The effects of different choice feeding methods on laying hen performance, egg quality, and profitability

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ABSTRACT

This study was conducted to investigate the effects of using whole wheat in choice feeding on performance, egg quality, and income of laying hens. In the study, a total of 160-Hyline W-80 white commercial laying hens aged 28 weeks were divided into four treatment groups and fed for 84 days. The treatment groups were as follows: 1) Control (C, standard commercial laying hen feed), 2) C feed+choice feeding continuously with whole wheat in a separate cup (CW), 3) C feed+weekly intermittent choice feeding with whole wheat in a separate cup (WW), 4) C feed+choice feeding with continuous whole wheat+limestone together in a separate cup (WL). Choice feeding by using whole wheat methods (continuous, weekly intermittent, and with limestone) caused a significant decrease in the live weight change of laying hens (P<0.01), increased feed consumption, and feed conversion ratio compared to the control group (P<0.05). Total egg yield and egg weight were not affected by choice feeding with whole wheat methods (P>0.05). Choice feeding by using whole wheat caused a decrease in total eggshell weight, thickness, shell weight per unit area, and egg yolk color (P<0.01). However, it did not significantly affect the egg shell ratio, surface area, albumen height, and Haugh unit values of eggs (P>0.05). Also, total production costs, egg sales income, and net profit values were similar in all groups (P>0.05). In conclusion, the choice feeding by using whole wheat in laying hens did not affect the performance and economic parameters negatively; however, it caused reductions in some egg quality values.

Introduction

The egg poultry industry is an alternative branch of animal production in which an economical, non-substituted, and highly biologically valuable protein source is produced in a short period. The continuously increasing world population requires reducing the production costs (mainly feed) and increasing productivity for a profitable and sustainable production in the poultry industry due to its competitive structure. In recent years, natural disasters such as droughts, floods, hail, and tornados experienced as an effect of changing climatic conditions have adversely affected crop production, thus increasing livestock production costs. Considering the current conditions, scientists are making great efforts to prepare the lowest cost rations that can meet the changing nutritional needs of animals because the forecasted savings in feed cost have a tremendous economic impact on poultry enterprises. The increase in feed costs has brought about alternative feeding methods such as choice feeding in laying hens, as it is in all livestock sectors.

Nowadays, choice feeding studies in chickens have become increasingly important, particularly in the poultry industry, both for profitable production and for the public's concerns about animal welfare. Wheat is one of the most essential options for the whole grain feeding of hens. Since wheat can be produced directly on the farm, and feed processing, transportation, labor, and operating profits are not included in the costs, it creates a cheaper alternative feed source than a complete mixed feed (12). In addition, studies have shown that when feeding grains are used as a whole, the size of the gizzard increases (20, 26), and there is more digestive fluid secretion, which increases the acidity in the digestive system (11, 13), and pathogen microorganisms are eliminated in the acidic environment. The damage caused by pathogen microorganisms is prevented and an increase in performance and yield characteristics can be seen due to the savings in the nutrients they use (25).

Feed selection in poultry is done by combining the metabolic effects of these feeds with one or more previously learned sensory characteristics. In addition, factors such as the smell, taste, form, and color of the feeds are also determinative in the feed selection of poultry (9, 10). Studies were conducted to determine the ability of poultry to create the most suitable combinations among feed sources when allowed to choose free feed (19, 20, 25, 26). By recognizing the feed selection characteristics of poultry, choice feeding can be applied to specific environmental (such as temperature, humidity) or physiological features (sex, yield, age, etc.), a flexible, practical, and economical feeding technique that can meet the individual needs of chickens has been created. This provides poultry nutritionists several advantages in practice, including reducing commercial food consumption, utilizing crop over-production, minimizing available opportunities for feed, and reducing manure production (9). Saikhlai et al. (28) reported that the inclusion of wheat between 0 and 25% of laying hen diets might not affect performance and egg quality traits, digestibility of dry matter, organic matter, apparent metabolizable energy, and also economic compared to corn diets. However, due to the presence of xylene as an antinutritional factor in wheat (6), dirty egg amounts may increase in laying hens (34). As an alternative, sequential feeding with whole wheat may not negatively affect egg production and feed efficiency and can be used as an alternative to conventional feeding of laying hens (8). On the other hand, whole wheat has low calcium (Ca, 0.05%) concentration compared to laying hen diets (more than 3.25 % Ca) (23). When the hens are choice fed with wheat, their Ca intake will be decreased, so deterioration in the quality of the shell and weakening of the bones may occur. For this reason, when selective feeding with cereals, the poultry should reach Ca sources as grit feeding, which may support bone and egg shell quality (1).

Therefore, this study aimed to determine the effects of whole wheat (continuous and weekly intermittent) and limestone given to laying hens as choice feeding, on performance, egg internal and external quality characteristics, and their economic reflections on the production process.

Materials and Methods

Animals and experimental design: This experiment was carried out in the Erciyes University Poultry Experimental Unit (ERUTAM) and approved by the local ethical committee before the experiment (approval date and number: 03.06.2020 and 20/087).

In the study, a total of 160 Hyline W-80 white commercial laying hens, 28 weeks old, were used in enriched cages (90 x 60 x 50 cm) for 84 days, excluding the 14-day adaptation period before the experiment. The hens were divided into four experimental groups, each consisting of 40 chickens, and distributed to 10 cages as replicate and four chickens were placed in each cage. Before the experiment, hens were weighed individually, and egg production and egg weight were recorded for 14-day intervals and ranked according to their body weight and egg traits to minimize differences among the groups. Feed and water were given to all groups *ad-libitum*. The daily lighting was arranged for 16 h light (05:00 am to 9:00 pm). The composition of the basal ration used in the study is given in Table 1.

Table 1. The composition of the basal ration used in the study.

Feed raw materials	**Control**
Corn	515.83
Sunflower meal (%36 HP)	180.40
Soybean meal (% 46 HP)	98.00
DDGS[¥]	41.90
Meat-bone meal	34.22
Rendering oil	22.42
Molasses	20.00
Limestone	79.31
Salt	2.50
Lysine	0.69
Methionine	0.73
Phytase	1.00
Toxin binder	0.50
Sodium bicarbonate	0.50
Vit.-Min. mixture*	2.00
Total	1000
Analyzed nutrient content, %	
Dry matter	90.60
Crude protein	18.10
Raw oil	4.60
Ash	13.10
Raw cellulose	5.30
Calcium	3.20
Total phosphorus	0.53
Calculated nutrient content, %	
Methionine	0.40
Lysine	0.80
Sodium	0.21
Metabolizable energy, MJ/kg	11.21

[¥]Dried distiller grain solubles. [*]Vitamin-mineral premix per kilogram of the diet, Vitamin A, 12,000 IU; Vitamin D3 2000 IU; Vitamin E, 30.0 mg; Vitamin K, 5.0 mg; Vitamin B1 (thiamine), 3.0 mg; Vitamin B2 (riboflavin), 6.0 mg; Vitamin B6, 5.0 mg; Vitamin B12, 0.03 mg; Niacin, 30.0 mg; Biotin, 0.1 mg; Calcium D-pantothenate, 12 mg; Folic acid, 1.0 mg, Choline chloride, 400 mg, Manganese, 80.0 mg; Iron, 35.0 mg; Zinc, 50.0 mg; Copper, 5.0 mg; Iodine 2.0 mg; Cobalt, 0.4 mg; Selenium, 0.15 mg assures. 2 Dry matter, crude protein and calculate nutrient composition of diets calculated according to NRC (1994) nutrient values.

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Laying hens were fed in addition to the standard (basal) feed through the normal feeder of the chickens. Approximately 500 g of wheat was given in a separate metal cup (15 cm long x 12 cm high and 10 cm wide) continuously or with weekly changes (one-week basal feed, and one-week basal feed + wheat alternately). In another group, 100 g of granule limestone and 500 g of wheat in a separate metal cup, and basal feed, were added together with the metal cup *ad libitum*. The experimental groups were designed as follows: 1) Control (C, only commercial feed), 2) C feed + whole wheat with separate cups, 3) C feed + weekly interval whole wheat with separate cups, 4) C feed + whole wheat and limestone in the same feeder with separate cups.

Determination of performance traits: Body weights of hens were recorded at the beginning (initial) and end of the experiment. Body weight changes were calculated by considering the initial and final weights. Feed consumption was recorded every 14 days and divided by the number of hens (4) in a cage. Feed consumption was calculated by subtracting the weights of the remaining feeds from the feeds given based on subgroups. Average daily feed consumptions (FC) and feed conversion ratio (FCR) were determined for each 14 d (on day 14, 28, 42, 56, 70, and 84) however, data were given for each 28 d in three periods in the tables 2- 6). Egg mass and FCR were calculated according to the formula below;

Egg mass:egg yield (%) x egg weight (g)

FCR: feed consumption (g) in a period/egg mass (g)

There was no mortality throughout the experimental period.

Egg production was recorded daily at 15:00, and egg yield (% of egg production number/hen per cagex100) was calculated at 14-day intervals. Daily egg production was recorded and calculated at 28-day intervals for three periods.

Determination of egg quality characteristics: To determine the internal and external quality of eggs for three consecutive days at the end of each period (on days 14, 28, 42, 56, 70, and 84; however, data were given for each 28 d in the tables 2-6, eight eggs were randomly selected (80 eggs/group, a total of 320 eggs) from each subgroup. Egg weight, albumen height (Hmm), Roche yolk color fan, and Haugh unit (HU) values were determined by an automated egg analyzer (EggAnalyzer, Orka Food Technology, Israel).

The cracked egg shells were washed and dried for three days, then weighed with a precision balance (±0.1 g) to determine the shell weight (g). The shell ratio was determined by dividing the shell weight by the egg weight. The shell thickness was measured with a sharp digital gauge micrometer (±0.01 mm) from three points (sharp end, blunt end, and the equator) of the broken eggs; then, the shell thickness was determined by taking the arithmetic mean of these three measurements.

The egg shell surface area (ESA) was calculated according to the formula reported by Carter (3); Surface Area = 3.9782 × egg weight$^{0.7056}$. Per unit area, shell weight (USW, mg/cm^2) was calculated by dividing the absolute shell weight by the egg surface area.

Determination of protein and energy consumption for per kg egg production: Basal feed consumption is calculated every 14 days. The total protein and energy amount of the consumed feed were divided by the number of eggs mass-produced, and the protein and energy consumed per kg of egg was calculated.

Economic analysis: Economic analyses were made according to the following criteria;

- Egg sales income by weight (<62 gr = $ 0.069; ≥ 62 gr = $ 0.071) and
- Feed cost is in the total expenses; commercial chicken feed (0.37 $/kg), wheat (0.3 $/kg) limestone (0.037 $/kg) chicken cost ($ 2.2) and 15% (30) other expenses (labour, electricity, water etc.) are taken into account.

Total expenses (costs) are subtracted from total income in the net profit calculation. In economic analysis, it was accepted as 1 $ = 13.5 TL (converted in 2021).

Statistical analysis: The conformity of the data to the normal distribution and the homogeneity of the variances were checked using the Shapiro-Wilk and Levene tests, respectively. The significance of the difference between the beginning (initial) and final body weights within the group was evaluated with the Paired Sample T-test. The significance of the difference between the groups for all other performance traits, egg quality characteristics, protein and energy consumption for per kg egg production and economic characteristics was tested with One Way ANOVA. The statistical significance level was determined as P<0.05.

Results

The BW of hens at the beginning and at the end of the study, BW change, FC, and FCR values are given in Tables 2, 3 respectively.

There were no significant differences between the treatment groups regarding the beginning (initial) and final BW values (P>0.05). However, differences in BW changes of W, WW, and WL groups were significantly lower that of the control group (P<0.01). While the difference between beginning and final BW in the control group is not significant, within the treatment groups the difference was found to be significant (P<0.001; Table 2).

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Table 2. The effects of choice feeding with whole wheat continuous, weekly intermittent and with limestone on body weight values of laying hens.

Parameters (BW, g)	Groups ($\bar{X} \pm S_{\bar{X}}$) C	W	WW	WL	P
Beginning	1643.72±19.80	1643.14±18.11	1640.02±16.25	1639.65 ±16.42	NS
Final	1646.56±17.55	1594.72±14.68	1604.23±17.05	1597.08±13.25	NS
Change	+2.85 ± 6.35^{a}	-48.41 ± 6.04^{b}	-35.77 ± 5.05^{b}	-42.55 ± 5.44^{b}	**
P (T-test)	NS	***	***	***	

C: Control. W: choice feeding with continuous whole wheat. WW: choice feeding with whole wheat weekly. WL: continuous choice feeding with whole wheat + limestone. P: probability. a.b: The differences between the averages shown with different superscripts on the same line are statistically significant. NS: non-significant. *: P<0.05. **:P<0.01. ***:P<0.001.

Table 3. The effects of choice feeding with whole wheat continuous, weekly intermittent and with limestone on FC, FCR, protein consumption, amount of protein consumed per kg of egg, metabolic energy consumption and amount of energy consumed per kg of egg of laying hens.

Parameters	Groups ($\bar{X} \pm S_{\bar{X}}$) C	W	WW	WL	P
FC, g/day/hen					
1st period	113.73±2.44	113.06±4.32	113.56±2.60	117.39±1.79	NS
2nd period	124.84±2.70^{b}	123.81±2.60^{b}	133.52±3.54^{a}	130.26±1.01^{ab}	*
3rd period	109.38±2.90	114.91±1.67	113.75±1.69	117.74±2.18	NS
Total	115.98 ±1.80	117.26±2.12	120.28±1.91	121.80±1.25	NS
FCR, g feed/egg mass					
1st period	2.03±0.06	2.21±0.05	2.06±0.04	2.14±0.06	NS
2nd period	2.06±0.03	2.21±0.07	2.20±0.07	2.18±0.03	NS
3rd period	1.84±0.03^{b}	2.00±0.04^{a}	1.93±0.04^{ab}	2.02±0.03^{a}	**
Total	1.99±0.03^{c}	2.15±0.05^{a}	2.02±0.05^{bc}	2.12±0.03^{ab}	*
Protein consumption, g/day/hen					
1st period	19.33±0.42^{a}	17.08±0.64^{b}	18.15±0.40^{ab}	18.05±0.27^{ab}	*
2nd period	21.22±0.46^{a}	19.08±0.48^{b}	21.61±0.61^{a}	20.31±0.19^{ab}	**
3rd period	18.59±0.49	17.91±0.26	18.35±0.98	18.49±0.34	NS
Total	19.72±0.31^{a}	18.02±0.33^{b}	19.37±0.31^{a}	18.95±0.17^{a}	**
Amount of protein, consumed, per kg of egg					
1st period	345.06±10.92	334.51±7.41	328.93±7.21	329.49±8.26	NS
2nd period	349.99±4.51	340.40±10.14	356.85±11.48	340.06±5.40	NS
3rd period	312.79±4.68	311.94±5.72	312.28±7.11	317.23±4.27	NS
Total	335.68±4.24	328.00±5.45	339.12±7.95	328.85±3.86	NS
Metabolic energy consumption, g/day/hen					
1st period	312.76±6.72	321.60±12.40	318.10±7.36	332.34±5.28	NS
2nd period	343.32±7.42^{c}	350.31±7.04^{bc}	372.59±9.70^{a}	367.38±2.93^{ab}	*
3rd period	300.79±7.97^{b}	324.10±4.79^{a}	317.72±4.56^{ab}	331.43±6.22^{a}	**
Total	318.96±4.95^{b}	332.01±6.03^{ab}	336.14±5.34^{a}	343.71±3.76^{a}	*
Amount of energy, consumed, per kg of egg					
1st period	5581.77±176.69^{c}	6298.09±150.33^{a}	5764.12±121.00^{bc}	6069.03±168.65^{ab}	*
2nd period	5661.64±73.01^{b}	6263.24±213.82^{a}	6151.17±185.52^{a}	6151.50±94.69^{a}	*
3rd period	5059.78±75.77^{b}	5645.64±110.82^{a}	5405.79±113.65^{a}	5697.27±89.35^{a}	**
Total	5430.13±68.55^{b}	6044.84±118.65^{a}	5884.02±136.08^{a}	5965.99±89.89^{a}	**

C: Control. W: choice feeding with continuous whole wheat. WW: choice feeding with whole wheat weekly. WL: continuous choice feeding with whole wheat + limestone. P: probability. a.b: The differences between the averages shown with different superscripts on the same line are statistically significant. NS: non-significant. *: P<0.05. **:P<0.01.

Table 4. The effects of choice feeding with whole wheat continuous, weekly intermittent and with limestone on egg production, yield, weight and mass traits of laying hens.

Parameters	Groups ($\bar{X} \pm S_{\bar{X}}$)				P
	C	W	WW	WL	
Egg production, number					
1st period	52.25±1.15	49.60±1.75	52.15±0.76	52.80±0.73	NS
2nd period	54.00±1.12	52.15±2.00	55.20±0.25	55.05±0.38	NS
3rd period	53.60±0.55	53.15±0.68	54.05±0.54	53.90±0.29	NS
Total	53.28±0.0.87	51.63±1.31	53.80±0.38	53.92±0.23	NS
Egg yield, %					
1st period	93.30± 2.05	88.57 ± 3.13	93.13 ± 1.36	94.29 ± 1.31	NS
2nd period	96.43 ± 2.00	93.13 ± 3.57	98.57 ± 0.45	98.30 ± 0.68	NS
3rd period	95.72 ± 0.98	94.91 ± 1.22	96.52 ± 0.96	96.25 ± 0.51	NS
Total	95.15 ± 1.55	92.20 ± 2.35	96.07 ± 0.67	96.28 ± 0.40	NS
Egg weight, g					
1st period	60.35±0.35[a]	57.80±0.54[c]	59.31±0.51[ab]	58.28±0.37 [bc]	**
2nd period	62.96±0.67[a]	60.74±0.41 [b]	61.55±0.62[ab]	60.82±0.29[b]	*
3rd period	62.06±0.93	60.60±0.54	61.01±0.52	60.43±0.38	NS
Total	61.79±0.63	59.71±0.42	59.64±1.15	59.84±0.30	NS
Egg mass, g/day/hen					
1st period	56.31±1.27[a]	51.19±1.90[b]	55.19±0.55[a]	54.96±0.94[a]	*
2nd period	60.73±1.50	56.54±2.17	60.68±0.74	59.79±0.49	NS
3rd period	59.42±1.15	57.49±0.73	58.90±0.87	58.17±0.49	NS
Total	58.83±1.20	55.10±1.40	57.32±1.18	57.65±0.40	NS

C: Control. W: choice feeding with continuous whole wheat. WW: choice feeding with whole wheat weekly.
WL: continuous choice feeding with whole wheat + limestone. P: probability. a.b: The differences between the averages shown with different superscripts on the same line are statistically significant. NS: non-significant. *: P<0.05. **: P<0.01.

There were no differences between the treatment groups regarding FC values in the 1st, 3th, and total periods (P>0.05). However, in the 2nd period, the FC value of the WW group was higher than those of the C and W groups (P<0.05). In the 3rd period and total, the FCR value of the control group was lower than those of the W and WL groups (P<0.01), similar to that of the WW group (P>0.05). There were significant differences among the treatment groups regarding total protein (P<0.01) and metabolic energy consumption (P<0.05) and also the amount of energy per kg of egg (Table 3).

Egg production (number) and yield (%), egg weight, and egg mass values are presented in Table 4.

The differences between the treatment groups in terms of egg yields (number and %) were not significant (P>0.05). The egg weight of the W and WL groups was significantly lower than that of the control group in the 1st (P<0.01) and 2nd (P<0.05) periods. The egg mass value was significantly lower in the W group than in other groups in the 1st period (P<0.05; Table 4).

Egg internal and external quality parameters are given in Tables 5 and 6.

There were no differences amongst groups regarding albumen height and Haugh unit values (P>0.05). However, the yolk color values obtained in the W group were generally lower than the other groups (P<0.01; Table 5).

The egg shell ratio was lower in the W group than in other groups in the 1st and 2nd periods (P<0.01). Also, in the 1st and 2nd periods of the study, the eggshell weights of the W and WL groups were significantly lower than the control group (P<0.05). However, the difference was insignificant in the WW group (P>0.05). Eggshell thickness was significantly higher in the control group than in the other groups throughout the experiment (P<0.01). At the same time, the egg shell thickness in the W group was significantly lower than in the WW and WL groups in the 1st, 2nd, and total periods (P<0.01). ESSA values in the 1st and 2nd periods were significantly lower in the W and WL groups than in the control group (P<0.05). Eggshell unit weight was found to be lower in the W group in the 1st, 2nd, and total periods than in the other groups (P<0.01; Table 5).

The results of the economic analysis (egg income by weight, net income, and total expenses) amongst the study groups are given in Table 6.

In terms of total expenses, the W group was lower than other groups in the 2nd period (P<0.05). The lowest expense per laying hen was in the W group (0.205 $/hen). Egg sales income and net profit values were similar in all groups throughout the experiment (P>0.05). The lowest egg income per laying hen was in the W group (0.269 $/hens), but the net profit per laying hen was similar with control group (0.064 $/hens; Table 6).

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Table 5. Effect of choice feeding on egg internal (albumin height, yolk color, haugh unit) and external (shell ratio. shell weight. shell thickness, shell surface area, shell unit weight) quality characteristics of the study groups.

Parameters	Groups ($\bar{X} \pm S_{\bar{X}}$)				P
	C	W	WW	WL	
Albumen height, mm					
1st period	3.98±0.18	3.96±0.18	4.36±0.25	4.53±0.21	NS
2nd period	4.43±0.28	3.76±0.13	4.04±0.27	4.01±0.15	NS
3rd period	3.74±0.13	3.89±0.19	4.22±0.18	3.99±0.07	NS
Total	4.05±0.13	3.87±0.12	4.18±0.17	4.18±0.08	NS
Yolk color, Roche color fan value					
1st period	9.13±0.12^{a}	7.11±0.34^{c}	9.17±0.06^{a}	7.81±0.29^{b}	**
2nd period	9.03±0.11^{a}	7.15±0.17^{c}	8.73±0.11^{a}	7.70±0.18^{b}	**
3rd period	8.44±0.20^{a}	6.83±0.28^{b}	7.34±0.26^{b}	7.53±0.18^{b}	**
Total	8.86±0.07^{a}	7.03±0.21^{d}	8.38±0.14^{b}	7.68±0.18^{c}	**
Haugh unit					
1st period	53.75±1.90	54.53±2.64	58.99±2.96	61.43±2.71	NS
2nd period	57.63±4.00	51.20±2.00	52.52±3.64	54.70±1.93	NS
3rd period	52.35±1.43	54.77±2.24	57.69±1.98	55.99±1.19	NS
Total	54.58±1.64	53.50±1.64	56.04±1.92	57.38±0.81	NS
Shell ratio, %					
1st period	10.50±0.08^{a}	10.00±0.10^{b}	10.46±0.08^{a}	10.57±0.09^{a}	**
2nd period	10.03±0.08^{a}	9.69±0.06^{b}	10.08±0.07^{a}	10.10±0.05^{a}	**
3rd period	10.01±0.09	9.91±0.09	9.88±0.07	10.09±0.07	NS
Total	10.18±0.08	9.87±0.06	9.97±0.20	10.26±0.06	NS
Shell weight, g					
1st period	6.34±0.02^{a}	5.78±0.06^{c}	6.20±0.05^{ab}	6.16±0.06^{b}	**
2nd period	6.31±0.03^{a}	5.88±0.04^{c}	6.20±0.04^{ab}	6.15±0.04^{b}	**
3rd period	6.21±0.05	6.00±0.07	6.02±0.06	6.10±0.07	NS
Total	6.28±0.02^{a}	5.89±0.04^{c}	6.04±0.12^{bc}	6.13±0.05^{ab}	**
Shell thickness, mm					
1st period	35.56±0.34^{a}	32.30±0.39^{b}	35.76±0.51^{a}	35.70±0.56^{a}	**
2nd period	41.35±0.23^{a}	37.75±0.40^{c}	39.97±0.23^{b}	40.08±0.22^{b}	**
3rd period	41.35±0.27^{a}	39.45±0.34^{b}	40.03±0.26^{b}	41.03±0.30^{a}	**
Total	39.42±0.19^{a}	36.50±0.26^{c}	38.59±0.25^{b}	38.93±0.17^{ab}	**
Egg shell surface area (ESSA)					
1st period	71.80±0.30^{a}	69.64±0.46^{c}	70.92±0.43^{ab}	70.05±0.31^{bc}	**
2nd period	73.97±0.56^{a}	72.13±0.35^{b}	72.80±0.52^{ab}	72.19±0.25^{b}	*
3rd period	73.22±0.77	72.00±0.45	72.35±0.44	71.87±0.32	NS
Total	73.00±0.52	71.26±0.35	71.18±0.98	71.37±0.25	NS
Egg shell unit weight					
1st period	0.0884±0.00056^{a}	0.0829±0.00069^{b}	0.0875±0.00054^{a}	0.0879±0.00074^{a}	**
2nd period	0.0852±0.00039^{a}	0.0817±0.00047^{b}	0.0851±0.00041^{a}	0.0850±0.00045^{a}	**
3rd period	0.0848±0.00039	0.0833±0.00073	0.0833±0.00060	0.0848±0.00066	NS
Total	0.0862±0.00042^{a}	0.0825±0.00043^{b}	0.0848±0.00076^{a}	0.0860±0.00058^{a}	**

C: Control. W: choice feeding with continuous whole wheat. WW: choice feeding with whole wheat weekly. WL: continuous choice feeding with whole wheat + limestone. P: probability. a.b: The differences between the averages shown with different superscripts on the same line are statistically significant. NS: non-significant. *: P<0.05. **: P<0.01.

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Table 6. Economic reflection of choice feeding in laying hens.

Parameters	Groups ($\bar{X} \pm S_{\bar{X}}$)				P
	C	W	WW	WL	
Total cost, $					
1st period	2.79±0.06	2.61±0.08	2.70±0.06	2.74±0.05	NS
2nd period	3.06±0.06[ab]	2.88±0.06[b]	3.18±0.09[a]	3.05±0.02[ab]	*
3rd period	2.69±0.07	2.70±0.04	2.71±0.04	2.77±0.05	NS
Total	8.54±0.13	8.19±0.13	8.59±0.12	8.56±0.07	NS
Average	2.85±0.04	2.73±0.04	2.86±0.04	2.85±0.02	NS
Per hen	0.214±0.003	0.205±0.003	0.215±0.003	0.214±0.002	NS
Egg sales income, $					
1st period	3.58±0.09	3.43±0.13	3.66±0.07	3.64±0.06	NS
2nd period	3.80±0.08	3.63±0.14	3.88±0.03	3.82±0.03	NS
3rd period	3.74±0.05	3.70±0.05	3.77±0.05	3.74±0.02	NS
Total	11.12±0.19	10.76±0.28	11.31±0.11	11.20±0.05	NS
Average	3.71±0.06	3.59±0.09	3.77±0.04	3.73±0.02	NS
Per hen	0.278±0.005	0.269±0.007	0.283±0.003	0.280±0.001	NS
Net Profit, $					
1st period	0.79±0.11	0.82±0.09	0.96±0.09	0.90±0.07	NS
2nd period	0.74±0.03	0.75±0.10	0.70±0.08	0.77±0.05	NS
3rd period	1.05±0.05	1.00±0.06	1.06±0.06	0.97±0.04	NS
Total	2.58±0.13	2.57±0.20	2.72±0.11	2.64±0.11	NS
Average	0.86±0.04	0.86±0.07	0.91±0.04	0.88±0.04	NS
Per hen	0.064±0.003	0.064±0.005	0.068±0.003	0.066±0.003	NS

C: Control. W: choice feeding with continuous whole wheat. WW: choice feeding with whole wheat weekly. WL: continuous choice feeding with whole wheat + limestone. P: probability. a.b: The differences between the averages shown with different superscripts on the same line are statistically significant. NS: non-significant. *: P<0.05. **: P<0.01. 1 US$=13.5 TL.

Discussion and Conclusion

One of the main costs of livestock production in laying hens is feed. If the difference between the daily feed expense and the next day's egg income is positive, laying hen farms can continue to produce. Although more studies have been carried out in broilers (26) and other poultry (20) to continue without impairing performance and product quality in poultry, the number of choice feedings based on grains in laying hens is less. Especially in laying hens, due to the low Ca level in grains, free-choice feeding studies have been concerned about the deterioration of egg shell quality and, therefore, the decrease in the number of eggs that can be marketed. Both choice feedings with continuously whole wheat and limestone (given as grit against the possible Ca deficiency) and, at the same time, the effects of weekly choice feeding with whole wheat were examined.

In the current study, the initial and final BW values at the trial were not significantly affected by the treatments, but the BW change increased in the control group and decreased in the choice feeding groups. Body-weight gain or loss is related to the difference between the energy taken into the body and the energy lost or given. Under normal conditions, small increases in body weight occur in commercial flocks fed on a standard diet. Although small body weight gains occurred in this study, choice wheat consumption with different methods caused a loss in body weight. Other researchers found similar results (14, 31, 33) when they gave wheat selection. The BW of laying hens decreased.

In contrast, some reports showed that choice feeding with wheat did not change the BW of laying hens (15) and quails (22). This may show the ration balance slightly deteriorated with the addition of wheat. This situation manifested itself with the increase in feed consumption and the decrease in FCR in the selectively fed groups. The FC values obtained from the control group were generally lower than the choice feed offering groups. Bennett and Classen (2), reported that feeding with whole barley increased the feed intake and body weight gain in laying hens, in contrast to current findings (14-16). Also, Robinson (27) showed that combined use of wheat and limestone decreased feed intake in hens.

Although more studies have been carried out in broilers (7, 18, 26) and quail (19) and Türkiye chicks (20) to continue without impairing performance and product quality in poultry, the number of selective feedings based on grains in laying hens is limited. Especially in laying hens, due to the low Ca level in grains, free-choice feeding studies have been concerned about the deterioration of egg shell quality and therefore the decrease in the number of eggs that can be marketed. In this study, both choice feeding was applied and limestone was given as grit against the possible Ca deficiency. At the same time, the effects of choice feed presentation in weekly changes were examined. Feed efficiency was lower in whole wheat selection groups, but group C used feeds more effectively than the choice feeding treatment groups. Similar results were obtained by Traineau et al. (32) and Mirzaie et al. (21). However, Cho et al. (5) and Kerman (17) reported that whole wheat feeding did not affect FCR in laying hens. Ciftci et al. (4) showed that triticale and additional enzymes did not affect FC and FCR in laying hens.

In the current experiment, continuous/weekly choice feeding with whole wheat and limestone addition did not affect egg yield, mass, or weight (except periods 1 and 2). These results showed that hens adapted to choice feeding of wheat in two programs, and they were given together with limestone as a calcium source. Similar results were reported by Karunajeewa (16), Cho et al. (5), Kerman (17) and Jordan et al. (15) that egg yield was not significant amongst the groups; however, egg weight increased (16, 27) and decreased (14, 27) in laying hens. Bennett et al. (2) reported that choice feeding with barley and access to insoluble grit did not affect production parameters in hens.

There were no significant differences among the treatment groups in HU and albumen height values in the present study. However, there was a substantial difference in terms of egg yolk color. One of the critical issues to be considered in whole wheat choice feeding practices is the changes in the egg yolk color (16). Although corn is rich in carotenoids, however, other common grains such as barley and wheat have a low concentration of carotenoids (24), and may cause a decrease in egg yolk color. Saikhlai et al. (28) reported a lighter yolk color between 15, 20, and 25% in wheat additions in laying hen diets.

Eggshell weight, thickness, ratio, shell surface area, and unit shell weight were decreased in the group (W) in which whole grain wheat was given continuously compared to the control and other treatment groups. Weekly administration of wheat and wheat+grit limestone did not improve eggshell properties compared to the control. Still, it was found to be slightly superior to group W. The effect of the low Ca content of wheat was reflected in the weight and thickness of the eggshell. As it is well known, Ca, P, and vitamin D are essential traits for bioavailability in the body, and a deficiency or excess of one of them reduces the level of utilization of the other two. Therefore, giving grit limestone along with wheat could not improve the thinning of the eggshell. A similar result was reported by Faruk et al. (8), and sequential feeding with wheat causes a decrease in eggshell weight in laying hens. However, Karunajeewa (16) issued with whole wheat feeding and Sakomura et al. (29) exclusive wheat+limestone feeding did not change eggshell weight and thickness.

In conclusion, choice feeding with wheat (continuous and weekly) and limestone in laying hens did not negatively affect some performance and economic parameters (FC, cost, income, and net profit). However, some quality parameters (yolk color, shell weight, and thickness) were regressed. With choice feeding, which does not have a negative economic impact, both animal welfare is ensured and animals are protected from some metabolic diseases. In addition, by means of choice feeding, transport, grinding, and feed mixing costs are decreased. Thus, it is thought that the profitability of the enterprises may increase due to a decrease in metabolic diseases of poultry. Therefore, in the future the use of choice feeding is considered important in terms of both economic and animal welfare.

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Conflict of Interest

The authors declared that there is no conflict of interest.

Author Contributions

MK, contributed to data collection and writing. GG, designed the study material and carried out analyzes. BRY, contributed to data collection and literature review. SS, designed the research, contributed to reviewing and editing the manuscript. YK, carried out the literature reviewing process and writing the manuscript.

Data Availability Statement

The data supporting this study's findings are available from the corresponding author upon reasonable request.

Ethical Statement

This study was approved by the Erciyes University Animal Experiments Local Ethics Committee (approval date and the number: 03.06.2020 and 20/087).

Animal Welfare

The authors confirm that they have adhered to ARRIVE Guidelines to protect animals used for scientific purposes.

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