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Original Article

Effects of Adding Different Levels of Hydroponic Barley Fodder on the Productive Performance and Economic Value of Broiler Chickens

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Abstract

The present study was conducted to disclose the impact of adding different levels of hydroponic barley fodder (HBF) on some productive features of the economic value of broilers chickens. One hundred forty-four one-day-old Ross 308 chicks were used in this study. Birds were randomly distributed into four treatments, with three replicates per each treatment (12 birds per replicate): The first treatment had no addition (T1:control). As for T2 and T3 treatments, 10% and 20% of HBF were added to the feed pellet. In T4, fresh HBF was chopped and fed as an additional free fodder. Results reflected an increase in the weekly live body weight (BW), body weight gain (BWG), feed intake (FI), and feed conversion ratio (FCR) of T2 birds; along with an improvement in the cumulative BWG, FI, and FCR of T2 and T4 during the 3rd to 5th weeks compared with the other treatments. Bacteriology and gut morphology demonstrated a decrease in total fungi, bacteria, and E. coli count with an increase in Lactobacillus count, in conjunction with an increase in the villus height and crypt depth of the jejunum of T2 birds. Economic value measures showed an increase in the production index and economic marker for broilers treated with T2 and T4. It can be concluded that there is an opportunity to include HBF by 10% or present it as freshly chopped HBF to ameliorate production performance, improve economic indicators and reduce broiler production costs by 9%.

Keywords: Hydroponic, Barley fodder, Broiler, Productive, Economic value

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1. Introduction

Poultry is considered the main source of animal protein, besides its high efficiency in converting non-human compounds into valuable foodstuff of high nutritional value. Due to high feed prices, broiler chicken production in Iraq (156.5 thousand tons annually) does not meet the local consumption needs (1). Thus, the country depends on importing large quantities of poultry products, which costs massive amounts of money. To cope with feedstuff limitations, hydroponic production is considered a promising feed. Hence its characterized by low production cost and high economic value (2). Due to its high nutritional value, barley is the most used seed in hydroponic fodder production (3). Hydroponic barley fodder (HBF) is utilized for supplying fresh and high-nutrient green forage at all times without the need for large areas of arable lands and reducing the quantities of irrigation water (4). Due to the exposure to moisture during the soaking and cultivating of HBF, enzyme activity increases inside the grain, which breaks down starch and protein into simple and easy for digestion and absorption. Also, in germination, protein and mineral content increased, vitamin B doubled 3-12 times, vitamin A doubled 3 times, and vitamin C created a high proportion (5).

In addition to reducing total production cost, it is well documented that green barley fodder has potential benefits for production (5) and reproduction performance in dairy cattle (6) and buffaloes (7), as well as enhancing productive parameters and beef quality (3). Researchers indicate that HBF extensively utilizes growth performance (8) and milk yield and composition (9) in sheep. Furthermore, HBF improves rabbits' productive and reproductive features (10). In poultry, using HBF reduced the cost of egg production by 62-64% compared with concentrate feed of laying hens (11); also, it contributes to enhancing growth parameters (12) and egg production (13) of quails. Feeding HBF up to 40% in ducklings improves productivity parameters, digestibility coefficients, and nutritive values (14). Furthermore, feeding 15-20% HBF increases productivity and meat performance and improves metabolism and broilers' vitamins (15).

Unlike ruminants, Jacob and Pescatore (16) published that growing poultry fed barley-based diets negatively influences the digestive tract, which reflects on productive performance. Those authors mentioned that the antagonistic impact of barley on digestion and absorption is due to the presence of non-starch polysaccharides (mainly β-glucans), which is the main reason for increasing intestine viscosity and altered gut morphology and microflora, besides reducing the availability of nutrients. Although β-glucans from yeast, fungi, and some cereals enhance avian, and many different animals' immune system, high-level inclusion of barley has adverse effects on poultry performance (17, 18).

Although numerous reports study the impacts of HBF on animal performance, the main limitation of the experimental results is that most of these studies focused on ruminants while neglecting the advantages of feeding HBF to poultry. In Iraq and the other arid and semi-arid ecosystem regions, water scarcity and availability of cultivable lands are the most important restrictions to the agricultural sector due to climatic changes. Even though the use of HBF in feeding animals is very limited in Iraq and has not reached commercial feeding, most animal breeders are not even aware of this technique. Despite all efforts, only a few scientific studies are carried out in Iraq regarding this subject (e.g. (19-23). Hence, this study investigated the impact of adding HBF to feed on the productive performance, microbial and morphological intestine, and economic value in broilers chickens.

2. Materials and Methods

2.1. Birds Management

This study was conducted at the Poultry Farm and laboratories of the College of Agriculture, Basrah University, from 26/12/2019 to 17/02/2020. The current study used one hundred forty-four one-day-old unsexed broiler chicks (Ross 308 strain) with an average initial weight of 41.5 g. Birds were randomly distributed into 4 treatments with 3 replications for each group (12 birds in each replication). The rearing house system is a wire floor (birds placed on a wire-net floor, 1 m above the concrete ground), supplied with automatic feeding, water, and ventilation equipment. Open cover metal cages (2×1.5× 0.6 meters used for 12 birds) were utilized for separating replications. All chicks were reared under conformable management and environmental conditions (temperature, ventilation, water, heating, lighting, nutrition, vaccination, and monitoring performance) in accordance with Aviagen (24) recommendations for Ross 308 broilers during the study period of 35 days.

2.2. Preparations of Hydroponic Fodder

Seeds were Iraqi barley (*Hordeum Vulgare* L.) obtained from the local market of Basrah city, Iraq. For cultivation, a simple hydroponic system was designed in a 3×5×3 meters room, equipped with metal stands, shelves, and semi-automatic irrigation, lighting, cooling, and ventilation systems. Before use, seeds were subjected to a germination test (81.7%), while the preparation for cultivating HBF took one week before the feeding experiment. After cleaning grains from impurities, barley was sterilized by soaking for 30 min in a 20% sodium hypochlorite to control mold formation. Then, the seeds were washed and soaked in water for 12 h. Later, seeds were sown in 40×60 cm polystyrene planting trays containing holes to facilitate drainage. Grains were irrigated with a tap of water (without any nutrients) 4 times a day and 24 h lighting daily till the harvesting date on the 7th day. Temperature (24±2 ºC) and relative humidity (60-80%) were maintained at approximately constant ranges inside the hydroponic system. The chemical composition of HBF and the original barley seeds were determined according to the standard procedures of AOAC (25).

2.3. Treatments and Composition of Diets

The whole fresh HBF (root and grass) is cut into small pieces (1-2 cm) before addition to the birds' diets. The chopped barley fodder mixed well with the commercial broiler feed on two levels. A small poultry feed pellet machine was used to convert the mixture into broilers pellet feed. Birds were fed the basal diet formulated to meet the nutrient requirements of broiler chickens according to NRC (26) and allowed free access to water and feed. Four dietary treatments were used in this investigation; the control treatment (T1) fed the commercial pelleted diet. Birds in the second (T2) and third (T3) treatments were fed the commercial diet with 10% and 20% HBF, respectively. The two levels of HBF were added to the complete commercial diet and compressed within the pellet feed. In the fourth treatment (T4), birds were fed the commercial broiler diet with fresh chopped HBF, which was provided twice daily, separately from the concentrate feed. T4 birds had free access to the fresh barley fodder (placed outside) by small slots in the cage. Ingredients and chemical composition of diet used in the experiment for starter (1-21 days of age) containing 23.33% crude protein and 2873 metabolizable energy (kcal.kg^{-1}) and finisher (22-35 days of age) periods containing crude protein 20.24% and 3119 metabolizable energy (kcal.kg^{-1}) are shown in table 1.

Table 1. Ingredients and chemical composition of diets used in the experiment for starter (1-21 days) and finisher (22-35 days) periods

Ingredients	**Starter (1-21 days)**				**Finisher (22-35 days)**			
	T1 Control	**T2 10 % HBF[1]**	**T3 20 % HBF**	**T4 fresh HBF**	**T1 Control**	**T2 10 % HBF**	**T3 20 % HBF**	**T4 fresh HBF**
Yellow corn	45	40.5	36	45	51.5	46.35	41.2	51.5
Soybean meal	32	28.8	25.6	32	23	20.7	18.4	23
Wheat	15	13.5	12	15	15	13.5	12	15
Concentrate protein (44%)[2]	4	3.6	3.2	4	4	3.6	3.2	4
Premix (29%)	1	0.9	0.8	1	1	0.9	0.8	1
Calcium carbonate	2	1.8	1.6	2	2	1.8	1.6	2
Sodium chloride	0.5	0.45	0.4	0.5	0.5	0.45	0.4	0.5
Vegetable oil	0.5	0.45	0.4	0.5	3	2.7	2.4	3
Barley fodder	-	10	20	Free	-	10	20	Free
Chemical composition[3]								
Crude protein (%)	23	22.2	21.4	23	19.3	18.87	18.44	19.3
Metabolic energy (kcal/kg)	2940	3006	3072	2940	3170	3213	3256	3170

[1] HBF= Hydroponic barley fodder, the additional HBF was compressed within the pellet feed in levels of 10% and 20%, or fresh chopped HBF free of choice.[2] Protein concentrate used from Al-Hayat Company-Jordan, providing (per kg of diet): 44% protein, 2800 kcal/kg, ME, 12% fat, 25% ash, 5% calcium, 2.9% phosphorus, 2.55% methionine + Cysteine, 2.8% lysine. [3] Calculated according to the chemical composition of feedstuff by NRC (26)

2.4. Production Performance and Economic Value

Live body weight (BW; gram) was recorded weekly for each replicate using a digital-sensitive balance. Body weight gain (BWG; g) was calculated weekly based on the difference between every two weeks in BW. Feed was provided, and the feed residual was recorded weekly for each replicate, where the difference was used to calculate the feed intake (FI; g). Feed conversion ratio (FCR; g feed to g gain) was calculated weekly using data of weekly FI per BWG. Cumulative (1-5 weeks) BWG, FI, and FCR were calculated for the whole feeding period (35 days). Mortality was recorded daily for all replicates, where the activity ratio was calculated as:

Activity ratio = 100 - mortality ratio.

Productive index and economic marker calculated according to Martins, Carvalho (27) as follow:

Productive index= BW × activity ratio/ FCR × feeding period (35 days) × 10

Economic marker= Total BW for selling birds× 1000/ number of birds × rearing period (days) × FCR.

2.5. Morphology of Intestine

At the end of the experiment (day 35), two birds from each replicate were slaughtered and used for an intestinal morphological determination, as mentioned by Naderinejad, Zaefarian (28). In brief, a section from the jejunum was flushed with cold saline and put in 10% formalin solution, and after 72 h, moved to 70% ethanol for fixation. The samples were dehydrated through graded alcohol and isopropyl alcohol, impregnated with Histosec pastilles and embedded in wax, and cut using a rotary Microtome. Alcian blue and hematoxylin-eosin were used for staining the slides and examined by light microscopy. Two variables were measured: villus height (the distance from the top of the villus to the junction between the villus and crypt) and crypt depth (the distance from the junction to the bottom of the crypt). The villus: crypt ratio was calculated by dividing villus height by crypt depth.

2.6. Microbiology of Intestine

3M petrifilm™ plates were used for estimating total bacterial count (aerobic bacteria), total coliforms bacteria (*Escherichia coli*), lactic acid bacteria (*Lactobacilli*), and total fungi count in the jejunum. According to the method described by Blackburn and McCarthy (29), swab samples of jejunum contents were collected, and the tubes were transferred to the microbial population lab. After dilutions, samples were incubated using 3M Petrifilm plates. Then, 1 ml of dilution is prepared for the implanting and transferred by micro-pipette to the 3M Petrifilm slowly. The incubation of the plates was at 37°C for 24 h for bacteria and 48-72 h for fungi.

2.7. Statistical Analysis

The data were statistically analyzed with a one-way variance ANOVA according to CRD design using the SPSS program (30). Duncan's multiple range tests (31) were used to compare means wherever significant differences were at $P \leq 0.01$ and $P \leq 0.05$.

3. Results and Discussion

3.1. Chemical Composition of HBF and Barley Grains

Results in table 2 refer to the chemical composition of the original barley grains and the 7 days of germinated HBF. It is clear from the table that CP% and ash% (19.17% and 5.09%, respectively) were duplicated in HBF compared with the original barley grains (9.92% and 2.78%, respectively), while the main decline (in addition to DM%) presented in values of nitrogen-free extract (NFE) (80.66% in grains and 66.13 in HBF). These changes in HBF components may be due to the increases in nutrients, which reflect the loss of DM mainly in the form of carbohydrates (NFE) due to barley grains' respiration during sprouting (16). Furthermore, the sprouting of grains enhances modifying the level of enzyme activity in the seeds, increasing total protein, fat, vitamins, and minerals (5, 8). Also, Alshamiry (32) claimed an increase in CP%, EE%, and ash% (14.67, 3.86, and 4.11 %, respectively) of 8 days HBF compared with the original barley grain (11.73, 1.9, and 2.81 % respectively), with decreasing in OM% and ME% in HBF. Results in this study were nearly similar to other studies, which demonstrated that barley sprouted is higher in CP%, CF%, and ash% compared with barley grain (14, 33, 34).

Table 2. Nutrients composition of the original barley grains and the hydroponic barley fodder (HBF) at day 7 of germination

Feedstuff	DM%	Ash%	OM%	% DM basis			
				CP	CF	EE	NFE
Barley grains	89.12	2.78	97.22	9.92	4.45	2.19	80.66
HBF	12.64	5.09	94.91	19.17	6.26	3.35	66.13

HBF: hydroponic barley fodder; DM: dry matter; OM: organic matter; CP: crude protein; EE: ether extract; CF: crude fiber; NFE: nitrogen-free extract

3.2. Live Body Weight (BW)

The influence of adding different levels of HBF to the diet of broilers on the weekly average BW is shown in table 3. During the first two weeks of feeding, results did not show a significant effect of adding different levels of HBF on the live BW of broilers. Generally, birds fed with 10% and 20% HBF distinguished with the highest and lowest BW throughout the 3^{rd}-5^{th} weeks of feeding. In the last week of feeding HBF, significant differences appear among all treatments, where T2 is characterized by the highest BW (1922.40 g), and T3 reached the lowest value (1816.70 g). The increase in BW of T2 may be attributed to the fact that broilers obtained the optimum inclusion level of HBF, which contains many biologically active compounds that have an influential role in raising the nutritive value of the feed (35). The high nutritional value of HBF is related to the conversion of complex compounds, reducing antinutritional, and increasing minerals and vitamins in the seeds throughout sprouting (16). Also, during the germination of cereal grains, the amino acid profile alters, resulting in highly digestible feed (36). It seems that birds in T4 get utilized from consumption of the high nutrient value of the chopped HBF as an additional fresh feed to get higher body weight compared with T1 and T3 treatments. At the same time, increasing the proportion of HBF in the diet of T3 perhaps leads to a decline in nutrient availability by increasing the level of indigestible fibers (6), which in turn caused decreasing the BW. The results of this study are comparable to that of Talalay, Matserushka (15), who reported that adding hydroponic barley in an amount of 15-20% contributed to an increase in BW by improving carcass characteristics and blood profile in broilers. This increase in BW was 15-17% higher than the control at the 5^{th} week and rose to 18% at the 8^{th} week of feeding on HBF (37).

3.3. Body Weight Gain (BWG)

The impact of adding different levels of HBF on average BWG and cumulative BWG is summarized in table 4. Incorporating HBF into broilers' diets has positive effects on the weekly BWG starting from the 3^{rd} week. During the 3^{rd}, 4th, and 5^{th} weeks of feeding, T2 characteristics with higher BWG (434.84, 466.36, and 500.90 g, respectively) compared to other treatments, where no significant differences appear between T4, T1, and T3. This order pattern of findings in BWG is clearer in considering the cumulative BWG, as the highest cumulative body weight gain was for T2 (1880 g), followed by T4 (1819 g), and T1 (1793 g), while the lowest value was for T3 (1775 g). This improvement in weekly BWG and the cumulative BWG in treatment fed with 10% HBF may be indicated that those birds get used to the high nutritive value of HBF in its proper level of pellet diet to ameliorate production performance (14). Al-Kaisey, Mohammad (23) found that supplementing 60-100% of yellow corn with sprouted barley did not negatively affect the BWG of broilers at 35 days. Another reason for improving productive parameters in T2 and T4 is that supplementing sprouted grains reduces oxidative stress and improves immune responses in broiler chickens (38). Additionally, the high rate of BWG is associated with an improvement in the digestibility of nutrients of the ileal contents in broilers-fed diets based on high-moisture barley (39). Subsequently, replacing barley with 33% germinated barley increased body weight gain compared to those fed a normal or enzyme-barley diet at 7–42 days of broiler's age (33).

Table 3. Effect of adding different levels of hydroponic barley fodder (HBF) to the diet of broilers on the weekly average body weight (g) (mean ± standard error)

Dietary treatments	Age in weeks				
	1st week	2nd week	3rd week	4th week	5th week
T1	182.77±2.83	530.37±4.01	914.53±5.18[b]	1364.97±4.19[ab]	1835.17±6.02[c]
T2	173.9±3.73	520.3±4.39	955.14±4.92[a]	1421.50±5.25[a]	1922.40±4.62[a]
T3	176.13±2.47	515.1±6.02	912.73±3.97[b]	1338.73±5.51[b]	1816.70±4.57[d]
T4	177.2±4.93	523.97±5.12	926.07±4.77[b]	1380.37±4.56[ab]	1860.73±3.88[b]
P-value	0.409	0.247	0.001	0.000	0.000

T1: control; T2: 10% HBF; T3: 20% HBF and T4: free fresh HBF. [abcd] = Mean values with different superscripts within the same column differ significantly ($P \leq 0.05$)

Table 4. Effect of adding different levels of hydroponic barley fodder (HBF) to the diet of broilers on the weekly average body weight gain (g) and cumulate body weight gain (g) (mean ± standard error)

Dietary treatments	Age in weeks					Cumulative weight gain
	1st week	2nd week	3rd week	4th week	5th week	
T1	140.77±2.83	347.6±3.59	384.17±1.19[b]	450.43±9.36[ab]	470.20±1.21[b]	1793.167±6.02[d]
T2	131.9±3.73	346.4±6.92	434.84±7.85[a]	466.36±8.95[a]	500.90±0.70[a]	1880.40±4.62[a]
T3	134.13±2.47	338.97±7.64	397.63±5.99[b]	426.00±9.48[b]	477.97±1.03[b]	1774.70±4.57[c]
T4	135.2±4.93	346.77±8.64	402.10±5.85[b]	454.30±4.60[ab]	480.37±5.23[b]	1818.73±3.88[b]
P-value	0.409	0.803	0.012	0.049	0.028	0.000

T1: control; T2: 10% HBF; T3: 20% HBF and T4: free fresh HBF. [ab] = Mean values with different superscripts within the same column differ significantly ($P \leq 0.05$)

3.4. Feed Intake (FI)

The effect of adding different levels of HBF to the diet on the average weekly FI (g) and cumulative FI (g) of broilers are presented in table 5. During the first two weeks, no significant differences appear between the treatments. While, the results revealed that throughout the 3rd-5th weeks of feeding, there was a significant decrease ($P \leq 0.05$) in the average weekly FI of T3 (652.50, 793.17, and 1119.04 g, respectively) and T2 birds (618.16, 754.69 and 1015.05 g respectively) compared to the other treatments, and T4 was registered with the lowest FI (603.92, 751.33 and 995.37 g respectively). Generally, the significant effect of adding different levels of HBF in BW (Tab. 3) and FI (Tab. 5) was more pronounced in the 5th week of the experiment, which reflects the development of the gut ability for digestion and absorption (10). The data on the cumulative feed consequently showed highly significant differences between the treatments, as the highest cumulative FI was for T3 birds (3103 g), followed by T1 (3019 g) and T2 (2908 g), while T4 birds recorded the lowest cumulative FI (2865 g). It seems that the high palatability of HBF let birds of T3 treatment consume a high amount of the fresh chopped fodder (which is given as a free additional choice), which in turn, led to a decline in feed intake of concentrate feed compared to other treatments. In this scientific context, T2 birds may be utilized from the high nutritive value of HBF to reach their feeding requirements and get efficient eating by decreasing feed intake to the same level as T3 birds.

On the contrary, the high percentage of indigestible and unabsorbable substances in the diets of T4 may lead birds to consume an extra amount of feed to compensate for the imbalance in the composition of their diets (22). Studies indicated that the inclusion of 50 g hydroponic maize fodder reduced the mean cumulative feed intake from 3624 to 3321 g in broilers (40). In contrast, an investigation by Dastar, Sabet Moghaddam (33) has suggested that replacing barley grain with 33%-66% germinated barley increased feed intake in broiler chickens. Whereas (41) did not find a significant effect for adding 10 and 20 g/ bird green fodder on the feed consumption in slow-growing chicken.

3.5. Feed Conversion Ratio (FCR)

Table 6 displays the effect of adding different levels of HBF to the diet of broilers on the weekly FCR and the cumulative FCR. Average weekly FCR showed significant differences as affected by adding different levels of HBF starting from the 3rd week of broiler feeding. During the 3rd, then 4th, and the 5th weeks of feeding, T2 (1.422, 1.618, and 2.026 g/g, respectively) and T4 (1.504, 1.655, and 2.072 g/g, respectively) birds showed a significant improvement in FCR compared to birds of T1 (1.657, 1.726 and 2.284 g/g respectively) and T3 (1.643, 1.863 and 2.341 g/g respectively). The improvement confirmed these results in the average accumulative FCR in T2 and T4 birds (1.446 and 1.470 g feed/ g gain, respectively) compared to birds of T1 and T3 treatments (1.564 and 1.620 g feed/ g gain, respectively). The improvement in FCR of T2 and T4 demonstrates the appropriate conditions for these birds to express their high capability in digestion and absorption and then their efficiency in converting the limited amount of feed into an increase in weight (14). Moreover, during seed germination, aflatoxin and some anti-neutral factors disappear from the sprouted seedling, whereas the presence of these toxic substances in the cereals consisting of the feed has an accumulative adverse influence on broilers' immunity and health which is reflected afterward in the animal performance (42). The relationship between the improvement of immunity and productive parameters reflects more metabolic activity, which is highly attributed to the enhancement of blood measurements (43). These results are in accordance with the findings of (40), who indicated that the inclusion of 25% hydroponic fodder reduced the cumulative FCR values from 1.74 to 1.60 g/g in the 6th week of feeding the broilers.

Table 5. Effect of adding different levels of hydroponic barley fodder (HBF) to the diet of broilers on the weekly average feed intake (g) and cumulate feed intake (g) (mean ± standard error)

Dietary treatments	Age in weeks					Cumulative feed intake
	1st week	2nd week	3rd week	4th week	5th week	
T1	146.66±2.43^{a}	385.86±3.93^{a}	636.78±5.14^{ab}	776.58±5.49	1073.34±8.67^{b}	3019.23±25.65^{a}
T2	139.94±1.08^{b}	380.61±2.28^{ab}	618.16±4.76^{bc}	754.69±29.03	1015.05±14.48^{c}	2908.46±37.75^{b}
T3	147.25±1.91^{a}	391.28±3.63^{a}	652.50±6.72^{a}	793.17±13.63	1119.04±6.81^{a}	3103.23±21.58^{a}
T4	140.14±1.27^{b}	373.83±2.92^{b}	603.92±8.00^{c}	751.33±9.97	995.37±14.04^{c}	2864.61±22.67^{b}
P-value	0.028	0.027	0.003	0.330	0.000	0.001

T1: control; T2: 10% HBF; T3: 20% HBF and T4: free fresh HBF. ^{abc} = Mean values with different superscripts within the same column differ significantly ($P \leq 0.05$)

Table 6. Effect of adding different levels of hydroponic barley fodder (HBF) to the diet of broilers on the weekly average feed conversion ratio (g feed/g gain) and cumulative feed conversion ratio (g feed/g gain) (mean ± standard error)

Dietary treatments	Age in weeks					Cumulative feed conversion ratio
	1st week	2nd week	3rd week	4th week	5th week	
T1	1.042±0.004	1.110±0.017	1.657±0.010^{a}	1.726±0.043^{ab}	2.284±0.041^{a}	1.564±0.010^{b}
T2	1.063±0.038	1.100±0.027	1.422±0.018^{b}	1.618±0.050^{c}	2.026±0.031^{b}	1.446±0.020^{c}
T3	1.098±0.006	1.156±0.032	1.643±0.053^{a}	1.863±0.044^{a}	2.341±0.016^{a}	1.620±0.009^{a}
T4	1.040±0.045	1.079±0.032	1.504±0.051^{b}	1.655±0.039^{b}	2.072±0.022^{b}	1.470±0.016^{c}
P-value	0.521	0.322	0.006	0.019	0.000	0.000

T1: control; T2: 10% HBF; T3: 20% HBF and T4: free fresh HBF. ^{abc} = Mean values with different superscripts within the same column differ significantly ($P \leq 0.05$)

3.6. Microbial Population and Morphology of the Jejunum

Table 7 represents the effect of adding different levels of HBF on the microbial population and morphology of the jejunum. At 35 day-olds, broilers showed a significant decrease in total fungi count, total bacterial count, and *Escherichia coli* bacteria in birds fed 10% HBF, in conjunction with increasing of beneficial bacteria (*Lactobacillus*) as compared with the presence in the jejunum of other treatment birds. These results are along with Shaheed (44) findings, which observed a decrease in the number of harmful *E. coli* bacteria and an increase in the number of beneficial aerobic bacteria in the jejunum of broilers fed 10 and 20% germinated date kernel powder. The destructive effect of intestinal fungi products (mycotoxins) could impair the immunity system and induce inflammation, concomitantly, more energy appropriate for maintenance and recovery from disease. This could lead to reduced feed consumption and utilization of nutrients and a decline in production performance in broilers (45).

Morphology of the intestine showed a significant increase in the villus height and crypt depth of jejunum in T2 birds compared to other treatments, whereas the control group had the lowest values of these traits (Table 7). On the other hand, we noticed that the villus: crypt ratio is not significantly different. These results concur with other studies which have shown a morphological modification in the intestine morphometry as affected by the inclusion of different diets in growing broilers (16) and quail (46). Yamauchi (47) suggests that the nutritional value of diets produced a microscopic alteration in intestinal morphology, which differ relative to feed intake, body weight, and rapid growth rate. Such an explanation could illustrate the answer to the following question: Why do birds feed on the appropriate amount of HBF to improve production characteristics and develop morphological and bacteriological parameters? Morphology of the gastrointestinal tract is directly associated with the existence of the detrimental microflora, as many bacteria and fungi strain distinguished to have a destruction alteration on villus height and crypt depth and their ratio in the jejunum, duodenum, and ileum of poultry (17).

Based on the results shown in the current approach, the improvement in productive performance perhaps not only be caused by the high nutritional value of HBF. However, it appears that the harmful microorganisms are reduced by HBF by increasing the beneficial bacteria, which is visible in the enlargement of villus height and crypt depth in broilers' intestines. This enhancement in morphological traits develops the ability of absorption and nutrient utilization in the intestine. Furthermore, improving the beneficial microbial count impairs the antagonistic toxic and pathogens microbial, leading to more energy orientation for growth and improving productive traits (45).

3.7. Economic Value

Mortality ratio, production index, and economic marker as affected by adding different levels of HBF are depicted in table 8. Mortality was recorded as 0.08, 0.00, 0.08, and 0.03 for T1, T2, T3, and T4, respectively. In agreement with Perera, Abdollahi (48), the mortality observed in the recent study was negligible (only 7 out of the 144 birds died), and the death was not linked to any experimental treatments. Birds in T2 treatment showed the highest ($P \leq 0.001$) production index (380.01), followed by T4 (361.62) and T1 (334.99), where T3 resulted in the lowest (320.09) production index. Also, the economic marker of broilers showed the same results context of the production index.

Meanwhile, the statistical analysis of economic value ordered T2 (379.31) in the first order of the study treatments, followed by T4 (361.06) and T1 (334.65), whereas T3 got the lowest economic marker (319.77). In T2 and T4 treatments, the low mortality rate and the improvement in the economic value indicators may contribute to the barley cultivars enhancing blood parameters which help in better immunity performance (49). This study's economic value results are compatible with the findings of Ali, Miah (50), who stated that feeding HBF up to 15% causes a reduction in feed cost and total production cost in turkey poults.

Table 7. Effect of adding different levels of hydroponic barley fodder (HBF) to the diet on the microbial population, villus height, crypt depth and villus to crypt ratio of the jejunum of 35-day-old broilers (mean ± standard error)

Traits	Dietary treatments				*P*-value
	T1	T2	T3	T4	
Total fungi count (×10^3)	5.23±0.064^a	4.424±0.086^b	4.989±0.168^a	4.517±0.109^b	0.003
Total bacterial count (×10^3)	5.416±0.078^a	4.629±0.133^c	5.083±0.155^{ab}	4.775±0.064^{bc}	0.005
Lactic acid bacteria (×10^3)	4.359±0.099^b	4.863±0.082^a	4.665±0.088^a	4.819±0.092^a	0.017
Escherichia coli (×10^3)	4.326±0.124^a	3.615±0.063^c	3.954±0.032^b	3.908±0.115^b	0.004
Villus height (µm)	573.24±8.34^c	656.41±7.12^a	592.59±6.48^{bc}	607.23±8.92^b	0.000
Crypt depth (µm)	76.03±3.17^b	97.33±7.47^a	86.53±3.58^{ab}	91.57±2.53^{ab}	0.047
Villus : crypt ratio	7.56±0.21	6.84±0.61	6.87±0.21	6.64±0.09	0.314

T1: control; T2: 10% HBF; T3: 20% HBF and T4: free fresh HBF. ^{abc} = Mean values with different superscripts within the same column differ significantly ($P \leq 0.05$)

Table 8. Effects of adding different levels of hydroponic barley fodder (HBF) to the diet of broilers on the mortality ratio, production index and economic marker at day 35 (mean ± standard error)

Traits	Dietary treatments				*P*-value
	T1	T2	T3	T4	
Mortality (%)	0.08±0.05	0.00±0.00	0.08±0.00	0.03±0.03	0.161
Production index	334.99±2.39^c	380.01±5.21^a	320.09±1.77^d	361.62±4.13^b	0.000
Economic marker	334.65±2.22^c	379.31±5.20^a	319.77±1.77^d	361.06±4.15^b	0.000

T1: control; T2: 10% HBF; T3: 20% HBF and T4: free fresh HBF. ^{abcd} = Mean values with different superscripts within the same row differ significantly ($P \leq 0.05$)

Cultivating barley grains to produce HBF was easy, simple, and inexpensive and required little equipment or devices. By the end of the 7 days of germination only with water, the HBF looks like a 19-22 cm mat in height. The results of this study indicate that each 1 kg of barley grain produced 8.7 kg of HBF (including the sprouted grains embedded in their white roots and green shoots). After calculating the costs according to Iraqi market prices, it becomes clear that the cost of producing 1 ton of HBF is about 100,000 Iraqi Dinars (about 68.5 US$). Thus, the price of the broilers diet with 10% HBF will decline from 1000 to 910 ID. In other words, using HBF by 10% in broiler diets has led to a 9% reduction in broiler production costs. Atturi, Chakravarthy (40) stated that the inclusion of 25% hydroponic maize fodder reduced feed cost by 0.139 $ per broiler chicken. Researchers found that the optimal inclusion of HBF for the best performance was 23% of dry matter intake, which reduced 63% of the broiler's production cost (34). In geese, the optimum dosage of hydroponic green herbage was 25-30% of the diet, which reduced the cost of feeding by 30% (5).

Regardless first two weeks, it can be concluded that adding 10% HBF along with presenting it as a fresh hydroponic chopped barely led to improves productive performance, microbial population and morphology of intestine, and the economic value indicators with a reduction of the broilers production costs by 9% during feeding up to 5 weeks. Moreover, using locally barley seeds and low-cost equipment has the potential to develop the technical and economic sustaining of this technique in competition to find effective and cheap alternative poultry feed.

Authors' Contribution

Study concept and design: A. J. J. A.
Acquisition of data: A. J. J. A.
Analysis and interpretation of data: A. J. J. A.
Drafting of the manuscript: A. J. J. A.
Critical revision of the manuscript for important intellectual content: A. J. J. A.

Statistical analysis: A. J. J. A.
Administrative, technical, and material support: A. J. J. A.

Ethics

This study was approved by the Ethics Committee of the University of Basrah, Basrah, Iraq.

Conflict of Interest

The authors declare that they have no conflict of interest.

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