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Does feed restriction and pasture affect carcass composition and meat quality of fast-growing chickens?

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Abstract: The aim of the study was to evaluate the effect of feeding regime (FR) and the combination of FR with pasture on the carcass composition and meat quality parameters of fast-growing chickens. Ross 308 chickens were split into three groups: Group 1 was fed *ad libitum*, and Groups 2 and 3 had a restricted diet. The chickens were feed-restricted at a rate of 70% *ad libitum* from 8 to 14 days of age. In Group 3, after restriction at the age of 21 days, chickens were kept on a pasture until the end of the experiment at 35 days of age. The chickens were fed *ad libitum* prior to and following restriction. Feed restriction and the combination of feed restriction and pasture significantly reduced final body weight, but the dressing out percentage was not affected. The breast percentage was the highest (P = 0.005) in the *ad libitum* group (30.5%), followed by the restricted group (28.2%) and the lowest in the group with a combination of feed restriction and pasture (27.4%). Breast pH and colour measured 24 h *post mortem* were not affected, whereas texture expressed as F_{max} was the lowest in the group with the combination of feed restriction and pasture (P = 0.05). There was no effect of the group on meat dry matter, crude protein, cholesterol, and fatty acid content, but ether extract was the highest, and significantly so, in the *ad libitum*-fed group. In summary, feed restriction and the combination of feed restriction and pasture negatively affected final body weight and breast and abdominal fat percentages, which might be related to a short realimentation period for compensatory growth. However, these conditions negligibly affected carcass composition and the physical and chemical parameters of the meat.

Keywords: chicken; limited feeding; pasture; meat characteristics

Feeding strategies and welfare play a vital role in chicken meat production when animal welfare is related to consumer demand, such that the well-being of chickens and the feeding strategies used with them lead to improved profitability. In terms of feeding strategies, *ad libitum* and feed restric-

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tion (FR) techniques have been applied. *Ad libitum* feeding of fast-growing chickens supports growth and reduces the feed conversion ratio (FCR); however, it is associated with metabolic disorders, higher mortality, and meat myopathies (Ebeid et al. 2022a). FR applied in early life improves chickens' health and minimises breast myopathies (Ebeid et al. 2022b). The results of FR are affected by the age at which feed restriction commences and by the restriction intensity (Tumova et al. 2002). In our recent studies, FR was applied at three weeks of age on 70% *ad libitum* and led to decreased growth, improved FCR, and negligible effects on carcass composition and physical and chemical meat quality parameters (Tumova et al. 2021, 2022 a, b). However, it is better to use limited feeding at two weeks of age for fast-growing chickens with a short growing period because of the lower impact on growth (van der Klein et al. 2017; Tumova and Chodova 2018; Lunedo et al. 2019).

Pasture/outdoor access for poultry is an important feature of chicken welfare, and pasture may provide some additional nutritional benefits by promoting lower fat and higher vitamin and mineral content in meat (Sossidou et al. 2015). Sales (2014) indicated that pasture increases meat protein content, n-3 fatty acid quality, shear force and meat colour b* parameter. Woo-Ming et al. (2018) stated that chickens foraging on pasture showed a tendency to have reduced meat fat and cholesterol and increased protein concentration. The beneficial effect of pasture on meat quality depends on pasture intake. Ponte et al. (2008) and Englmaierova et al. (2021) suggested that the restriction of a cereal-based diet on free-range chicken increased foraging on pasture, leading to higher meat n-3 PUFA. Both authors carried out their experiments on chickens with slower growth; thus, the question remains whether FR in free-range chickens has a similar effect in fast-growing chickens. Therefore, the study's objective was to evaluate the effect of the feeding regime and the combination of FR with pasture on carcass composition and meat quality parameters of fast-growing chickens.

MATERIAL AND METHODS

The fattening experiment with fast-growing chickens was approved by the Ethics Committee of the Central Commission for Animal Welfare at the Ministry of Agriculture of the Czech Republic. The feeding tests agreed with Directive 2010/63/EU for experiments with animals and were carried out at the International Poultry Testing Station Ústrašice (Tábor, Czech Republic).

Animals and experimental design

The experiment was conducted with 1 260 males of the fast-growing hybrid Ross 308. The chickens were weighed at the age of one day, labelled by wing banding, and split into nine littered pens. There were 140 chickens in one pen with a stocking density of 14 birds per m^2. The experiment was divided into three treatments: Group 1 was fed *ad libitum* over the whole experiment (ADL), Group 2 was restricted from eight to 14 days of age at a rate of 70% *ad libitum* (R), Group 3 was restricted to Group 2, and at the age of 21 days, chickens were transferred to outdoor pens with pasture (4 m^2 per bird) until the end of the experiment at 35 days of age (RP). The amount of feed for restricted groups was calculated daily based on the daily feed intake of the ADL group. In the restricted groups, chickens were fed *ad libitum* prior to and after restriction. Each group had three replicates. The chickens in the experiment were fed the starter diet until 14 days (216 g/kg crude protein, 12.6 MJ metabolisable energy), the grower from 15 to 28 days (196 g/kg crude protein, 12.9 MJ metabolisable energy) and the finisher from 29 to 35 days of age (185 g/kg crude protein, 13.5 MJ metabolisable energy). The environmental conditions were according to Ross 308 recommendations. The chickens were individually weighed on Day 1 and at the end of the experiment at 35 days of age, and data were used to count the daily weight gain (DWG). The feed conversion ratio (FCR) was calculated per pen from weekly records.

Carcass composition

At the end of the experiment, 10 cockerels per group were selected for carcass analysis. The chickens were selected on weight close to the final weight of each group and slaughtered after 12 h fasting at the International Poultry Testing Station slaughterhouse Ústrašice. The chicken slaughtering and carcass cuts are described in detail in Tumova et al. (2021). Weights of the carcass and cuts were used

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to calculate breast, thigh, thigh meat and abdominal fat (AT) percentage. The dressing out percentage (DOP) was calculated using the following formula:

$$DOP = [(\text{carcass weight} + \text{heart} + \text{liver} + \text{gizzard weights})/\text{slaughter weight}] \times 100 \quad (1)$$

Physical meat quality

Physical meat quality measurements were performed on the right breast. pH was measured 24 h *post mortem* by a Jenway 3 510 pH meter (Jenway, Essex, UK). Additionally, meat colour was determined 24 h *post mortem* using a Minolta SpectraMagic NX analyser (Konica Minolta Sensing, Inc., Osaka, Japan). Drip loss was calculated as the difference between the weight of the right breast at the time of slaughter and after storage for 24 h at 4 °C. The cooking loss was detected by calculating differences between the raw and cooked breast samples. The Warner–Bratzler method was used to determine meat tenderness. All the methods are described in detail by Chodova et al. (2021).

Meat chemical analyses

Basic chemical analysis of chicken meat was performed on left breast meat, and fatty acid determination was performed on the left deboned thigh meat. After cutting, the samples for analyses were immediately vacuum-packed and frozen at −20 °C and then stored until analyses. Approximately 24 h before analyses, samples were thawed at +4 °C. Samples were analysed using the methods of AOAC (2005). The dry matter was determined by drying in an oven (procedure 934.01), the ether extract was determined by extraction with petroleum ether (procedure 920.39), and the protein content was determined using a Kjeltec Auto (procedure 954.01). The cholesterol content was detected by a gas chromatographic method using a Perkin Elmer 5000 apparatus (Perkin Elmer Inc., Wellesley, MA, USA). The total cholesterol content was calculated based on an external standard technique from a standard curve of peak area to concentration. Detailed methods of chemical analyses are described by Tumova et al. (2022b)

Fatty acids were assessed following extraction of total lipids according to the methods of Folch et al. (1957) and as described by Okrouhla et al. (2013). Methanolysis was performed by the catalytic effect of potassium hydroxide and extraction of acids in the form of methyl esters in heptane. The methyl ester content was analysed by gas chromatograph Master GC (Dani Instruments S.p.A., Cologno Monzese, Italy) with a flame ionisation detector and a column with polyethylene glycol as the stationary phase (FameWax; 30 m. 0.32 mm. 0.25 μm). The results were analysed using Clarity software, v5.2 (Clarity Software Group, Solihull, UK) and quantified based on known retention times from a standard Food Industry FAME Mix (Restek Co., Bellefonte, PA, USA). The atherogenic index (AI) was calculated according to Chilliard et al. (2003) as follows:

$$AI = [C12{:}0 + (4 \times C14{:}0) + C16{:}0]/(\Sigma MUFA + \Sigma PUFA) \quad (2)$$

where:
AI – atherogenic index;
MUFA – mono-unsaturated fatty acid;
PUFA – poly-unsaturated fatty acid.

The thrombogenic index (TI) was calculated in accordance with Ulbricht and Southgate (1991) using the formula:

$$TI = (C14{:}0 + C16{:}0 + C18{:}0)/[(0.5 \times \Sigma MUFA)] + [(0.5 \times \Sigma n\text{-}6\ PUFA) + (3 \times \Sigma n\text{-}3\ PUFA) + (n\text{-}3/n\text{-}6\ PUFA)] \quad (3)$$

where:
TI – thrombogenic index;
MUFA – mono-unsaturated fatty acid;
PUFA – poly-unsaturated fatty acid.

Statistical analysis

Records of growth, feed consumption, carcass analyses, and physical and chemical analyses were processed by one-way analysis of variance using ANOVA in SAS software v9.4 (SAS Institute, Inc., Cary, NC, USA). The differences between groups in growth measurements were tested by the Scheffe test, FCR, carcass composition, and physical and chemical parameters by the Duncan test.

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Significance was considered at the level $P \leq 0.05$ and is indicated by different superscripts.

RESULTS AND DISCUSSION

Performance and carcass composition

Table 1 shows the basic results for the performance of the chickens. The growth of chickens, final weight at 35 days of age and DWG, were significantly reduced in both restricted groups compared to the ADL feeding group. The final weight and DWG of the restricted groups were 75% those of the ADL group. There were no differences between the two restricted groups. However, Ponte et al. (2008) and Englmaierova et al. (2021) observed that pasture foraging positively affected the growth of restricted chickens. These contrasting results may be related to the chicken genotype, given that in the present experiment, we used fast-growing chickens. In contrast, the cited authors used medium-growing chickens with a longer realimentation period. Presumably, a short time to recover growth depression after FR in the present study led to lower growth, in contrast to the findings of our previous study (Tumova et al. 2022a). The lack of compensatory growth in both the restricted groups might have been affected by lower feed consumption expressed by FCR, and pasture foraging did not enhance nutrient supply. Feed restriction decreased FCR in Group R by 9% and in group RP by 11%.

FR and the combination of FR with pasture foraging had negligible effects on carcass measurements (Table 2). The significantly lower slaughter weight of both restricted groups did not affect DOP, thigh percentage or thigh meat percentage, which aligns with the findings of Tumova et al. (2021; 2022a) and Ebeid et al. (2022a) but contrasts with the findings of Ponte et al. (2008) and Englmaierova et al. (2021), who observed lower DOP and thigh percentage in restricted chickens. The discrepancies are presumably due to differences in genotypes used in the studies. Similar differences between genotypes are described by Tumova et al. (2021). In the present study, FR reduced the breast percentage ($P = 0.005$), with significant differences between R and RP group. The negative effect of FR on breast percentage has been described (Livingston et al. 2019; Englmaierova et al. 2021; Ebeid et al. 2022b; Tumova et al. 2022a) and, according to Velleman et al. (2014), relates to a short recovery time after restriction. The decrease in the breast per-

Table 1. Results of growth and feed consumption

Measurement	Group			SEM	Significance
	ADL	R	RP		
Final weight (g)	2 034[a]	1 520[b]	1 534[b]	9.81	0.001
Daily weight gain (g)	56.8[a]	42.2[b]	42.6[b]	2.54	0.001
FCR (kg)	1.70	1.55	1.52	0.04	0.152

ADL = *ad libitum*; FCR = feed conversion ratio; R = feed restriction; RP = combination of feed restriction and pasture; SEM = standard error of the means

[a,b]Means within a row differ ($P \leq 0.05$)

Table 2. Results of carcass composition

Measurement	Group			SEM	Significance
	ADL	R	RP		
Slaughter weight (g)	2 201[a]	1 600[b]	1 599[b]	54.90	0.001
Dressing out percentage (%)	77.7	76.3	76.9	0.32	0.199
Breast percentage (%)	30.4[a]	28.2[b]	27.4[c]	0.43	0.005
Thigh percentage (%)	28.4	29.6	29.2	0.31	0.294
Thigh meat percentage (%)	20.8	20.4	20.4	0.26	0.819
Abdominal fat percentage (%)	0.82[a]	0.62[b]	0.48[c]	0.05	0.016

ADL = *ad libitum*; R = feed restriction; RP = combination of feed restriction and pasture; SEM = standard error of the means

[a–c]Means within a row differ ($P \leq 0.05$)

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centage of RP group chickens compared to R group is in contrast with the data of Englmaierova et al. (2021), who reported a higher breast percentage of chickens on pasture and stated that it is associated with higher locomotor activity in outdoor chickens. The inconsistency of the results may be related to the genotypes used in the studies, given that fast-growing chickens are less active than medium- or slow-growing chickens (Branciari et al. 2009). Abdominal fat was reduced by FR (P = 0.016) and significantly differed in both restricted groups. The results are aligned with the findings of Englmaierova et al. (2021). Yang et al. (2010) suggested that FR resulted in suppressing hepatic lipogenesis, activating fatty acid oxidation, and minimising the number of abdominal adipose cells throughout the FR period. The further reduction in abdominal fat in RP chickens corresponds with the findings of Ponte et al. (2008) and Sales (2014) and might be associated with energy requirements for physiological processes (Omosebi et al. 2014). The effect of FR on carcass composition and discrepancies between the present study and literature are related to different genotypes and selection targets (Tumova et al. 2021).

Physical and chemical meat quality

Physical meat quality parameters were not affected by FR or the combination of FR and pasture (Table 3). The marginal effect of FR on physical measurements of meat was described in previous studies (Englmaierova et al. 2021; Ebeid et al. 2022b; Tumova et al. 2022b). In terms of the effect of pasture, Fanatico et al. (2005) and Woo-Ming et al. (2018) similarly describe that access to pasture did not affect physical meat parameters; however, Sales (2014) and Englmaierova et al. (2021) reported the effect of pasture on shear force and meat colour. Pasture foraging increases the redness and yellowness of meat through the consumption of herbage containing carotenoids (Sales 2014). Inconsistent results lead to the conclusion that the effect of pasture on meat quality depends on the duration of pasture access and pasture composition.

A negligible effect of treatments was observed in the chemical composition of the meat (Table 4). Only intramuscular fat was significantly reduced in both restricted groups, which corresponds with the findings of our previous study (Tumova et al. 2022b). On the other hand, Ebeid et al. (2022b) reported inconsistent results for the effect of FR on meat content, which might be associated with different methods of FR. Englmaierova et al. (2021) observed a reduction in cholesterol in restricted chickens; however, in the present study, FR did not affect cholesterol content. The combination of FR and pasture tended to increase meat cholesterol in the present study. Ponte et al. (2008) explain that increased meat cholesterol was observed in chickens subjected to the higher intensity FR. This might be the case in the present study when pasture in the realimentation period might reduce feed mixture consumption.

In contrast with the findings of Sales (2014) and Englmaierova et al. (2021) but in agreement with those of Ponte et al. (2008) and Woo-Ming et al. (2018), pasture foraging did not affect fatty acid composition. Pasture foraging is affected by many factors and forces chickens to have a higher intake

Table 3. Data of physical meat quality

Measurement	Group			SEM	Significance
	ADL	R	RP		
pH24	5.65	5.61	5.58	0.03	0.642
Meat colour					
L*	52.7	52.0	51.7	0.74	0.856
a*	–1.31	–1.84	–1.31	0.14	0.166
b*	7.80	7.14	8.6	0.32	0.116
Drip loss (%)	0.40	0.45	0.41	0.03	0.715
Cooking loss (%)	25.9	25.3	24.5	0.32	0.166
Texture (N)	14.9^{a}	14.3^{a}	13.1^{b}	0.31	0.050

ADL = *ad libitum*; R = feed restriction; RP = combination of feed restriction and pasture; SEM = standard error of the means
^{a,b}Means within a row differ ($P \leq 0.05$)

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Table 4. Results of meat chemical composition

Measurement	Group			SEM	Significance
	ADL	R	RP		
Dry matter (g/kg)	270.8	266.4	270.1	0.12	0.266
Crude protein (g/kg)	221.9	225.0	224.5	0.10	0.422
Ether extract (g/kg)	1.85[a]	1.36[b]	1.34[b]	0.07	0.001
Cholesterol (mg/kg)	414.6	414.3	430.5	8.35	0.679
SFA (%)	34.9	34.7	33.3	0.37	0.164
MUFA (%)	38.2	38.3	37.8	0.22	0.668
PUFA (%)	26.9	27.0	28.8	0.39	0.071
PUFA n-6 (%)	24.5	24.7	26.4	0.38	0.074
PUFA n-3 (%)	2.16	1.11	1.31	0.02	0.883
n3/n6	0.089[a]	0.088[a]	0.081[b]	0.01	0.043
AI	0.527[a]	0.518[a]	0.464[b]	0.01	0.040
TI	0.905	0.897	0.842	0.01	0.148

ADL = *ad libitum*; R = feed restriction; RP = combination of feed restriction and pasture; SEM = standard error of the means
[a,b]Means within a row differ ($P \leq 0.05$)

of pasture forage, which reflects that the composition of fatty acids is restricted by mixed feed Englmaierova et al. (2021). However, Woo-Ming et al. (2018) stated that fast-growing broilers may not forage actively.

In conclusion, the present study shows that FR on 70% of *ad libitum* deteriorated performance and negligibly affected carcass composition and meat quality. Pasture foraging in feed-restricted chickens impaired growth, decreased breast and abdominal fat percentages, and had marginal effects on physical and chemical meat quality parameters. The negative effect of treatments in the present study, presumably, is related to the short growing period of fast-growing chickens, which does not allow compensation for deprivation after FR. Moreover, pasture foraging is insufficient, presumably due to foraging activity being too low to consume enough nutrients that the fast-growing genotypes consume.

Conflict of interest

The authors declare no conflict of interest.

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