement for optimising broiler performance through improved nutrient utilisation efficiency.

Table 4. Effect of supplementation of different levels of mannan oligosaccharides on nutrient digestibility of broilers in the starter period.

Parameter	Treatments					MSE (±)	P value
	T1	T2	T3	T4	T5		
Dry matter (%)	71.1^{b}	72.8^{ab}	71.4^{ab}	77.2^{a}	71.0^{b}	1.6	0.033
Crude fat (%)	61.3^{b}	76.5^{ab}	86.5^{a}	90.2^{a}	90.0^{a}	2.4	0.016
Crude fibre (%)	57.1^{b}	68.7^{a}	69.7^{a}	74.6^{a}	63.8^{ab}	1.3	0.002
Crude protein (%)	66.3	70.9	67.0	73.5	68.1	1.4	0.626
Ash (%)	49.1^{c}	68.3^{a}	69.1^{a}	66.1^{ab}	53.4^{bc}	3.4	0.001

a, b, c, d: Means having different letters within the same row are significantly different (p<0.05).

MSE: Standard error of the mean.

Treatments: T1 - Basal feed with no supplement (Control), T2 – Basal feed +MOS (0.5 g per kg), T3 – Basal feed + MOS (1.0 g per kg), T4 – Basal feed + MOS (1.5 g per kg), T5 – Basal feed + MOS (2.0 g per kg).

Table 5. Effect of supplementation of different levels of mannan oligosaccharides on nutrient digestibility of broilers in finisher period.

Parameter	Treatments					MSE (±)	P value
	T1	T2	T3	T4	T5		
Dry matter (%)	67.5	77.4	69.5	67.9	67.6	2.3	0.078
Crude fat (%)	78.5	88.1	85.7	85.4	81.1	2.4	0.224
Crude fibre (%)	57.8[b]	69.0[ab]	62.8[ab]	70.6[a]	64.2[ab]	1.9	0.025
Crude protein (%)	56.2[b]	70.3[a]	57.7[b]	56.3[b]	63.7[ab]	1.7	0.002
Ash (%)	51.3[b]	87.3[a]	57.2[b]	64.9[ab]	52.4[b]	3.3	0.011

a, b, c, d: Means having different letters within the same row are significantly different (p<0.05).

MSE: Standard error of the mean.

Treatments: T1 - Basal feed with no supplement (Control), T2 – Basal feed +MOS (0.5 g per kg), T3 – Basal feed + MOS (1.0 g per kg), T4 – Basal feed + MOS (1.5 g per kg), T5 – Basal feed + MOS (2.0 g per kg).

In the finisher period (Table 5), the digestibility of the crude protein and ash was significantly improved (p<0.05) by the 0.5 g per kg MOS supplementation. Further, crude fiber digestibility was significantly (p<0.05) improved in birds fed with T4 compared to the control. However, digestibility of dry matter and crude fat was not significantly (p<0.05) affected by supplementing MOS during the finisher period. Based on the results, an age-dependent response can be observed by supplementing different levels of MOS. Crude protein digestibility improvement in the finisher period in MOS-supplemented birds could be a reason for the maturation of the digestive tract, as well as the amount of the digestive enzyme secretin over time. A similar study conducted by Silva et al. (2018) supported the above results. The lower effect of the crude protein digestibility on MOS is more consistent with the age-dependent response on MOS in broiler birds in the starting stage, when the digestive tract is developing (Mohammadi et al. 2019). These age-dependent variations in MOS efficacy of nutrient digestibility could be the reason for the lower digestibility of dry matter and crude fat and improved digestibility of crude protein crude fiber and ash, in the finisher period.

3.4. Cost-Benefit Analysis

The effect of different treatments on the total cost-benefit is shown in Table 6.

Table 6: Effect of supplementation of different levels of mannan oligosaccharides on cost, income and net profit.

Parameter	Treatments					MSE (±)	P value
	T1	T2	T3	T4	T5		
Total cost per bird (LKR)	733	737	765	754	745	2	0.395
Income per bird (LKR)	1,368^{c}	1,660^{b}	1,397^{c}	1,959^{a}	1,473^{bc}	46	0.000
Net profit per bird (LKR)	616^{b}	822^{ab}	632^{b}	1157^{a}	677^{b}	5	0.002

a, b, c: Means having different letters within the same row are significantly different (p<0.05). MSE: Standard error of the mean.

Treatments: T1 - Basal feed with no supplement (Control), T2 – Basal feed +MOS (0.5 g per kg), T3 – Basal feed + MOS (1.0 g per kg), T4 – Basal feed + MOS (1.5 g per kg), T5 – Basal feed + MOS (2.0 g per kg).

According to Table 6, there was no significant difference (p>0.05) in total cost per bird (LKR) by supplementing birds with different levels of MOS. The income and profit per bird varied significantly (p<0.05) among the different treatment diets, as shown in Table 6. Significantly (p<0.05) highest income and profit were reported in the birds fed with T4 compared to other treatments. Moreover, as shown in Table 2, higher carcass weight and dressing percentage in the T4 group compared to other treatments could result in the observed higher net profit values in the 1.5 g kg^{-1} MOS supplemented group.

4. Conclusions

This study concludes that the supplementation of MOS positively impacts broiler performance by enhancing body weight, body weight gain, nutrient digestibility, and carcass quality. The most significant body weight improvements can be observed when broilers are fed with higher levels of MOS (1.5 and 2.0 g of MOS per kg of feed) during the starter period. Further, birds fed 1.5 g MOS per kg achieved the numerically highest carcass weights. However, MOS supplementation appears to have a negligible effect on feed intake and FCR in broilers. In meat quality parameters, significantly improved WHC was observed with MOS supplementation at a level of 1.0 and 1.5 g of MOS per kg of feed. In addition, the digestibility of dry matter, crude fat and ash increases by the supplementation of 1.5 g of MOS per kg of feed in the starter period, while crude fibre digestibility increases in both starter and finisher periods. Economic analysis reveals that while there is no difference in the total cost of production per bird, the income and net profit per bird are higher when birds are supplemented with 1.5 g of MOS per kg of feed, suggesting that MOS supplementation can provide a cost-effective way to enhance broiler production efficiency.

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