Neem–Okra Aqueous Extracts as Natural Alternatives to Antibiotics in Broiler Production

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Abstract

Background: The poultry industry is focusing on natural alternatives to antibiotics to maintain growth and health performance. Neem (Azadirachta indica) and okra (Abelmoschus esculentus) are considered promising plant-based supplements with potential benefits in broiler production. **Objective:** This study evaluated the effects of aqueous extracts of neem leaves and okra pods, individually and in combination, on growth performance, carcass traits, feed conversion ratio (FCR), and survivability in antibiotic-free broiler production. **Methods:** A total of 240 Cobb 500-day-old mixed-sex chicks were randomly assigned to four groups (four replicates of 15 chicks each). T1 served as the control (no supplementation); T2 received 3 mL/L neem leaf extract; T3 received 5 mL/L okra pod extract; and T4 received a combination (1.5 mL/L neem + 2.5 mL/L okra). Extracts were administered via drinking water for 35 days. **Results:** Birds in T4 showed significantly higher body weights across all growth stages (7–35 days) compared with other groups ($P < 0.05$). Final body weight gain was greatest in T4 (2068.28 ± 92.48 g), followed by T3 (1891.09 ± 75.14 g), T2 (1860.78 ± 104.36 g), and lowest in T1 (1834.34 ± 21.01 g) ($P < 0.01$). Although FCR was numerically best in T4, treatment differences were not statistically significant. Dressing percentage was highest in T4 (74.97% ± 1.01) and lowest in T1 (67.68% ± 1.00), with all supplemented groups significantly outperforming control ($P < 0.05$). Survivability improved in all supplemented groups (98% ± 2.01) compared with the control (87% ± 1.51; $P < 0.01$). **Conclusion:** Supplementing drinking water with neem and okra aqueous extracts, particularly in combination, significantly enhanced growth, carcass yield, and survivability in broilers without antibiotic use. This herbal-based strategy shows strong potential to support sustainable antibiotic-free broiler production.

Keywords: Broiler, Supplement, Production Performance, Survivability, Antibiotics, Herbal Extracts

Significance | This study highlights neem and okra extract as effective natural growth promoters enhancing broiler performance, carcass yield, and survivability sustainably.

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1. Introduction

Bangladesh is a highly populated country, and the growth of the population is increasing day by day. The demand for the protein of this massive population is a great challenge to us. More than half of the people are dependent on agricultural-based livestock farming for their livelihood in Bangladesh (Rahman et al., 2015). Currently, the poultry industry is a highly promising and emerging sector in Bangladesh, and consumers are searching for antibiotic-free, safe foods (Islam et al., 2024). Broilers bring a return within a very short time to the farmer, and their meat is popular to all, and there is no religious restriction to consuming broiler meat (Rahman et al., 2015). Although commercial poultry farming is a profitable business, it is facing different constraints. Among them, infectious

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and non-infectious diseases are due to poor biosecurity and husbandry practices. Over several decades, some antibiotics have been used in broiler feed not only for controlling, preventing, and treating diseases but also to boost performance and feed efficacy in the host gut (Tollefson and Miller, 2000; Gaskins *et al*., 2002). In Bangladesh, commercial poultry farmers extensively utilize antibiotics without any veterinary advice, even without observing the consecutive withdrawal period (Haque *et al*., 2020). In many developing countries, including Bangladesh, antibiotics can be sold and distributed without a prescription. This practice often leads to incomplete treatment courses, inappropriate drug selection, and incorrect dosing (Haque *et al*., 2020). Informal prescribers (IPs) act as intermediaries between the sale and administration of antibiotics in both poultry and livestock sectors. However, most of them sell or prescribe antibiotics without consulting a veterinarian (Sani *et al*., 2023). Low education, complexity, or beyond appropriate veterinary facilities, and high-level income motive prompt the local producers to apply antimicrobial agents illegally (Saiful *et al*., 2016). Unfortunately, it is observed that many pharmaceutical companies are convincing farmers to use antibiotics as a growth promoter to get more return within a short period. The antibiotic residues enter the human body and may cause serious human health hazards with drug residues after the consumption of antibiotic-fed broiler meat (Kibria *et al.,* 2009). Throughout the world, the use of antibiotics as dietary growth promoters in poultry diets differs dramatically. Concern has arisen that the use of antibiotics as therapeutics and for growth promotion could lead to a problem of increasing resistance in bacteria of human and animal origin, particularly regarding resistance in gram-negative bacteria (Salmonella *spp*. and *E. coli*) and *Enterococci*. These zoonotic enteropathogens in food animals are of special concern to human health because these bacteria are likely to transfer from the food chain to humans (Rahman *et al.* 2015 and Hamid *et al.* 2017). Therefore, it should ensure that antibiotic residues in meat do not impair human health. Especially, it has been recommended that the use of penicillins, tetracyclines, tylosin, and sulfonamides as growth promoters be discontinued (Hamid *et al.* 2017). As a result, recently, there has been increasing public and government pressure in several countries to search for natural alternatives to antibiotics (McCartney, 2002). Consequently, there is considerable research interest in the possible use of natural products, such as essential oils and extracts of edible and medicinal plants, herbs, and spices, for the development of new additives in animal feeding (Rahman *et al.,* 2015). There are several compounds and products in nature that have the potential to stimulate growth by virtue of being antibacterial and antifungal. Most of the plant parts, such as fruits, seeds, leaves, bark, and roots, contain compounds with proven antiseptic, antiviral, antipyretic, anti-inflammatory, antiulcer, and antifungal uses. In this connection, neem (*Azadirachta indica*) contains several active ingredients like nimbidin, sodium nimbolide, gedunin, azadirachtin, mahmoodin, gallic acid, epicatechin and catechin, margalone, margolonone and isomargolonone, cyclic trisulphides, polysaccharides GIa, GIIa, GIIIa, GIb, NB-II peptidoglycan, which all contribute to its beneficial medicinal properties (Biswas *et al.,* 2002). Neem leaves and their constituents have been demonstrated to exhibit immunomodulatory, anti-inflammatory, antihyperglycemic, antiulcer, antimalarial, antifungal, antiviral, antioxidant, antimutagenic, and anticarcinogenic properties (Subapriya and Nagini 2005). When neem, as an herbal drug, is incorporated in a feed mixture, it promotes growth and improves feed efficiency and live body weight due to its antibacterial and hepatoprotective properties. It has a vast range of medicinal properties, including promoting the growth and feed efficiency of birds because of its antibacterial and hepatoprotective properties. Furthermore, neem showed immune modulator actions that induce cellular immune reactions (Devakumar and Sukkt, 1993).

Okra (*Abelmoschus esculentus)* is a member of the family Malvaceae, which contains potassium, vitamin B, vitamin C, folic acid, calcium, and fiber. Research on the cultivation and utilization of okra has mainly focused on several aspects, including its cultivation as a vegetable, as a medicine and for health care, as a beverage, and in gardening. The vegetable it produces contains many nutritious ingredients:100 g of dry, tender okra pods includes 2.11 g of deoxidized sugar, 1.06 g of cellulose, 2.44 g of CP, 0.682 g of carotene, 26.5 mg of vitamin C, 1.25 mg of vitamin A, 10.2 mg of vitamin B, and many minerals, having slightly more than common vegetables and fruits (Liu *et al.* 2007). The okra stem and leaf contain 17.47% CP, 13.48% crude ash, 10.9% crude fiber, 7.08% crude fat, and 51.07% nitrogen-free extract (Liu *et al.* 2007). Despite having medicinal properties, there are no research findings available on commercial broiler performance using okra pods. Therefore, considering the advantages of both neem and okra, the present study was undertaken to determine the effect of aqueous extracts of neem leaves and okra pods as a growth promoter on the production performances of antibiotic-free broiler production.

2. Materials and Methods

2.1 Design and layout of the experiment

The experiment was conducted to know the effect of aqueous extract of neem (*Azadirachta indica*) leaves and okra (*Abelmoschus esculentus*) pods as a growth promoter on the production performance of commercial broilers under farming conditions, and to produce antibiotic-free broiler meat. The performance was monitored from day 7 to 35 days of age of the birds. Chicks were randomly divided into 4 groups with 4 replicates with 15 birds in each replicate, where T_1 was considered as the control without any herbal materials, T_2 was treated with neem leaves extract (3 ml/L),

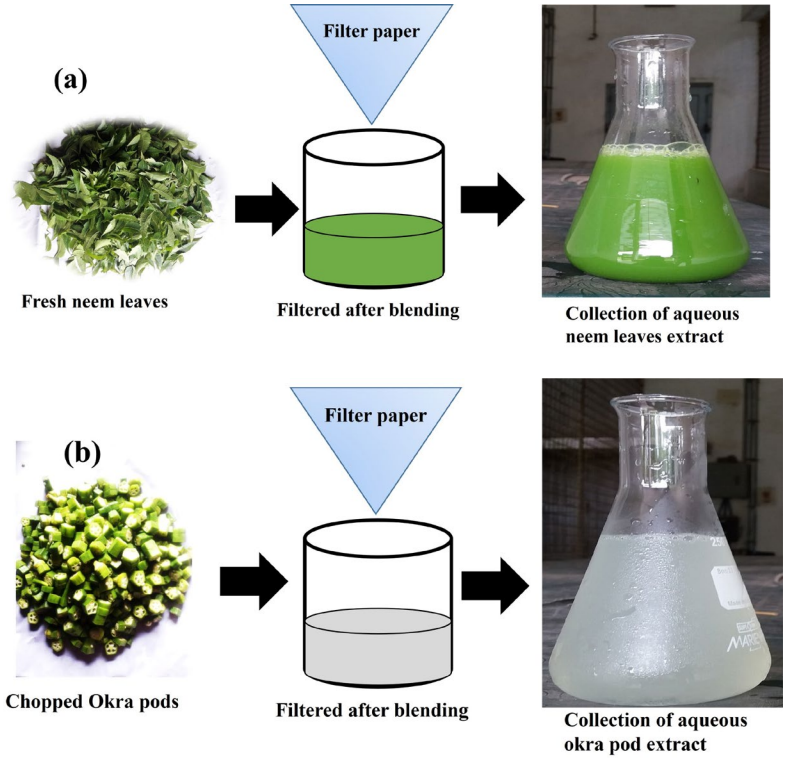


Figure 1. Preparation of aqueous extracts from neem leaves and okra pods. Preparation and collection of aqueous neem leaf (a) and okra pod (b) extract. (a) Fresh neem (*Azadirachta indica*) leaves were washed, blended, and filtered to obtain a clear aqueous extract. (b) Fresh okra (*Abelmoschus esculentus*) pods were sliced, soaked in distilled water for 24 hours, and filtered to produce a mucilaginous extract. Both extracts were stored at 4°C for use in the experiment.

T_3 was treated with okra pods extract (5ml/L) and T_4 was treated with combined extract of neem leaves and okra pods (1.5ml/L and 2.5ml/L, respectively) following the Completely Randomized Design (CRD) experimental design.

2.2 Preparation of aqueous neem and okra leaf extract

Neem leaves and okra pods were selected for effectiveness as growth promoters to utilize their antimicrobial activity on commercial broilers. Fresh and green neem leaves and okra pods were collected from the University campus. The leaves and pods were washed with tap and distilled water. Then the neem leaves were blended by Miyako Blender BL 51 with distilled water @ 250g/L. The obtained aqueous extract was filtered with Whatman filter paper (Grade 4). Then the filtered aqueous extract was collected and preserved at 4°C in the refrigerator for further use (**Figure. 1a**). Furthermore, the washed fresh and green okra pods (3 kg) were cut into slices and immersed in 6L of distilled water for 24 h. After 24 h, it formed a mucilaginous solution with distilled water. The solution was filtered with Whatman filter paper (Grade 4). Finally, the okra pods extract was collected in a conical flask (**Figure 1b)** and preserved at 4°C temperature in the refrigerator for further use in experimental purposes.

2.3 Management procedure

The brooder house was ready for the chicks before they were put in the house. First, the brooder house was scrubbed and cleaned at least one week before the chicks arrived in the brooder house. At first, the old litter present in the brooder house was removed, and all the required equipment was disinfected with a disinfectant solution. The house was allowed to dry out thoroughly after being properly cleaned the house and equipment. The brooder was switched on at least 24 hours before the chicks arrived. For the first few days, a simple paper or newspaper was spread on litter materials along with sprinkled feed. This was helpful to avoid the chicks eating the litter materials. After 3 days, the paper was removed, and feeders and waterers were evenly distributed around the brooder. The electric brooder was adjusted for 24 hours before the arrival of chicks, and the temperature was adjusted to 95°F (35°C) at the edge of the brooder 2 inches (5cm) above the litter during the first week. The temperature was decreased by 5°F (2.8°C) each week until it reached 70°F. The broiler chicks were fed pellets *ad libitum* from day old to 35 days of age. The broiler chicks were given different diets (pellets) according to their age, prepared in the feed mill of CP. Feed Ltd. The pre-starter and starter feed were in crumble, and grower/finisher feed was in pellet form. Normal pure drinking water was supplied *ad libitum* to the experimental birds to fulfill

Table 1. Effect of neem leaf and okra pod aqueous extract on feed intake (g), water intake (L), body weight, feed conversion ratio (FCR), and breast meat yield in broilers.

Variables	Treatments (mean ± SD)				p value
	T_1	T_2	T_3	T_4	
Feed intake (g)	3192.65±71.22	3289.175±46.04	3269.125±71.56	3295.25±31.25	p = 0.09331
Water intake (L)	6.09^{c} ± 0.09	5.82^{d}±0.03	6.60^{b} ± 0.25	6.89^{a}±0.08	ρ <0.0001
Body weight (g)	1968.45^{b} ± 86.38	1990.00^{b} ± 102.61	2021.25^{b} ± 74.99	2202.50^{a} ± 81.42	p = 0.01149
FCR	1.74±0.11	1.77±0.12	1.73±0.08	1.59±0.06	p = 0.08484
Breast meat yield (g)	468.75±31.19	543.75±57.93	542.50±48.39	550.00±45.64	p = 0.09214

Values are presented as mean ± standard deviation (SD) for each treatment group (T1–T4). Superscripts denote statistical differences ($P < 0.05$). T1 = control (no extract), T2 = neem extract (3 mL/L), T3 = okra extract (5 mL/L), T4 = combined neem (1.5 mL/L) + okra (2.5 mL/L). Birds receiving combined supplementation (T4) showed the highest body weight and water intake, indicating improved growth performance and feed efficiency under antibiotic-free conditions.

their requirements. Round hanging drinkers were used for the experimental broilers. Clean, cool, and fresh water were always provided to the experimental birds. The aqueous extract of neem leaves and okra pods was added to the supplied drinking water according to the design of the experiment. A typical broiler lighting program was followed, which consists of light intensity of at least 20 lx provided continuously from 1 to 7 days. After 7 days, a restriction in both intensity (3 to 5 lx) and duration (16 to 20 hours of light) was implemented according to Cobb Broiler Management Guide (2012). Twenty-three-hour photoperiod and one-hour darkness were provided in experimental birds, as it is advantageous over continuous lighting, as the former allows maximum growth while giving the birds some experience of darkness so that they are less apt to panic during electricity failure. Standard ventilation was checked carefully to ensure fresh air inside the house. Only three vaccines are required for broiler rearing. The experimental birds were vaccinated accordingly, using no antibiotics.

2.4 Data Collection

Body weight is an important parameter in this study. The body weights of individual birds were recorded at three-day intervals, and the cumulative body weight was determined at the end of the experiment. It is noteworthy that all the experimental birds were brooded together until 7 days of age and distributed to different treatment groups according to the design of the experiment. The average body weight gain was calculated by subtracting the initial body weight from the final body weight, where the body weight at 7 days was considered the initial body weight. Feed consumption of each replicate was recorded at weekly intervals, on a cumulative basis, and final feed consumption per bird was determined at the end of the experiment. The FCR was calculated as feed intake per unit body weight gain from 7 days to 35 days of age using the following formula:

$$\boldsymbol{FCR = \frac{Total\ amount\ of\ feed\ consumed}{Total\ live\ weight\ gain}}$$

At the end of the experimental period (35 days), four birds from each dietary group (two birds from each replicate) were slaughtered to calculate dressing yield. It is an important measured parameter during the study and is measured by the following formula:

$$\text{Dressing \%} = \frac{Carcass\ weight}{Live\ weight} \times 100$$

The survivability of birds from every individual treatment was recorded until the end of the experiment (35 days). It was calculated as

$$Survivability\ \% = \frac{Total\ survived\ bird}{Total\ birds\ housed} \times 100$$

2.5 Statistical Analysis

The data obtained from this study were subjected to statistical analysis between control and treated groups of broilers by the one-way analysis of variance (ANOVA) technique in a completely randomized design (CRD). All data were presented as means ± standard deviation (SD). Analysis of variance (ANOVA) was conducted to evaluate the recorded data using Kaleida Graph (Synergy Software, Reading, PA, USA), and statistical analysis was performed by Fisher's LSD comparison test, in which any difference was considered statistically significant when the p-value was smaller than 0.05. Test results are marked with * ($P < 0.05$) for significant and ** ($P < 0.001$) for highly significant differences or correlations.

3. Results

3.1 Feed Consumption

The results revealed that the highest average total feed intake (g) was obtained in T_2 (3289.175±46.04), and the lowest intake was

recorded for T_1 (3192.6±70.59). The differences in feed intake among the treatments were statistically nonsignificant ($P > 0.05$) (**Table 1**). The average feed intake was increased from the beginning to the end under all treatments because of the increased requirement of growing birds.

3.2 Water intake

It was revealed that the average total water consumption (L) under four treatments was significantly higher ($P<0.01$) in T_4 (6.89±0.08). On the other hand, comparatively the lowest water consumption was recorded for T_2 (5.82±0.03). The comparative statistical analysis revealed significant differences in the mean water consumption ($P<0.05$).

3.3 Body Weight

The results indicated that the average body weight of experimental birds at all stages of growth from 7 to 35 days of age was higher under T_4, followed by T_3 and T_2. The difference among the means under all the treatments was found to be statistically significant ($P<0.05$) at all stages of growth (**Table 1**). It was worth mentioning that under T_4 at days 27 and 31, comparatively lower body weight was noticed, which might be due to the dislike of birds to drink herbal extracts treated water.

3.4 Body Weight Gain

The body weight gain of the birds is an important parameter, especially for the broiler. The average final body weight gain at different stages of growth from 7 to 35 days of age is presented in **Figure 2.** The results indicated that the average body weight gain (g) of experimental birds at all stages of growth, from 7 to 35 days of age, was higher in T_4 (2068.28±92.48), followed by T_3 (1891.09±75.14) and T_2 (1860.78±104.36). On the other hand, the lowest average body weight gain was recorded in T_1. The difference among the means under all the treatments was found to be statistically highly significant ($P <0.01$) at all stages of growth. The lowest body weight gain was recorded in T_1 (1834.34±21.01), whereas the highest body weight gain was found in the T_4 group, where the birds were supplied the combined supplementation of neem leaves aqueous extracts with okra pods aqueous extracts. The result revealed that body weight gain under T_4 was significantly ($P <0.05$) different from T_1, T_2, and T_3 (Figure 2).

3.5 Feed Conversion Ratio (FCR)

The superior FCR exhibited by the birds under combined supplementation of neem leaves aqueous extracts with okra pods aqueous extracts (T_4), but the differences among the means were non-significant. Therefore, proven that birds on this combined supplementation level optimally utilize the feed consumed due to the sound gut health. Further, the results showed that birds were the most efficient feed converter in T_4, followed by T_3, T_1, and T_2 at all the stages of growth (**Table 1**). During the experimental period, the worst FCR was recorded in T_2 with neem leaves supplementation. The results indicated that all the supplementation of neem leaves aqueous extract along with okra pods aqueous extracts (T_4) through drinking water had a very prominent but non-significant effect on FCR of the experimental broilers.

3.6 Dressing Percentage

The effect of supplementation of neem leaf extracts, okra pod extracts, and their combination on dressing percentage is shown in **Figure 3**. The highest dressing percent (74.97%±1.01) was obtained under the birds treated with combined neem leaves extracts and okra pods extract supplementation through drinking water,

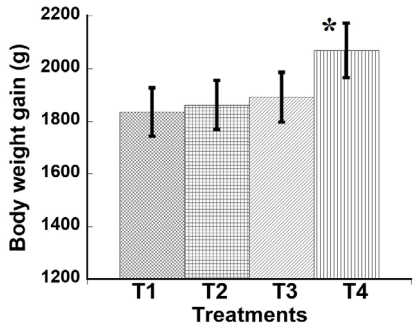


Figure 2. Variation in body weight gain of birds at 35 days under different treatments. Here, vertical bar indicated the error, * = significant at 05 % level (ρ <0.05) and n = 32.
Each bar represents the mean ± SD of body weight gain for 32 birds per treatment group. Birds receiving combined neem and okra supplementation (T4) achieved the greatest weight gain compared to all other groups ($P < 0.05$), highlighting the synergistic benefits of dual plant extract supplementation.

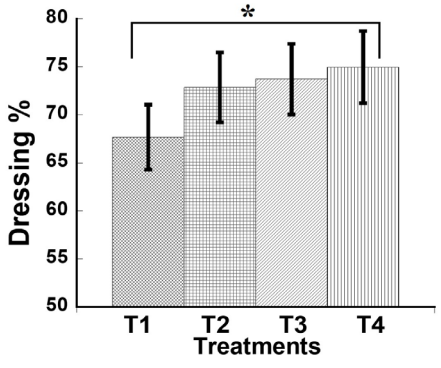


Figure 3. Dressing percentage of birds in various treatments.
Here, vertical bar indicated the error, * = significant at 05 % level (ρ <0.05) and n = 32.
Mean ± SD values (n = 32) are shown for each treatment group. Birds in the combined treatment (T4) exhibited significantly higher dressing percentage ($P < 0.05$) compared to the control, demonstrating improved carcass yield through herbal supplementation.

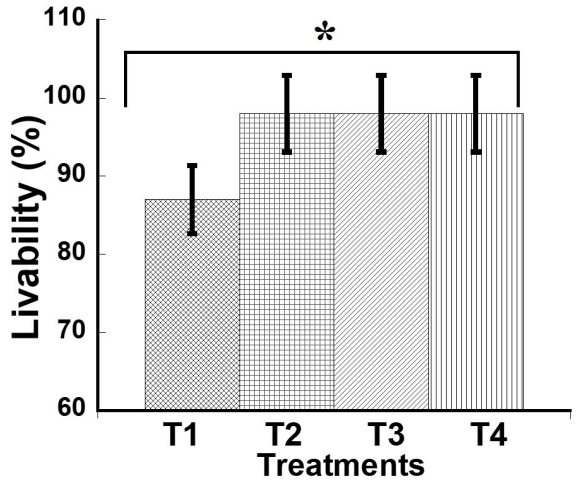


Figure 4. Survivability of birds until 35 days in various treatments. Here, vertical bar indicated the error, * = significant at 05 % level (ρ <0.05) and n = 32.
The figure illustrates the mean ± SD of survivability (%) over a 35-day period for each treatment group. Birds receiving neem, okra, or combined extracts (T2–T4) showed markedly higher survival (98%) compared to the control group (87%) (P < 0.01), confirming the protective effects of herbal supplementation on bird health and resistance to stress.

whereas the lowest dressing percent (67.68%±1.00) was recorded for birds in the control group. The statistical analysis revealed that neem leaf extracts and okra pod extract supplementation alone (T_2, T_3) and their combination (T_4) significantly ($p<0.05$) influenced the dressing yield, and there was an improved dressing percent among the supplemented broilers.

3.7 Breast Meat Yield

The effects of supplementation of neem leaf extracts, okra pod extracts, and their combination on breast meat yield (g) are presented in **Table 1**. The highest breast meat yield (550.00±45.64) was obtained under T_4, whereas the lowest breast meat yield (468.75±31.19) was recorded for birds under the T_1 (control) group. Although the highest breast meat yield was obtained under T_4 among the treatments but the differences in average breast meat yield were non-significant among the treatment groups (**Table 1**).

3.8 Survivability

The recorded livability of the experimental birds from day 7 to 35 days of age is presented in **Figure 4**. The results indicated that the percent survivability was lowest under T_1 (87%±1.51) whereas the highest survivability was noticed for T_2, T_3, and T_4 (98%±2.01). It was revealed from the statistical analysis that the mean differences in survivability between the three supplemental groups (T_2, T_3, and T_4) and control (T_1) were significant ($P<0.01$).

4. Discussion

Landy *et al.* (2011) found that there were no significant differences between treatments in feed intake when adding neem leaf powder to the broiler diet at the age of 42 days, whereas it is reported that increased feed efficiency occurs in neem-fed groups of poultry. Moreover, it is reported that neem leaves help to reduce the microbial load of birds and improve the feed consumption and feed efficiency of the birds (Kale *et al.* 2003). On the other hand, Durrani *et al.* (2008) observed a significant decrease in the amount of feed intake when adding a powder of neem leaves to drinking water. In the current study, inclusion of aqueous neem leaf extract and okra pod extract or their combination slightly increased feed intake in comparison to the control. It was assumed that the highest feed intake in T4 was due to the increased appetite of birds. It was reported from a previous study that inclusion of neem leaf extract had no significant effect on water intake (Zanu et al., 2011). Further, Durrani et al. (2008) observed a significant decrease in the amount of water intake when adding a powder of neem leaves to drinking water. In this study, water intake significantly differed among the treatments, and we assumed that it might be due to the taste differences. It may be concluded that the lowest water intake under the T_2 group might be due to the bitter taste of the neem leaves extract.

Ansari *et. al.* (2012) reported that daily weight gains in broilers fed a diet supplemented with neem leaf meal than antibiotics (positive control), where an increasing trend was found in body weight gain with better feed efficiency with increased levels of neem leaf meal infusion up to 2.5 g/ kg of diet. In this present study, significantly higher body weight was recorded in birds under T_4, where birds were supplied a combined supplementation of neem leaves and okra pods extracts (1.5 ml/L+1.5 ml/L). Further, the results of the present study are in agreement with the study of Manwar *et al.* (2007), who supplemented neem leaf powder @ 1-2 gm/kg feed and reported a significant increase in the live body weight of broilers

with an improvement of feed efficiency in the leaf powder-fed groups when compared with a control group. Similar findings have been reported by Tipu *et al.* (2002), who used salinomycine and *A. indica* fruit as a feed additive and anti-coccidial in broilers and reported better results in terms of weight gain. Mohamed *et al.* (2018) reported that supplementation of probiotics, garlic, and neem leaf in the ration caused a significant increase in body growth. However, in this study, the highest final body weight was recorded in birds under T_4, where birds were supplied a combined supplementation of neem leaves and okra pods extracts, and it was assumed that this prominent growth performance might be due to the synergistic effects of neem leaves and okra pods extracts.

The present finding was supported by Rahman *et al.* (2015), where the authors reported the maximum weight gain obtained under combined supplementation of neem leaf and ginger group (I3), where birds were treated with 3ml of combined herbal extract/liter drinking water for consecutive six weeks. Neem plays a role in free radical scavenging properties due to its rich source of antioxidants. It was reported that neem leaves contain ingredients such as nimbin, nimbanene, 6-desacetylnimbinene, nimbandiol, nimbolide, ascorbic acid, n-hexacosanol, and amino acid, 7-desacetyl-7benzoylazadiradione, 7-desacetyl-7-benzoylgedunin, 17-hydroxyazadiradione, and nimbiol (Ali 1993, Hossain *et al.* 2011, Kokate *et al.* 2010). Yerima *et al.* (2012) experimented to evaluate the antibacterial activity of the bark, leaf, seed, and fruit extracts of *Azadirachta indica* (neem) on bacteria isolated from adult mouth, and results revealed that bark and leaf extracts showed antibacterial activity against all the test bacteria used. It was noteworthy to mention that to the best of our knowledge, this is the first report of the utilization of aqueous okra pod extracts in antibiotic-free broiler meat production. It was assumed that the combined effects of neem leaves and okra pod extracts accelerated the body weight gain of the experimental birds.

This finding is supported by Rahman *et al.* (2015), where the authors reported that supplementation of neem leaf and ginger extracts in the treatment caused improvement in the feed efficiency as compared to that of the control group. Further, similar results were observed by Nemade *et al.* (1993), who reported an increase in feed efficiency in the neem leaf and ginger extracts fed groups. It is also reported that the highest body weight gains and best feed conversion ratio were achieved as compared to control when offered neem leaf and ginger extracts to broilers from 1 to 6 weeks (Chakravarty, 1991). Ansari *et al.* (2012) also reported that feed efficiency (weight gain/feed intake) was significantly influenced by the treatments used at both 28 and 42 days of age. At both ages, the feed efficiency improved significantly ($p<0.05$) in broilers fed a diet had 2.5 g/kg of leaf meal compared with those fed the diets of other levels of leaf meal and controls.

It is reported that aqueous neem extract has a potent herbal anti-bacterial effect against several microorganisms and enhances broiler performance due to containing many minerals that improve digestibility and body weights of broilers (Ahmed, 2018). Therefore, it is assumed that significantly higher body weight gains were recorded in the supplemented group of birds due to the anti-bacterial effect, progressive digestibility, and enhanced feed conversion efficiency of herbal extracts.

An earlier study reported significant ($p<0.05$) differences between the treatment groups of birds with respect to the relative weights of the different body parts, and concluded that the leaf meals had positive effects on the carcass weights of the finisher broiler birds (Essiet and Solomon, 2013).

However, a non-significant higher breast meat yield was recorded under the supplemental groups of birds in comparison to the non-supplemented control (T_1), is might be due to the health-beneficial effects of herbal extracts.

Haque *et al.* (2018) showed no significant difference in mortality among the treatment groups treated with neem leaf meal. Ansari *et al.* (2012) found no significant effect on mortality at any time during the study with the herbal extract. Zanu *et al.* (2011) also found no significant effect of neem decoctions on mortality. The mortality of the birds in the present study was in an acceptable range in herbal supplemental groups (T_2, T_3, and T_4), and it was noticed that almost 13% of birds died in T_1 (control), where birds were supplied neither antibiotics nor herbal extracts. Therefore, due to a lack of enough immunity, birds in the control group died frequently, whereas birds treated with neem leaf extracts alone or with the combination of okra pod extracts showed better survivability (2% mortality) without antibiotics.

According to Biswas *et al.* (2002), neem contains several active ingredients like nimbidin, sodium nimbolide, gedunin, azadirachtin, mahmoodin, gallic acid, epicatechin and catechin, margalone, margolonone and isomargolonone, cyclic trisulphides, polysaccharides GIa, GIIa, GIIIa, GIb, NB-II peptidoglycon, which all contribute to its beneficial medicinal properties. Further, Subapriya and Nagini (2005) stated that neem leaves and their constituents have been demonstrated to exhibit immunomodulatory, anti-inflammatory, antihyperglycemic, antiulcer, antimalarial, antifungal, antiviral, antioxidant, antimutagenic, anticarcinogenic properties.

Koul *et al.* (1990) reported that neem leaf and ginger extracts suppress pathogenic bacteria, including *Staphylococcus aureus*, *Salmonella paratyphi,* etc. The authors concluded that the higher body weight gain of broilers supplemented with neem leaf and ginger might be due to antimicrobial and anti-protozoal properties of neem leaf and ginger extracts, which helped to reduce the microbial load of birds, thus improving the feed consumption and feed efficiency of the birds (Kale *et al.* 2003). Due to the active

ingredients in these additives, the formation of more stable intestinal flora and improved feed conversion efficiency is a consequence of better digestion (Tekeli, 2011)

On the other hand, okra mucilage from the immature pods was found to be suitable for industrial and medicinal applications (Sa'eed Halilu Bawa and Neela Badrie 2016). Okra has been suggested to help manage blood sugar in cases of type 1, type 2, and gestational diabetes. Medical research on okra for diabetes management is still in the early stages. It is now known that, according to Tian *et al.* (2015) okra water improved the blood sugar levels of pregnant rats that had gestational diabetes. Roasted okra seeds, which have long been used in Turkey to treat diabetes. It has also been studied and proven that okra has a positive effect on lowering blood sugar (Thanakosai *et al.* 2013).

In this current study, neem leaves and okra pod aqueous extracts solely and in combination were supplemented to the experimental birds through drinking water. No antibiotics were used throughout the experimental period to produce antibiotic-free broilers. The obtained findings revealed that the overall performance of the experiment birds was enhanced in the herbal-supplemented groups in comparison to the control group (non-supplemented). Therefore, it may be concluded that an antibiotic-free broiler meat product is quite possible by using herbal extracts as an alternative to antibiotics.

5. Conclusion

The present study demonstrated that supplementation of neem (*Azadirachta indica*) leaf and okra (*Abelmoschus esculentus*) pod aqueous extracts, either alone or in combination, had a positive impact on the growth performance, feed efficiency, dressing yield, and survivability of broiler chickens reared without antibiotics. Birds receiving combined supplementation of neem and okra extracts (T_4) showed the highest final body weight, body weight gain, dressing percentage, and survivability compared to the control and individual supplement groups. Feed intake was not significantly affected, while water consumption was significantly higher in the combined supplementation group. The findings indicate that the synergistic effects of neem and okra extracts improved overall performance and health of the birds. Therefore, these herbal extracts can serve as effective natural growth promoters, making antibiotic-free broiler production feasible and sustainable while ensuring better bird health and productivity.

Author contributions

M.S.I. supervised the research and conceptualized the theme of the manuscript. M.L.T. conducted the research and performed most of the experiments in the manuscript. M.Z.I., P.K., M.M.H., and M.M.I. prepared the herbal extracts and the images of the manuscript. M.L.T. wrote the original manuscript. S.S.J. and M.S.I. edited and reviewed the manuscript. All authors reviewed, revised, and approved the final draft for publication.

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Competing financial interests

The authors have no conflict of interest.

Availability of data and materials

The datasets used in this manuscript are available from the corresponding author upon request.

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