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Effects of Dietary Supergel on Growth Performance, Immunity Response, Gut Morphology, and Gene Expression of Turkey Chicks

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Abstract

In order to evaluate the effect of feeding Supergel on the biological traits of turkey chicks, 200 Bronze turkey chicks (mixed sex) were used. This study was done by completely randomized design with five treatments, five replicates, and eight chicks per replicate for five weeks. The experimental treatments were as follows: early access to feed and water, deprived of feed and water for 48 hours, feeding Supergel formula-1 for 48 hours, feeding Supergel formula-2 for 48 hours, and feeding Supergel formula-3 for 48. The results showed that the chicks fasted for 48 hours had lower body weight gain than other groups ($P < 0.05$). Chicks fed formula 1 of the functional Supergel had a better feed conversion ratio than control and fasted groups ($P < 0.05$). Mortality of the fasted group was higher than other groups ($P < 0.05$). The feed cost per 1 kg gain was lower in turkey chicks fed with Supergel formula-1 than in control and fasted groups ($P < 0.001$). The production efficiency index was lower in chicks deprived of feed and water ($P < 0.001$). The gene expression of IGF-1 in the jejunum was the lowest in the fasted group on d 35 ($P < 0.05$). Early feeding with Supergel decreased the HSP70 gene expression. In general, the results of the present study showed that feeding functional Supergel immediately after the hatch of turkey chicks positively affected the performance, feed cost, jejunum morphology, and decreased HSP70 gene expression in turkey chicks.

Introduction

Chicken and turkey meat are in the first and second place of meat production worldwide (Eratalar and Turkoglu, 2017). The mortality rate of turkey chicks at the first week of age can be up to 6 % (Ross, 2016). Opening the carcass of dead turkey chicks revealed no feed in the digestive tract. So, it is well known that early feed access is critical for turkey chicks to have healthy digestive tracts, good immune systems, and low mortality (Eratalar and Turkoglu, 2017). There are several strategies, such as raising more birds and improving the bird's livability and performance, to increase the production efficiency of turkey farms (Eratalar and Bulut, 2007). On the other hand, turkey chicks hatch a round 36 to 48 hours (hatching window) in hatcheries. The starvation is added to the transition time between the hatchery and the farm which cause lower growth with short to long-term effects (Gawel *et al*., 2022). The residual yolk at hatch accounts for 10-12% of the turkey chicks' body weight, and delayed feeding of the chicks can lead to dehydration (Lamot *et al*., 2014), metabolic disorders (Turner *et al*., 1999), lower performance, higher mortality. Early access to feed and water helps to ensure welfare issues and increases body weight and breast meat yield, which forms new nuclei from muscle progenitor satellite cells (Velleman *et al*., 2014). It was reported that 48 hours - hatch is the most important time for developing muscle size at slaughter age. Delayed access to feed causes a reduction in the miotic activity of satellite cells and decreases muscle development (Mozdziak *et al*., 2002; Halevy *et al*., 2003). Thus, feeding newly hatched turkey chicks as soon as possible is crucial in theturkey-rearing industry. Supergel is a hydrated feed that can be fed to chicks in the hatchery cartons. It contains both nutrients and water at the same time. Considering newly hatched chicks' supplement in the hatchery is a good strategy, especially when the distance from hatchery to the farm is long (Mikesell, 2017). Some approaches like solid feed, semisolid feed

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or liquid nutrients are considered to improve birds' early performance and livability. Previous researchers have found that early access to feed supplements containing 70% water, 10% protein, 20% carbohydrate, and less than 1% fat increased nutrient digestibility compared to starved chicks (Noy and Sklan, 1999; Batal and Parsons, 2002). Hesabi Nameghi *et al*. (2022) reported that feeding a nutritious gel improved yolk sac absorption, body weight gain and feed intake during the starter period of broiler chicks. Also, the broilers fed with nutritious gel had higher antibody titer against the bronchitis virus. A meta-analysis study showed that birds can reach their desired weight by compensatory growth despite delayed feeding, however this compensation is not complete and it depends on the duration of fasting time (De Jong *et al*., 2017). Turkey Supergel is a new nutrient-enriched powder that should mix with water to produce a jell to prevent early mortality and improve the bird's performance. Thus, this study aimed to assess the effects of early access to dietary Supergel on growth performance, carcass characteristics, immunity response, gut morphology, and gene expression of turkey chicks.

Materials and Methods

Birds and diets

A total of 200 Bronze turkey chicks (mixed sex) were used in a completely randomized design with five treatments, five replicates, and eight chicks per replicate for 35 days. The experimental treatments were as follows: early access to feed and water (control), deprived of feed and water for 48 hours (deprived-FW), feeding Supergel formula 1 for 48 hours (Supergel -F1), feeding Supergel formula 2 for 48 hours (Supergel -F2), and feeding Supergel formula 3 for 48 (Supergel-F3). Supergel formula 1 contained natural ingredients such as corn, soy peptide, *Spirulina* algae, thyme and garlic extracts, and it was formulated regarding turkey chicks̀ requirement. Supergel formula-2 had 10 percent higher amounts of thyme and garlic extracts than Supergel formula-1, while it was 20 percent for Supergel formula-3. Supergel contained 93.15% DM, 35.51 % crude protein, 3.69 % crude fat, 48.79 % nitrogen-free extract, 0.11% crude fiber, 5.05 % ash, 3528 kcal/kg gross energy, 0.05 ppm Cd, 0.04 ppm As, 0.22 ppm Pb, and less than 0.003 ppm Hg. The Supergel powder was mixed well with water in a 1 to 3 ratio before feeding to the birds. The birds were fed a diet formulated according to Leeson and Summers tables (2009). Birds in all groups except control were deprived of feed for the first two days of age, and after that, all birds had *ad-libitum* access to feed.

Growth Performance

Growth performance traits, including body weight gain, feed intake, and adjusted feed conversion ratio, were recorded weekly for each experimental unit. Production efficiency factor (PEF) was calculated according to the following formula: [live ability (%) × live weight (kg)]/[age (d) × FCR] × 100 according to Zaghari *et al*. (2020).

Carcass Characteristics

At 35 days of age, after 8 hours of feed withdrawal to discharge the digestive tract, two birds (one male and one female with an average mean near to the experimental unit) each replicate were selected, weighted, and slaughtered. After separating skin and feathers, the percentage of carcass, breast, back, and feet (hock joint to toe) were calculated as its ratio to live body weight.

Intestinal Morphology

The jejunum samples were separated from the intestine immediately after slaughter on 35 d of age. Jejunum was considered the segment from the bile duct entrance to Meckel's diverticulum. The samples were separated from the midpoint of each section and immersed in a phosphate-buffered formalin solution. The villus height, villus width, crypt depth, villus height/crypt depth, and absorptive surface area of the samples were assessed according to Hajati *et al*. (2015).

Feed Economic Efficiency

The economic conversion ratio (ECR, $/kg live weight of turkey) was considered an index of feed economic efficiency. The ECR was calculated by multiplying the feed conversion ratio and feed cost (Bai *et al*., 2022).

Antibody Titer Against Sheep Red Blood Cell (SRBC) Injection

On d 21 and 28, 1 mL sheep red blood cell (7:100, V/V in phosphate-buffered saline) was injected into the pectoral muscle of two turkeys in each experimental unit. The blood of the birds was collected on d 28 and 35. Blood samples were centrifuged, serum separated, and then total antibodies against SRBC, IgG (mercaptoethanol-resistant), and IgM (mercaptoethanol-sensitive) antibodies were measured according to Hajati *et al*. (2015).

Gene Expression of IGF-1, HSP70, INFγ

The gene expression of IGF-1, HSP70, INFγ was evaluated in the jejunum segment of the birds̀ intestine at 35 d of age. The internal control gene was glyceraldehyde 3-phosphate dehydrogenase (GAPDH). Real-Time PCR 7500 Fast System (Applied Biosystems, USA) was applied to amplify the genes in triplicate. To assess the gene relative expression, ΔΔCt model was applied according to Hajati *et al*. (2021).

Table 1. Ingredients and nutrient contents of the diet

Ingredients (%)	Feeding period		
	0-14 d	15-28 d	29-35 d
Corn grain	36.56	39.94	46.13
Soybean meal	48.14	43.78	40.41
Corn Gluten	5.00	5.00	1.5
Wheat	1.30	2.00	2.00
Herbal oil	2.85	3.51	4.58
Dicalcium phosphate	3.26	2.5	2.00
Oyster shell	1.32	1.63	1.72
Common Salt	0.32	0.32	0.32
Sodium bicarbonate	0.14	0.14	0.14
supplement[1]	0.50	0.50	0.50
D-L-Methionine	0.24	0.2	0.2
L-Lysine HCl	0.23	0.3	0.32
L-Threonine	0.13	0.15	0.15
Phytase Enzyme	0.01	0.01	0.01
Coccidiostat	-	0.02	0.02
Nutrients (Calculated %)			
ME_n (kcal/kg)	2800	2900	3000
Crude protein	27.5	26.0	23.0
Calcium	1.4	1.3	1.2
Available phosphorus	0.75	0.60	0.50
Na	0.18	0.17	0.17
Lysine	1.66	1.60	1.50
Methionine	0.60	0.55	0.50
Threonine	0.98	0.95	0.85
Nutrients (Analyzed %)			
Crude protein	27.62	26.14	23.24
Crude fat	5.4	5.8	7.1

[1]Vitamin premix (minimum levels per kg of premix); Vitamin A: 3800000 IU; Cholecalciferol: 1080000 IU; Vitamin E:16000 IU; Vitamin k3: 800 mg; Biotin: 100 mg; Folacin: 400 mg; Niacin: 32000 mg; Pantothenic acid: 6800 mg; Riboflavin: 2400 mg; Thiamine: 1200 mg. Choline (as choline chloride).Mineral premix (minimum levels per kg of premix); 400 mg, Copper (as cupric sulfate 5H2O): 4000 mg; Iodine (as calcium iodide): 180 mg; Iron (as ferrous sulfate $4H_2O$): 44000 mg; Manganese (as manganese sulfate): 32000 mg; Selenium (as sodium selenate): 120 mg, Zinc (as zinc chloride): 32000 mg.

Table 2. The sequences of forward and reverse primers of IGF-1, HSP70, INFγ

Primer name	Sequence (5-3)	length	Tm	Amplicon (bp)
HSP70-F	CGTCAGTGCTGTGGACAAGAGTA	23	60	145
HSP70-R	CCTATCTCTGTTGGCTTCATCCT	23	60.1	
INF-F	TCTCATTTCTCTCTGTCCAGTTC	23	60	183
INF-R	ACTTGTTTGTTCTGTCTGTCATC	23	60	
IGF1-F	GAGACAGAGGCTTCTACTTCAGTA	24	59.4	100
IGF1-R	CAACTCTGGAAGCAGCATTCA	21	59	
GAPDH-F	CTTTGGCATTGTGGAGGGTC	20	59	128
GAPDH-R	ACGCTGGGATGATGTTCTGG	20	60	

Statistical Analysis

The first step for data analysis was normalizing using arcsine for percentages of data. A completely randomized design was considered, and data was evaluated by the GLM procedure of SAS software (version 9.3, 2011). The means were compared by the Ducan test ($P < 0.05$).

Results and Discussion

Growth performance

The results of growth performance are shown in Table 3. During the first and second weeks of rearing, the chicks fed with the functional Supergel had numerically better body weight gain and feed conversion ratio than those who did not access feed and water. The body weight gain was lower in turkey chicks deprived of water and feed compared to the control group ($P < 0.1$). During the third week of rearing, the birds fed with Supergel-F1 had a lower feed conversion ratio than the control group ($P < 0.05$). During the fourth week of rearing, the birds fed with different formulas of Supergel had lower feed intake ($P < 0.05$). During the fifth week of rearing, the birds fed with varying formulas of Supergel had a lower feed conversion ratio compared to the control group numerically. During the whole rearing period (1-35 d), the body weight gain of the turkeys deprived of water and feed was lower compared to other groups ($P < 0.05$). The birds fed with Supergel formula-1 had a lower feed conversion ratio than the control group and the group deprived of feed and water ($P < 0.05$). The 1-35 d mortality of the group with no access to feed and water during the first 48 h was 5 percent, with a significant difference among the other groups ($P < 0.05$).

Table 3. The effect of feeding Supergel on native turkey poults feed intake, body weight gain and feed conversion ratio

	treatments						
	Control*	Deprive-F	Supergel-F1	Supergel-F2	Supergel-F3	*SEM*	P-value
1-7 d							
FI (g)	79.42	73.87	75.32	78.22	78.34	2.896	0.6346
BWG (g)	54.80	44.90	50.02	50.77	49.50	2.145	0.0597
FCR	1.45	1.64	1.51	1.54	1.59	0.075	0.4425
Mortality (%)	0.00	2.5	0.00	0.00	0.00	0.011	0.4307
8-14 d							
FI (g)	157.35	173.37	156.22	161.4	156.9	2.744	0.0955
BWG (g)	87.1	86.1	88.3	92.4	88.3	2.568	0.5019
FCR	1.81^{b}	2.01^{a}	1.77^{b}	1.74^{b}	1.78^{b}	0.064	0.0512
Mortality (%)	0.00	2.5	0.00	0.00	0.00	0.011	0.4307
15-21 d							
FI (g)	230.9	241.7	227.1	236.6	228.2	6.233	0.4504
BWG (g)	106.74	109.60	119.92	120.18	114.90	4.679	0.1759
FCR	2.16^{a}	2.20^{a}	1.89^{b}	1.97^{ab}	1.99^{ab}	0.084	0.039
Mortality (%)	0.00	0.00	0.00	0.00	0.00	-	-
22-28 d							
FI (g)	383.4^{a}	346.6^{b}	353.4^{b}	355.6^{b}	356.6^{b}	6.042	0.0038
BWG (g)	179.45	168.42	181.1	169.89	175.77	5.26	0.9459
FCR	2.13	2.12	1.95	2.09	2.02	0.153	0.9258
Mortality (%)	0.00	0.00	0.00	0.00	0.00	-	-
29-35 d							
FI (g)	419.8	393.2	414.5	409.1	416.4	8.991	
BWG (g)	176.25	158.98	179.6	174.4	171.95	8.05	
FCR	2.50	2.57	2.30	2.38	2.45	0.220	
Mortality (%)	0.00	0.00	0.00	0.00	0.00	-	-
1-35 d							
FI (g)	1271.04	1228.89	1226.72	1241.07	1236.62	15.107	0.2723
BWG (g)	604.37^{a}	567.12^{b}	618.95^{a}	607.62^{a}	600.45^{a}	7.857	0.0022
FCR	2.10^{ab}	2.16^{a}	1.98^{c}	2.04^{bc}	2.06^{bc}	0.027	0.0019
Mortality (%)	0.00^{b}	5.00^{a}	0.00^{b}	0.00^{b}	0.00^{b}	0.013	0.0423

Means within the same row with uncommon superscript differ significantly ($P < 0.05$).* Access to feed and water immediately after arrival at the rearing house. FI: feed intake; BWG: body weight gain; FCR: feed conversion ratio.

Carcass Characteristics

Results regarding the feeding of Supergel on the carcass traits of turkey chicks are shown in Table 4. Feeding different formulas of Supergel had no significant effect on the relative weight of carcass, breast, drumstick + thigh, back+ neck, feet (hock joint to toe), bursa Fabricius, and spleen percentages of turkeys at 35 d of age.

Table 4. The effect of feeding Supergel on carcass trait (% live body weight) on 35 d of age

	treatments						
	Control	Deprive-F	Supergel-F1	Supergel-F2	Supergel-F3	*SEM*	P-value
Edible carcass	68.5	67.68	69.06	68.70	68.01	2.485	0.9830
Breast	16.79	16.55	17.03	16.84	16.70	0.982	0.9919
Drumstick + thigh	16.86	16.70	17.16	16.92	16.83	1.011	0.9942
back+ neck	24.71	24.31	24.75	24.94	24.52	1.224	0.9886
feet	5.29	5.36	5.19	5.11	5.15	0.334	0.9395
bursa Fabricius	0.136	0.122	0.130	0.124	0.133	0.0100	0.6035
spleen	0.105	0.089	0.093	0.091	0.099	0.007	0.2700

Means within the same row with uncommon superscript differ significantly ($P < 0.05$).
*Carcass without head, skin, feather, and viscera. **Relative to live weight.

Intestinal Morphology

Results showed that deprivation of feed and water for 48 hours (deprived-FW treatment) decreased the length of the jejunal villi of turkeys at 35 d ($P < 0.0001$, Table 5). The crypt depth was higher in the control group compared to other groups ($P < 0.0001$). The ratio of jejunal villus height to crypt depth was higher in turkey poults fed with different Supergel formulas than in the control group ($P < 0.01$). The absorptive surface area of the jejunal villi was higher in turkey poults fed with varying formulas of Supergel ($P < 0.001$). The absorptive surface area of the jejunal villi of the turkey poults fed with Supergel formula 1 was higher than the control group ($P < 0.001$).

Table 5. The effect of feeding Supergel on intestinal morphology of turkey poults on 28 and 35 d of age

	treatments						
	Control	Deprive-F	Supergel-F1	Supergel-F2	Supergel-F3	*SEM*	P-value
Jejunum morphology (µ)							
Villus height (µ)	734.20^{a}	619.02^{b}	751.36^{a}	767.28^{a}	769.08^{a}	67.03	<0.0001
Villus width (µ)	117.20	123.48	133.82	121.62	136.26	15.19	0.0811
Crypt depth (µ)	127.46^{a}	99.42^{b}	109.44^{b}	109.36^{b}	110.26^{b}	11.43	<0.0001
Villus height/crypt depth	6.121^{b}	6.502^{ab}	7.280^{a}	7.299^{a}	7.236^{a}	0.944	0.0010
Absorptive surface area (μ^2)	273939^{bc}	241499^{c}	317448^{ab}	295792^{ab}	329102^{a}	47192.3	0.0003

Means within the same row with uncommon Superscripts differ significantly ($P < 0.05$).

Feed Economic Efficiency

The results of the effect of feeding supergel on feed cost per kilogram body weight gain and production efficiency index are shown in Table 6. The results showed that the feed cost per kg gain in turkey poults fed with Supergel formula-1 was lower than in the control group and the group deprived of feed and water ($P < 0.01$). Also, the production efficiency index of the birds deprived from feed and water was lower than other groups ($P < 0.001$).

Table 6. The effect of feeding Supergel on feed cost per gain and production efficiency index of turkeys during 1-35 d

	treatments					SEM	P-value
	Control*	Deprive-F	Supergel-F1	Supergel-F2	Supergel-F3		
FC/G**	0.726^{ab}	0.749^{a}	0.684^{c}	0.706^{bc}	0.712^{bc}	0.009	0.0021
PEI	88.90^{a}	77.23^{b}	96.34^{a}	91.65^{a}	89.99^{a}	2.410	0.0003

Means within the same row with uncommon superscript differ significantly (P < .05). * Access to feed and water immediately after arrival to rearing house; FC/G ($): feed cost per kilogram body weight gain; PEI: production efficiency index.

Antibody Titer Against SRBC Injection

Results of the effect of feeding Supergel on primary and secondary humoral immunity response in turkey poults are shown in Table 7. Regarding the results, feeding different formulas of Supergel during the first 48 hours of the turkey chicks' life did not affect the primary and secondary responses to SRBC intramuscular injection.

Table 7. The effect of feeding Supergel on primary and secondary responses to SRBC injection (Log_2) in turkey poults on 28 and 35 d of age

	treatments					*SEM*	P-value
	Control	Deprive-F	Supergel-F1	Supergel-F2	Supergel-F3		
Primary response (28 d of age)							
Total antibody	3.6	3.3	4.1	3.9	3.7	0.434	0.4299
IgY	1.3	1.1	1.3	1.5	1.5	0.365	0.7943
IgM	2.3	2.2	2.8	2.4	2.2	0.562	0.8138
Secondary response (35 d of age)							
Total antibody	4.9	4.5	5.3	5	5.1	0.543	0.6671
IgY	2.1	1.8	1.7	1.6	1.6	0.487	0.8341
IgM	2.8	2.7	3.6	3.4	3.5	0.466	0.1890

Gene Expression

The gene expression of IGF-1 was the lowest in the fasted group (P < 0.05, figure 1). The gene expression of IGF-1 was higher in birds fed with Supergel formula 3. Early feeding with Supergel decreased HSP70 gene expression (P < 0.05, figure 1). The highest HSP70 gene expression occurred in the fasted group. There was no significant difference in INF gamma gene expression among the birds (figure 1).

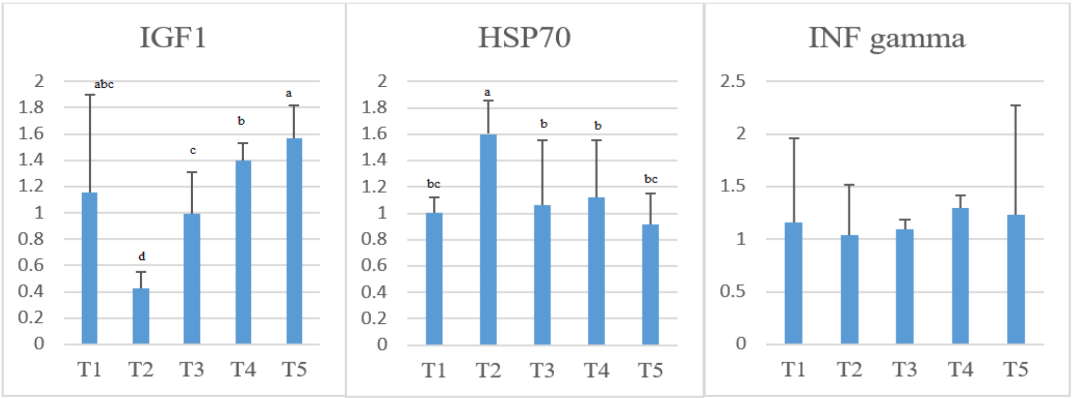

Figure 1. Gene Expression of IGF-1, HSP70, INFγ in the jejunum of turkeys; The experimental treatments were as follows: 1. early access to feed and water (control), 2. deprived of feed and water for 48 hours (deprived-FW), 3. feeding Supergel formula 1 for 48 hours (Supergel-F1), 4. feeding Supergel formula 2 for 48 hours (Supergel-F2), 5. feeding Supergel formula 3 for 48 (Supergel-F3).

Discussion

According to Panda *et al*. (2015), feed deprivation of newly hatched chicks can reduce growth and livability, weak effect of vaccination on promoting birds' health, inhibit the promoting of digestive and body defense, and increase the incidence of disease. It was reported that the mortality rate of turkey chicks during the first week of age is around 6 percent (Ross, 2016). The dead bird's gut has shown no feed in the digestive tract, leading to a situation named "Starve-Outs" (Roehrig and Torrey, 2019). In addition, a few numbers of the birds fall onto their backs or sides and cannot move themselves. This event is considered as "flips" (Roehrig and Torrey, 2019). In order to alleviate the disadvantages of delayed access to feed and water, there are different feeding strategies, which range from *in ovo* feeding to specially designed post-hatch diets (Uni and Ferket, 2004; Leeson, 2008). Recently, researchers reported that using hydrated gels which include different nutrients (amino acids, vitamins, minerals, etc) and additives (prebiotics, probiotics, phytobiotics, etc) is a good way to feed newly hatched chicks (Riva and Panisello, 2020).

In agreement with the present study, previous research has shown the positive effect of early nutrition on growth performance, gut morphology, microbiota, and immune system (Berrocoso *et al*., 2017; Hollemans *et al*., 2018). Early feeding of turkeys leads to higher body weight and breast meat yield at market age (Noy and Sklan, 1999). Velleman *et al*. (2014) reported that myoblast hyperplasia can cause higher meat yield, leading to nuclei formation in muscles. It should be considered that the time of nuclei formation and increasing muscle cells is limited to the first days of life (Batal and Parsons, 2002). Prabakar *et al*., (2016) found that muscle biomass enhances after passing this limited time because of higher cytoplasm. Feed consumption after hatching broiler chicks increases satellite cell multiplication thus leading to more growth of muscles (Halevy *et al*., 2000). Delays in providing water and feed for the birds can alter birds' metabolic process and increase the incidence of diseases due to immune system disorders which leads to higher production costs (Shira *et al*., 2005; Panda *et al*., 2015; Hesabi Nameghi *et al*., 2022). However, Selim *et al*. (2021) reported that early feeding of birds could not improve the growth of lymphoid and digestive organs at 14 d of age. This discrepancy can be due to the differences in feed composition, duration of usage, the amount of feed consumed, breed and strain of the birds. Previous researchers have found that 24-hour water and feed deprivation significantly decreased the duodenum's and jejunum's villus height (Biloni *et al*., 2013). At the present study, feeding Supergel increased villi height to crypt depth which can be due to early nutrient consumption of the chicks. Parallel to the present study, Hesabi Nameghi (2022) reported that using a super starter diet as gel improved the bird's growth performance, meat production, and immunity system. It was recognized that interferon-gamma is a natural cytokine that promotes the macrophage and T-helper 1 cells, leading to more powerful immune responses in birds (Hajati *et al*., 2021). In the present study, Supergel feeding had no significant effect on IFN-y gene expression which may be due to well condition of rearing and no challenge of the chicks with parasites. The expression of IGF-1 gene was lower in fasted turkeys, showing the positive effect of Supergel on IGF-1 gene expression and consequently better growth of the turkey poults. Also, Supergel feeding affected HSP70 gene expression, was affected by Super gel feeding which shows the positive effect of gel feeding due to its Spirulina algae content on lowering stress conditions which birds face during the transportation and rearing period. The *Spirulina platensis* microalgae contain selenium and it has been shown that *in ovo* injection of *Spirulina platensis* aquas extract decreased the HSP70 gene expression in the liver of quails or broilers (Hajati *et al*., 2021). Also, *Spirulina platensis* contains phenolic acids, C-phycocyanin, beta-carotene, tocopherol, and chlorophyll with strong antioxidant characteristics (Park *et al*., 2018). Using hydrated gel is an easy way that can be used in hatcheries to help the chicks tolerate long distances between hatcheries and rearing farms. This strategy can help the birds to have better performance as a carryover effect and improve their welfare issues.

Conclusion

In conclusion, feeding different formulas of Supergel immediately after the hatch of turkey chicks for 48 hours positively affected the performance, feed cost per one kg gain, jejunum morphology, and decreased HSP70 gene expression.

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Animal welfare statement

The authors confirm that the ethical policies of the journal have been considered and followed EU standards for the protection of the birds.

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