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INFLUENCE OF EARLY QUALITATIVE FEED RESTRICTION AND BARRIER PERCH ACCESS ON SOME MEAT QUALITY TRAITS, GROWTH PERFORMANCE, AND DIET COST ANALYSIS IN BROILER CHICKENS*

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Abstract

In this trial, the effects of early qualitative feed restriction and barrier perch access on some meat quality traits, growth performance, and diet cost analysis of broiler chickens were investigated. A total of 504 1-d-old male chicks (Ross 308) were randomly allocated to four treatments (qualitative feed restriction − QFR; absence-/presence+ and barrier perch − BP; absence-/presence+) with three replicate pens in a completely randomised design involving a 2 × 2 factorial arrangement of treatments. Broiler chickens in the treatment of QFR- were fed with a corn-soybean meal diet containing protein and energy at the level specified in the commercial hybrid catalogue during d 0−42. The treatment of QFR+ was fed with a corn-soybean meal diet containing lower energy (10%) and protein (20%) for the first 21 d, and then between d 22 and 42, they were fed with a diet specified in the commercial hybrid catalogue. In the treatment of BP+, the barrier perch was placed between the feeder and the drinker. Meat quality traits (pH, lightness − L*, redness − a*, yellowness − b*, chroma, hue angle, and cooking loss − CL), growth performance (body weight − BW, body weight gain − BWG, feed intake − FI, and feed conversion ratio − FCR), and diet cost analysis (total diet cost and diet cost per unit weight gain) were recorded. Except for the a* value and hue angle measured at 24-h post-slaughter, the effect of QFR treatments on meat quality traits was insignificant in all measurements. During d 0−42, in the treatments of QFR+, BW, BWG, and FI were lower (P<0.0001, and P=0.005, respectively), and FCR was worse (P=0.014). The QFR treatments did not differ significantly in dietary cost per unit weight gained during d 0−42. As a result, it can be said that early qualitative feed restriction did not significantly affect meat quality traits. The treatment of QFR+ resulted in reduced growth performance. However, diet cost per unit weight gain showed similar values in both QFR treatments (QFR+ €0.75, QFR- €0.76, P=0.511).

Key words: broiler chickens, protein and energy restriction, barrier perch, meat quality, growth performance

Poultry meat production and consumption have rapidly increased in parallel with both the world population growth and the number of consumers focused on healthy nutrition over the past decades (Lee et al., 2022). The growing demand for poultry meat has accelerated research on the development of genetic selection, maintenance management conditions, and feeding techniques (Rahimi et al., 2015; Oral Toplu et al., 2021). This situation resulted in dramatic increases in weight gain (Cavani et al., 2009; Huang and Ahn, 2018; Bailey et al., 2020), feed efficiency (Papah et al., 2018), and breast meat yield (Huang and Ahn, 2018; Bailey et al., 2020; Nawaz et al., 2022) of broiler chickens. Today compared to 50 years ago, broiler chickens reach about the target slaughter weight in half the time and they have been marketed almost twice the body weight (Barbut et al., 2008; Petracci and Cavani, 2012). Similarly, a significant increase in breast meat yield has been observed. When Ross 308 performance objectives of 2001 are compared with those of 2022, it is determined that breast meat yield increased from 15.8% to 24.07% at 2200 kg (Aviagen, 2001, 2022). However, these dramatic increases in growth rate and muscle size have caused some undesirable selection responses, such as high mortality (Rezaei et al., 2006; Chen et al., 2012; Xu et al., 2017), increased body fat deposition (Chen et al., 2012; Połtowicz et al., 2015; Xu et al., 2017), a higher incidence of metabolic disorders (Chen et al., 2012; Połtowicz et al., 2015; Xu et al., 2017), a higher incidence of leg problems (Lippens et al., 2000, 2002; Rezaei et al., 2006; Dibner et al., 2007; Chodova et al., 2021) and quality issues in breast muscle (Petracci and Cavani, 2012; Połtowicz et al., 2015; Huang and Ahn, 2018). In the poultry industry, it is thought that these undesirable selection responses are closely linked to the excessive growth rate in the early stages of life (Bessei, 2006). Thus, various feed restriction techniques

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or programmes as a management strategy are applied in the early stage of life to reduce problems related to the excessive growth rates of modern strains (Chen et al., 2012; Sahraei, 2012; Butzen et al., 2013; Połtowicz et al., 2015; Varol Avcılar and Onbaşılar, 2016; Xu et al., 2017). Qualitative feed restriction is related to nutritional dilution of the diet. Quantitative feed restriction is related to limiting the amount of daily feed intake (Cornejo et al., 2007). Daily feed intake restriction or dilution of the nutrient content of the diet cause a temporary reduction in the growth rate. However, once the restriction is lifted and *ad libitum* feeding is introduced, the target weight is achieved by the time of slaughter. This phenomenon is known as compensatory growth (Plavnik and Hurwitz, 1990). In summary, early-stage feed restriction does not negatively affect slaughter weight and provides significant welfare benefits in terms of health and reproduction, as highlighted by Mench (2002). Moreover, it also reduces feeding costs during the early stage, as noted by Omosebi et al. (2014). In recent years, to improve the welfare level in the poultry industry, some environmental enrichments have been used to raise the mobility of broiler chickens. There are many studies investigating the effects of using perches (Kiyma et al., 2016; Akşit et al., 2017; Kim et al., 2021; Dereli Fidan and Okur, 2022), barriers (Bizeray et al., 2002; Bench et al., 2017; Karaarslan et al., 2022), straw bales (Bailie et al., 2013; Baxter et al., 2018; Bach et al., 2019; Jones et al., 2020) or platforms (Pedersen et al., 2020; Güz et al., 2021) as environmental enrichment on broiler chickens. However, limited research has focused on the influence of environmental enrichments on meat quality traits (Marchewka et al., 2023).

The trial was designed by considering the problems and developing sensitivities in the broiler industry described above. During the determination of the feed restriction method and duration, it was considered that qualitative feed restriction would be more suitable in terms of animal welfare. Evaluating previous research, it was observed that restriction durations are often kept short. However, it was predicted that it would not be possible for the targeted improvement in animal welfare and meat quality attributes by keeping the restriction duration short.

Therefore, the aim was to reduce quality issues arising from rapid growth without causing an economic decline in performance. A feed cost analysis was planned to evaluate the potential decrease in performance parameters from an economic perspective. While the barrier perch was preferred, its widespread usability and cost in the chicken industry were taken into account. Based on the information presented, our objective was to investigate the effects of implementing qualitative feed restriction during early life to limit weight gain and usage of barrier perch to increase mobility, on meat quality attributes and growth performance.

Material and methods

Experimental design and treatments

A total of 504 1-d-old male broiler chickens (Ross 308) were used in a completely randomized design with a 2 × 2 factorial arrangement. The broiler chickens were divided into four treatments according to early qualitative feed restriction (QFR- and QFR+) and barrier perch (BP- and BP+). A total of 12 pens were used, with three replicates for each treatment. 42 broiler chickens were randomly placed in each pen. Broiler chickens were fed a diet diluted in protein and energy during d 0−21 in the QFR+ treatment. Broiler chickens were fed as specified in the commercial hybrid catalogue in the QFR+ treatment during d 22−42 and the QFR- treatment during d 0−42. In the BP+ treatments, a wooden barrier perch (between 3 and 14 days; 1.8 cm width × 5 cm height, other days; 1.8 cm width × 15 cm height) was placed between the feeder and the drinker in each pen (Figure 1).

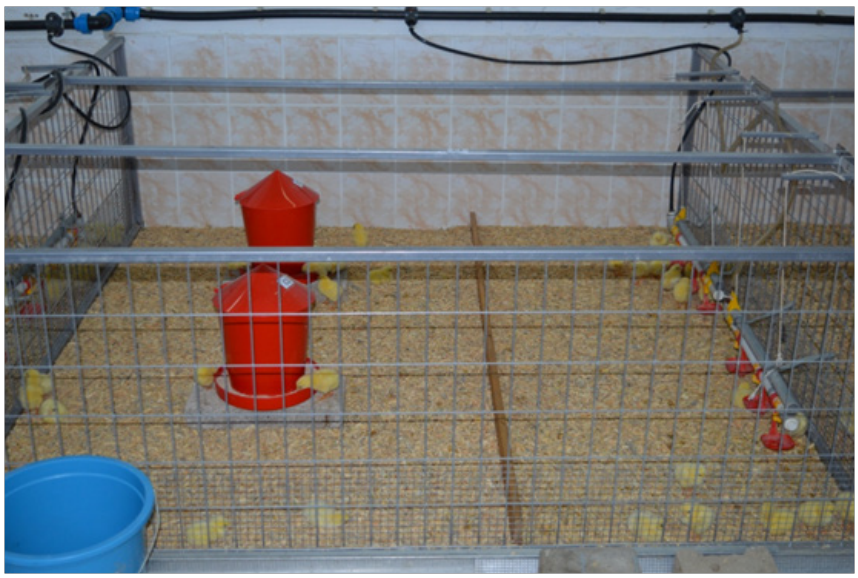


Figure 1. The design of the barrier perch and placement within the pen

Table 1. Ingredient and nutrient composition of diets

Items	QFR-			QFR+			
Ingredients (%)	starter	grower	finisher	starter	grower		finisher
	d 0–10	d 11–24	d 25–42	d 0–10	d 11–21	d 22–24	d 25–42
Maize	50.37	53.38	56.89	55.88	59.00	53.38	56.89
Soybean meal	39.80	36.20	32.00	24.30	20.85	36.20	32.00
Vegetable oil	3.00	4.00	5.00	0.10	0.80	4.00	5.00
Wheat bran	2.70	2.70	2.70	15.00	15.00	2.70	2.70
Limestone	1.27	1.21	1.13	1.40	1.38	1.21	1.13
Dicalcium phosphate	1.92	1.67	1.48	1.80	1.56	1.67	1.48
DL-methionine	0.21	0.17	0.15	0.29	0.25	0.17	0.15
L-lysine	0.13	0.07	0.05	0.63	0.56	0.07	0.05
Sodium chloride	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin mineral premix[1]	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Calculated nutrient composition of diets (%)							
Metabolizable energy (kcal/kg)	3000.17	3101.11	3204.15	2708.03	2790.01	3101.11	3204.15
Crude protein	23.05	21.55	19.58	18.63	17.20	21.55	19.58
Calcium	0.96	0.87	0.79	0.96	0.87	0.87	0.79
Phosphorus	0.76	0.70	0.65	0.76	0.74	0.70	0.65
Available phosphorus	0.48	0.435	0.395	0.48	0.435	0.435	0.395
Methionine	0.56	0.51	0.47	0.56	0.51	0.51	0.47
Lysine	1.44	1.29	1.16	1.44	1.29	1.29	1.16

[1]Supplied per kilogram of diet: vitamin A, 12,000 IU; vitamin D_3, 1500 IU; vitamin E, 30 mg; vitamin K_3, 5 mg; vitamin B_1, 3 mg; vitamin B_2, 6 mg; vitamin B_6, 5 mg; vitamin B_{12}, 0.03 mg; niacin, 40 mg; calcium D-pantothenate, 10 mg; folic acid, 0.75 mg; D-biotin, 0.075 mg; choline chloride, 375 mg; Mn, 80 mg; Fe, 40 mg; Zn, 60 mg; Cu, 5 mg; I, 0.4 mg; Co, 0.1 mg; Se, 0.15 mg; and antioxidant, 10 mg.

Birds and housing

All experimental procedures were approved by Aydın Adnan Menderes University Animal Experiments Local Ethics Committee (64583101/2016/175). Broiler chickens were supplied from a local commercial hatchery (EGE-TAV Agriculture and Livestock Investment Trade and Industry Inc. İzmir, Türkiye). Broiler chickens were reared in a floor pen (2 m width × 2 m depth × 0.75 m height) for 42 d at the Poultry Research Unit, Faculty of Veterinary Medicine, Aydın Adnan Menderes University, Türkiye. Two drinker lines (6 nipples; 1 nipple per 7 birds) and two round feeders (0.4 m diameters; 5.98 cm feeder length per bird) were placed in each floor pen. Feed and water were provided *ad libitum*. Wood shavings (6 cm in depth) were used as litter material. In the study, stocking density (33 kg/m^2) and lighting schedule (24L the first 7 days and 3 days before slaughter, 18L:6D on other days) were determined according to the European Union Directive (2007/43/EC). The broiler chickens were provided with optimum temperature and humidity conditions as specified in the Ross 308 rearing guide (Aviagen, 2018).

Diets

The diets based on corn-soybean meal indicated in Table 1 were used in the study. The diets were formulated as a starter (d 0 to 10), grower (d 11 to 24), and finisher (d 25 to 42) as specified in the Aviagen (2014) recommendations. The treatment of QFR- was given a starter diet containing 3000 kcal/kg ME and 23% HP in the first 10 days of the trial, a grower diet containing 3100 kcal/kg ME and 21.5% HP between d 11 and 24, and a finisher diet containing 3200 kcal/kg ME and 19.5% HP between d 25 and 42. The treatment of QFR+ was fed from d 0 to 21, whereby the quantity of soybean meal and vegetable oil was reduced and wheat bran was increased to 15%. Correspondingly, the amount of CP (18.6% and 17.2%) was reduced by 20% and the level of the metabolizable energy (2700 and 2790 kcal/kg ME) by 10%. During d 22−42, broiler chickens were fed as specified in the commercial hybrid catalogue (Aviagen, 2019).

Slaughter procedure and sample collection

At d 42, 10 broiler chickens from each pen (30 birds from each treatment) were randomly selected. Broiler chickens were carefully transported from the pens where they were grown to the slaughter room by seasoned researchers to avoid pre-slaughter stress. Slaughter was applied by decapitation. In a hot water bath set at 53−55°C for two minutes, broiler chickens were scalded after the exsanguination process. In order to evaluate the meat quality attributes, the pectoralis major muscles on the left side were removed from the carcass following the feather plucking and evisceration process.

Meat quality

Using a portable pH meter (Testo 205, Testo Inc., Lenzkirch, Germany) with a probe that has been calibrated and standardized, the breast muscle samples' pH values were measured at three different points from the cranial end of muscles at 15 min, 24 h, and 72 h post-slaughter. Colour attributes (L*, a*, and b*) of the breast muscle samples were measured from the cranial region of the bone-side surface at 24 h and 72 h post-slaughter with a chroma meter (CR-400; Konica Minolta, Osaka, Japan). According to the guidelines established by the American Meat Science Association for colour measurement, the hue angle and chroma values were determined (AMSA, 2012). The hue angle, which indicates the degree of discolouration, is calculated using (= arctan b^*/a^*). The chroma, which reflects colour saturation, is computed using the a* and b* values according to the formula (= $(a^{*2}/b^{*2})^{1/2}$). The CL was assessed at 24 h post-slaughter in breast muscle samples. They were first weighed, placed in a plastic bag, and cooked using a water bath to an internal temperature of 75°C. Then the cooked samples were cooled, blotted dry, and weighed again (Honikel, 1998). The CL was calculated with the below formula;

$$Cooking\ loss = \frac{weight\ before\ cooking\text{-}sample\ weight\ after\ cooking}{sample\ weight\ before\ cooking} \times 100$$

Growth performance

The BW of broiler chickens was individually weighed with a digital scale. The cumulative FI of each pen was recorded during d 0−21, d 22−42, and d 0−42. The BWG and FCR were cumulatively calculated during d 0−21, d 22−42, and d 0−42 per pen.

Diet cost analysis

Firstly, the kg prices of starter, grower, and finisher diets were determined in EURO (EUR/€) currency. The cost of the diet is calculated according to the current prices of April 2023. Then, total diet cost (€/feed consumed/bird) and diet cost per unit weight gain (€/kg BWG) were cumulatively calculated for the treatments at d 0−21, d 22−42, and d 0−42.

Statistical analysis

Statistical analyses were performed using the SPSS software version 22 (Inc., Chicago, II, USA). Shapiro–Wilk test/Kolmogorov–Smirnov test was used to determine the conformity of the variables to the normal distribution. The General Linear Model was used to compare the differences between the treatment averages in some meat quality traits (pH, L*, a*, b*, hue angle, chroma, and CL) and growth performance (BW, BWG, FI, FCR). The mathematical model of the statistical design was described as follows:

$$Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + E_{ijk}$$

Where: Y_{ijk} = the value observed, μ = the overall mean, α_i = the effect of qualitative feed restriction (QFR- and QFR+), β_j = the effect of barrier perch (BP– and BP+), $(\alpha\beta)_{ij}$ = the interaction between qualitative feed restriction and barrier perch, and E_{ijk} = test error per observation. The interaction between treatments was found to be insignificant for the investigated traits; therefore, it was not included in the tables. The Independent t-test was applied to compare the diet cost analysis of treatments. An overall p-value less than 0.05 was considered to show a statistically significant result.

Results

Meat quality

The pH of breast muscle measured at different times post-slaughter, and the CL measured at 24 h post-slaughter, were not affected by the QFR or BP treatments (Table 2). The a* value of breast muscle was higher (P=0.004) and the hue angle was lower (P=0.018) in the QFR+ treatment at 24 h post-slaughter. Nevertheless, neither the QFR nor BP treatments were determined to have an effect on these parameters at 72 h post-slaughter. The L*, b*, and chroma values of breast muscle were not influenced by the QFR or BP treatments at both 24 h and 72 h post-slaughter (Table 3).

Table 2. Effects of QFR and BP on pH and CL of breast muscle of broiler chickens[1,2] (mean ± standard error)

Traits[3]	Qualitative Feed Restriction				Barrier Perch			
	n	QFR-	QFR+	P	n	BP-	BP+	P
pH_{15}	60	6.34±0.02	6.33±0.02	0.533	60	6.36±0.02	6.31±0.02	0.068
pH_{24}	60	5.72±0.01	5.76±0.01	0.083	60	5.74±0.01	5.73±0.01	0.646
pH_{72}	60	5.69±0.02	5.71±0.02	0.208	60	5.70±0.02	5.70±0.02	0.928
CL (%)	60	37.87±0.33	38.02±0.33	0.750	60	37.55±0.33	38.34±0.33	0.096

[1]Data presented as the least square means.

[2]The interactions between treatments are not included in the tables as they were found to be insignificant (P>0.05) for the investigated traits.

[3]pH_{15}: pH value measured at 15 min post-slaughter, pH_{24}: pH value measured at 24 h post-slaughter, pH_{72}: pH value measured at 72 h post-slaughter, CL: cooking loss measured at 24 h post-slaughter.

Table 3. Effects of QFR and BP on the colour attributes of breast muscle of broiler chickens[1,2] (mean ± standard error)

Traits[3]	Qualitative Feed Restriction				Barrier Perch			
	n	QFR-	QFR+	P	n	BP-	BP+	P
24 h post-slaughter								
L*	60	60.18±0.39	59.32±0.39	0.124	60	59.42±0.39	60.08±0.39	0.239
a*	60	2.46±0.14	3.10±0.14	0.004	60	2.64±0.14	2.92±0.14	0.149
b*	60	8.03±0.28	8.09±0.28	0.890	60	7.89±0.28	8.23±0.28	0.396
hue angle	60	72.30±1.17	68.30±1.17	0.018	60	71.53±1.17	69.08±1.17	0.143
chroma	60	8.46±0.27	8.78±0.27	0.421	60	8.38±0.27	8.86±0.27	0.215
72 h post-slaughter								
L*	60	61.01±0.34	61.00±0.34	0.978	60	60.69±0.34	61.31±0.34	0.195
a*	60	2.61±0.12	2.70±0.12	0.597	60	2.50±0.12	2.81±0.12	0.072
b*	60	8.97±0.23	9.40±0.23	0.180	60	9.08±0.23	9.29±0.23	0.507
hue angle	60	73.43±0.78	73.88±0.78	0.683	60	74.26±0.78	73.05±0.78	0.277
chroma	60	9.40±0.23	9.82±0.23	0.187	60	9.46±0.23	9.76±0.23	0.360

[1]Data presented as the least square means.
[2]The interactions between treatments are not included in the tables as they were found to be insignificant (P>0.05) for the investigated traits.
[3]CIE L*: lightness; CIE a*: redness; CIE b*: yellowness; hue angle: a marker of discolouration; chroma: colour saturation.

Table 4. Effects of QFR and BP on growth performance traits of broiler chickens[1,2] (mean ± standard error)

Traits[3]	Qualitative Feed Restriction					Barrier Perch				
	n	QFR(-)	n	QFR(+)	P	n	BP(-)	n	BP(+)	P
BW (g/bird)										
d 0	252	46.73±0.24	252	46.72±0.24	0.978	252	46.73±0.24	252	46.72±0.24	0.993
d 21	252	863.02±6.96	247	681.22±7.03	<0.0001	249	761.78±7.00	250	782.45±6.98	0.037
d 42	222	2958.69±24.25	217	2718.16±24.52	<0.0001	219	2823.39±24.41	220	2853.46±24.36	0.384
BWG (g/bird)										
d 0 to 21	6	816.28±10.66	6	631.69±10.66	<0.0001	6	712.28±10.66	6	735.70±10.66	0.159
d 22 to 42	6	2095.68±18.42	6	2039.92±18.42	0.065	6	2064.39±18.42	6	2071.21±18.42	0.800
d 0 to 42	6	2911.96±23.79	6	2671.61±23.79	<0.0001	6	2776.66±23.79	6	2806.91±23.79	0.395
FI (g/bird)										
d 0 to 21	6	1110.89±18.47	6	1112.95±18.47	0.939	6	1096.98±18.47	6	1126.98±18.47	0.286
d 22 to 42	6	3517.07±27.96	6	3282.09±27.96	<0.0001	6	3398.10±27.96	6	3401.06±27.96	0.942
d 0 to 42	6	4627.95±42.58	6	4395.04±42.58	0.005	6	4495.09±42.58	6	4527.91±42.58	0.601
FCR (g feed/g weight gain)										
d 0 to 21	6	1.36±0.01	6	1.76±0.01	<0.0001	6	1.57±0.01	6	1.55±0.01	0.345
d 22 to 42	6	1.68±0.01	6	1.61±0.01	0.006	6	1.65±0.01	6	1.64±0.01	0.794
d 0 to 42	6	1.59±0.01	6	1.65±0.01	0.014	6	1.62±0.01	6	1.61±0.01	0.667

[1]Data presented as the least square means.
[2]The interactions between treatments are not included in the tables as they were found to be insignificant (P>0.05) for the investigated traits.
[3]BW: Body weight; BWG: Body weight gain; FI: Feed intake; FCR: Feed conversion ratio.

Table 5. Diet cost analysis of treatments in broiler chickens[1]

Traits	n	Qualitative Feed Restriction		P
		QFR-	QFR+	
Total diet cost (€/feed consumed/bird)				
d 0 to 21	6	0.53±0.008	0.45±0.011	<0.0001
d 22 to 42	6	1.67±0.017	1.56±0.014	<0.0001
d 0 to 42	6	2.20±0.024	2.01±0.022	<0.0001
Diet cost per unit weight gain (€/kg BWG)				
d 0 to 21	6	0.65±0.004	0.71±0.008	<0.0001
d 22 to 42	6	0.80±0.004	0.76±0.006	<0.0001
d 0 to 42	6	0.76±0.003	0.75±0.006	0.511

[1]The cost of the diet is calculated based on the current prices of April 2023. When converting the prices of diet ingredients to EUR (€) currency, the exchange rate was calculated as 1 EUR = 20.70 TRY. The current kg prices of the diet ingredients based on the calculation are as follows; maize €0.291, soybean meal €0.615, vegetable oil €1.610, wheat bran €0.251, limestone €0.028, dicalcium phosphate €0.870, DL-methionine €4.831, L-lysine €3.382, sodium chloride €0.386, vitamin mineral premix €1.160.

Growth performance

The effects of QFR and BP treatments on growth performance are presented in Table 4. The QFR+ treatment reduced (P<0.0001) BW at d 21 and d 42, as well as BWG during d 0−21 and d 0−42. However, the significant difference in BWG disappeared during d 22−42. During d 22−42 and d 0−42, the QFR- treatment had higher FI (P<0.0001, P=0.005, respectively). The FCR was better (P<0.0001, P=0.014, respectively) in the QFR- treatment during d 0−21 and d 0−42. Conversely, during d 22−42, the FCR of the QFR+ treatment was better (P=0.006). No significant effect of BP on growth performance was observed except for BW on d 21 throughout the trial.

Diet cost analysis

The effects of QFR treatments on diet cost analysis in broiler chickens are presented in Table 5. When the QFR treatments are compared in terms of total diet costs, it was determined that the total cost of feed consumed by broiler chickens in the QFR+ treatment was lower (P<0.0001) during d 0−21, d 22−42, and d 0−42. It was observed that diet cost per kg weight gain was higher (P<0.0001) during d 0−21, while it was lower (P<0.0001) during d 22−42 in the QFR+ treatment. No statistically significant difference (P=0.511) was found in terms of the diet cost per kg weight gain between both QFR treatments.

Discussion

Meat quality

The pH level is an important reference for the assessment of meat quality (Yuan et al., 2022), because the ultimate pH directly affects various meat quality traits, including colour, tenderness, water-holding capacity, cooking loss, juiciness, and shelf life (Fletcher, 2002; Barbut et al., 2008). Under normal conditions, the pH of breast muscles is around 7 before slaughter, and it rapidly decreases post-slaughter (Dransfield and Sosnicki, 1999; Lippens et al., 2000; Petracci et al., 2015). In broiler chickens, a pH value between 5.7 and 6.1 (measured at 14 to 16 h post-mortem) is considered normal for the breast muscle (Barbut et al., 2005). In all treatments, the pH value 15 min post-slaughter ranged from 6.31 to 6.36, which decreased to a range of 5.72 to 5.76 at 24 h post-slaughter. When the treatments are compared, the results indicate that neither the QFR nor BP treatments had an effect on the pH values of breast muscles at different times post-slaughter. In the literature review, the study with protein and energy restriction at a similar level and time could not be found. Results similar to those of the trial were reported by Ndazigaruye et al. (2019) and Chodova et al. (2021) that normal and low protein levels did not affect breast muscle pH (45 min and 24 h post-slaughter) in Ross 308 broiler chickens. Likewise, Hussein et al. (2019) declared that low energy levels in the diet had no significant effect on breast muscle initial and ultimate pH in Ross 308 broiler chickens. Furthermore, Lippens et al. (2000) and Üzüm and Oral Toplu (2013) stated that quantitative feed restriction did not affect the pH value of breast muscle at 15 min and 24 h post-mortem in broiler chickens. Unlike the present trial findings, Marcu et al. (2013) reported that the effect of energy and protein restriction during 42 d on pH (30 min and 24 h post-slaughter) in Ross 308 broiler chickens was significant. In their study, the pH was found to be lower in the feed restriction treatment. There is not much published data available describing the impact of perch access on breast muscle pH value. Our findings are generally consistent with previous studies that have reported no significant effect of BP treatment on the pH value of breast muscle at 15 min and 24 h post-mortem (Akşit et al., 2017; Dereli Fidan and Okur, 2022). The colour is a crucial parameter in assessing both the quality and freshness of the breast muscle (Yang et al., 2022). The colour of poultry meat is influenced by numerous factors, such as sex, age, strain, processing procedures, chemical exposure, cooking temperature, irradiation, and freezing conditions (Mugler and Cunningham, 1972; Fletcher et al., 2000; Mir et al., 2017). Different ranges for the L* value of breast muscle with normal properties have been reported in broiler chickens. Petracci et al. (2004) reported a range of L* values between 50 and 56, while Lee et al. (2022) stated a range of 56 and 62. In this trial, the range of L* value for all treatments at 24 h post-slaughter was observed to be between 59.32 and 60.18. Comparing the treatments, it was observed that the L*, b*, and chroma values of breast muscle remained unaffected by the QFR treatments at 24 h post-slaughter. However, it was observed that the QFR+ treatment had a higher a* value and lower hue angle at 24 h post-slaughter compared to the QFR- treatment. The observed differences in colour were significant; however, they were too small to be visually noticeable. The significance of the a* value and hue angle in the breast muscle disappeared in the colour measurement conducted at 72 h post-slaughter, suggesting that holding conditions may have influenced these parameters rather than the treatments in the trial. Several trials have previously reported that feed restriction did not affect the colour attributes of breast muscle (Lippens et al., 2000; Üzüm and Toplu, 2013; Hussein et al., 2019; Ndazigaruye et al., 2019). On the other hand, Chodova et al. (2021) reported that the low protein treatment had an impact on the colour attributes of the breast muscle in Ross 308 broiler chickens, with lower L* values and higher a* and b* values observed. In research on feed restriction, it is seen that feed restriction periods or levels of energy and protein restriction are constructed quite differently from each other. Variability in research results regarding colour attributes might be attributed to this reason, or it might be due to the complex interplay of numerous factors that can impact colour attributes. There is a dearth of published literature regarding the impact of barrier perch access on colour attributes. In previous studies on this topic, disparate results have been reported. Similarly to

the findings of the current trial, the study conducted by Dereli Fidan and Okur (2022) indicated that the impact of perch access was found to be non-significant on colour attributes. In contrast, Kiyma et al. (2016) reported that perch access affected the colour attributes of breast muscle, with higher L* values observed in the presence of perch, and higher a* and b* values observed in the absence of perch. Additionally, Akşit et al. (2017) reported that the effect of provided perch on the L* value was not significant, while the a* and b* values were higher in the presence of perch. These high a* and b* values were attributed to increased activity leading to more myoglobin storage in the muscle. However, it is thought that the perching behaviour (mean ± standard error = 6.10% ± 0.16%) was not observed at a level to create this effect in our trial. As the number of studies on this topic continues to increase, it is believed that a more comprehensive evaluation can be conducted regarding the impact of barrier perch access on colour attributes. The findings of our study are consistent with prior research that has demonstrated the lack of significant impact of the QFR (Lippens et al., 2000; Üzüm and Toplu, 2013; Hussein et al., 2019; Ndazigaruye et al., 2019; Chodova et al., 2021) and BP (Zhao et al., 2012; Dereli Fidan and Okur, 2022) treatments on CL.

Growth performance

It was observed that the final BW was higher in the QFR- treatment compared to the QFR+ treatment according to trial findings. Similarly, Robinson et al. (1992) and Nielsen et al. (2003) declared that the final BW was lower in broiler chickens subjected to qualitative feed restriction treatments. Contrary to our findings, there are also trials that the final BW is not affected by feed restriction (Hassanabadi and Moghaddam, 2006; Jang et al., 2009; Dairo et al., 2010; Azizi et al., 2011; Butzen et al., 2013; Üzüm and Oral Toplu, 2013; Yang et al., 2015; Xu et al., 2017). When the trial results were evaluated, it was determined that the feed restriction resulted in a decrease in BWG during d 0−21. The difference between the QFR treatments disappeared after the end of the feed restriction during d 22−42. However, the QFR+ treatment resulted in a total BWG of 2671.61 g, while the QFR- treatment resulted in a total BWG of 2911.96 g, and the difference between the means was statistically significant during d 0−42. These findings are consistent with the report by Cornejo et al. (2007). On the contrary, Jang et al. (2009) stated that the difference between the control and restriction treatments (15% and 30% energy + protein during d 8 to 14) in terms of average weight gain for d 0−35 was insignificant in their trial. Dairo et al. (2010) reported that the difference between the control and restriction treatments (10% protein + 7% energy during d 0 to 56) was insignificant in terms of average weight gain for d 0−56 in Archer Arbor broilers. As observed in the current trial, several trials have previously reported that feed restriction affects cumulative FI during d 0−42, with cumulative FI being lower in the feed restriction treatment (Robinson et al., 1992; Dairo et al., 2010; Üzüm and Oral Toplu, 2013). In contrast, some reports indicate that feed restriction does not affect total FI, contrary to trial findings (Hassanabadi and Moghaddam, 2006; Yang et al., 2009; Jang et al., 2009; Azizi et al., 2011; Butzen et al., 2013; Xu et al., 2017). Since feed restriction was applied during d 0−21 in the trial, it was determined that FCR was better in the QFR- treatment. During d 22−42, it was reported that FCR was better in the QFR+ treatment, unlike the first three weeks after the end of the feed restriction. When FCR during d 0−42 is considered, it was observed that the FCR was better in the QFR- treatment. Unlike the present trial, many researchers stated that the effect of feed restriction on FCR was insignificant (Hassanabadi and Moghaddam, 2006; Jang et al., 2009; Yang et al., 2009; Butzen et al., 2013). In research on feed restriction, it is seen that feed restriction periods or levels of energy and protein restriction are constructed quite differently from each other. The discrepancy among research findings about growth performance might be shaped due to this reason. Our findings generally support previous reports in the literature, which reported that the effect of BP presence on BW at d 42 (Pettit-Riley and Estevez, 2001; Bizeray et al., 2002; Estevez et al., 2002; Heckert et al., 2002; Şimşek et al., 2009; Ventura et al., 2010; Bailie et al., 2013; Bailie and O'Connell, 2015; Bench et al., 2017; Kıyma et al., 2016; Akşit et al., 2017; Yıldırım and Taşkın, 2017), BWG during d 0−42 (Şimşek et al., 2009; Hongchao et al., 2013; Bench et al., 2017), FI and FCR during d 0−42 (Pettit-Riley and Estevez, 2001; Bizeray et al., 2002; Şimşek et al., 2009; Ventura et al., 2010; Zhao et al., 2012; Hongchao et al., 2013; Bench et al., 2017; Kıyma et al., 2016; Akşit et al., 2017) was insignificant. In the trial, it was observed that the mobility level of broiler chickens was more influenced by age rather than the presence of barrier perch, which is consistent with the findings of Weeks et al. (2000) that the level of mobility decreases with increasing age (data not shown). Although the use of barrier perch became mandatory in the BP+ treatments as they were placed between the feeder and the drinker, the age-related decrease in the mobility level may have limited the effectiveness of the barrier perch. Therefore, it is thought that the presence of barrier perches may not have significantly affected the growth performance of broiler chickens.

Diet cost analysis

Diet costs constitute approximately 70% of the total production cost in the poultry industry (Alqaisi et al., 2017; Mallick et al., 2020). The cost of protein and energy sources in the diet represents around 95% of the overall feed cost (Mallick et al., 2020). Therefore, maximizing profitability from the feed is crucial for producers (Spring, 2013). Since the trial involved reducing the protein and energy levels in the diet, an economic evaluation was conducted through a diet cost analysis. A comparison was made between treatments in terms of total

diet costs and diet costs per kg weight gain. It was determined that the total diet cost per broiler chicken was lower in the QFR+ treatment during d 0−42 (QFR+ €2.01, QFR- €2.20, P<0.001). However, when the diet cost per kg weight gain is considered, no significant difference was between the treatments during d 0−42 (QFR+ €0.75, QFR- €0.76, P=0.511). These findings indicate that despite the reduced growth performance (final BW; QFR+ 2718.16 g, QFR- 2958.69 g, FCR during d 0−42; QFR+ 1.65, QFR- 1.59) resulting from protein and energy restriction in the QFR+ treatment, it did not adversely affect economic production.

Conclusions

Summarized, the present research has indicated that barrier perch access did not have a significant impact on growth performance and meat quality traits in broiler chickens. Based on the findings, it can be concluded that early qualitative feed restriction did not significantly affect the quality traits of the breast muscle. Although an improvement was observed in the FCR and BWG in the QFR+ treatment after the end of the feed restriction, it was not enough to catch up with the QFR- treatment. However, it is noteworthy that the cost of diet per unit weight gain was similar in both treatments. This indicates that the feed restriction treatments in the trial did not have a negative impact on economic production. Although some research has been conducted on these issues, it is thought that research should be continued in order to gain more comprehensive insights into the effects of these factors. In addition, it is thought that the information obtained from this research will be usable in terms of contributing resources to scientific investigations to be carried out with similar approaches.

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