doi: 10.17221/7974-CJAS

A mobile system for rearing meat chickens on pasture

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ABSTRACT: The effect of grazing on the productive performance and meat quality was evaluated for chickens (Ross 308, n = 192). Chickens were kept in two pens on wooden shavings (2 × 96) from one day of age. On day 23 of age, one group was moved to a pasture and kept in a portable floorless pen with an area of 0.11 m^2 per chicken. The field portion of the experiment was conducted from the 1st till the 18th of June 2013. A control group was kept in the original pen until the end of the experiment at 6 weeks of age. Both groups were fed the same pelleted feed *ad libitum*. For the pasture-reared group, the moveable shelter was moved twice daily around the pasture with a predominance of grass species. The herbage intake of chickens was indirectly assessed by compressed sward height measurement after each cage movement, which employed a rising plate-meter. In the pasture, chickens preferred grass over clover. There was no significant effect of grazing observed on chicken body weight. The mortality of chickens in the grazing group was lower than that in the control group. Pasture treatment improved meat flavour by 9% (P = 0.014), produced breast meat with significantly higher (P = 0.009) redness, and almost doubled the concentration of α-tocopherol (P < 0.001). There were no significant effects of grazing on the dry matter, fat, cholesterol or pH of the meat. The production of TBARS in the breast meat of the pasture group after storage at 4°C for 5 days was lower (P = 0.013) than that in the breast meat of the control chickens. Although the differences between K, Ca, P, Mg, and N concentrations in pasture and soil before and after grazing reached 20%, these differences were not significant.

Keywords: Ross 308; free ranging; grazing; meat; vitamin E; TBARS

INTRODUCTION

Free-range systems of rearing meat chickens on pasture utilize a variety of methods, conditions, and rearing factors. Specific legislative conditions only exist for organic rearing. In the organic rearing of poultry, birds must have free access to a pasture. Meat poultry must have yard access to a pasture for at least one half of the organic-rearing duration, and they can be restricted only due to unsuitable climatic conditions (Lorenz et al. 2013). The quality of the consumed forage varies throughout the season (Meisser et al. 2014). Although grazing is a natural part of chicken diet, it has been studied rarely. Preliminary results show that repeated stocking but not duration of stocking has a significant effect on herbage growth and canopy cover (Breitsameter et al. 2013) and that grasses are generally more suitable for outdoor chicken runs than are herbs. Free-range systems of chicken rearing on pasture can reduce supplementary feed and improve poultry welfare compared with poultry rearing in halls with limited area per bird (Ponte et al. 2008). One could predict that both factors (welfare and pasture) will improve the qualitative parameters of meat (Grashorn 2010). Genotype and age are other factors important for meat quality. Fanatico et al. (2009) showed that more meat quality differences were due to genotype than to outdoor access. Outdoor access resulted in leaner

Supported by the Ministry of Agriculture of the Czech Republic (Project No. MZE RO0714 and Project No. MZE RO0414).

doi: 10.17221/7974-CJAS

meat, but only in the case of slow-growing birds. Chicken grazing depends on supplementary feed and can account for 10–15% of the feed intake (Lorenz and Grashorn 2012). Herbage has a beneficial profile of fatty acids and antioxidants, which can improve the quality of poultry meat and eggs (Sales 2014; Skrivan and Englmaierova 2014) and the quality of heifer meat (Velik et al. 2013) on pasture. Pasture is a comparable source of carotenoids, such as algae (Englmaierova et al. 2013; Kotrbacek et al. 2013). Pasture is also a source of phytoestrogens. Phytoestrogens represent a family of plant compounds showing both estrogenic and antiestrogenic properties. They may potentially confer health benefits related to cardiovascular diseases or cancer (particularly of breast and prostate) (Kalac 2013). Free-range systems of chicken rearing are based on a slowly- (or medium- to slowly-) growing vital chicken genotype with a resistance to diseases and that is well-adapted to rearing outside of a hall. However, fast-growing chickens, which are usually intensively reared in small areas in halls, are also often chosen for free-range production. Meat functional properties of fast- and medium-growing strains of chickens reared in poultry houses with outdoor pasture availability appeared much more attractive both for industry and consumer (lower drip and cook losses and higher tenderness), whereas from a nutritional point of view, meat from slow-growing strains appeared healthier (less fat and higher content of n-3 polyunsaturated fatty acid) thus might better fit with the consumer's expectations of organic products (Sirri et al. 2011). These commercial hybrids, which are fed specific low-density diets, are usually slaughtered at a young age (35–55 days). Due to their low growth potential, these commercial chickens are not suitable for 81-day production, which is the minimum mandatory slaughter age for organic chickens. Free-range meat type chickens are usually reared in a paddock from 21 to 28 days of age and provided with a shelter that can protect them from sun, rain, and cold to some extent. (A canopy of trees may, alternatively, be suitable.) The surface area per chick varies from one m^2 to tens of m^2. If poultry are not transferred from one paddock to another frequently enough, poultry excreta destroys the green but enriches the soil with nutrients (though unevenly). Long term poultry grazing can disproportionably increase soil phosphorus concentration in relation to that of nitrogen (Hilimire et al. 2012). Mobile pens, as described by Eleroglu et al. (2013), are suitable for the protection of birds, as well as their feeding and grazing. Eleroglu et al. (2013) utilized chicken mobile housings (1.5 × 1.5 m), with each housing unit containing 20 birds, with 10 birds per m^2 stocking density, placed in a 100 m^2 grazing area. The objective of this research was to improve and verify the mobile system of meat chicken rearing on pasture.

MATERIAL AND METHODS

A total of 192 one-day-old chickens (Ross 308) were used in this experiment. Chickens were kept

Table 1. Diet composition and nutrient content in pasture (g/kg)

Ingredient	Starter	Grower	Finisher	Pasture
Wheat	413.5	538.4	597.9	
Maize	249.0	200.0	180.0	
Soybean meal	295.0	230.4	180.0	
Soya oil	18.0	10.0	15.0	
Monocalcium phosphate	9.5	6.0		
Limestone			12.0	
Sodium hydrogen carbonate	2.0	1.5	1.3	
Sodium chloride	2.0	2.6	2.6	
DL-Methionine	2.7	2.3	1.8	
L-Lysine	2.8	3.1	3.6	
L-Threonine	0.5	0.7	0.8	
Vitamin-mineral premix[1]	5.0	5.0	5.0	
Analyzed composition				
Dry matter	880.4	880.7	880.1	292.0
Crude protein	200.3	181.5	170.2	52.4
Crude fibre	32.8	30.6	29.8	72.7
Calcium	8.4	8.0	7.9	2.6
Total phosphorus	6.1	5.9	5.6	1.1
AME_N (by calculation, MJ/kg)	12.5	12.1	12.3	1.5

AME_N = apparent metabolizable energy

[1]vitamin-mineral premix provided per kg of diet: retinyl acetate 3.6 mg, cholecalciferol 13 µg, α-tocopherol acetate 30 mg, menadione 3 mg, thiamine 3 mg, riboflavin 5 mg, pyridoxine 4 mg, cyanocobalamin 40 µg, niacin 25 mg, calcium pantothenate 12 mg, biotin 0.15 mg, folic acid 1.5 mg, choline chloride 250 mg, copper 12 mg, iron 50 mg, iodine 1 mg, manganese 80 mg, zinc 60 mg, selenium 0.3 mg

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in 2 pens on wood shavings (96 birds per pen) with a 16-hour lighting program and ventilation provided by a temperature-controlled fan. Each pen was equipped with nipple drinkers and pan feeders. Feed and water were provided *ad libitum*. At 23 days of age, after a 2-day delay due to poor weather conditions, 96 chickens were relocated to floorless portable pen (Figures S2–S6) on pasture until the end of the experiment at 6 weeks of age (1st–18thof June). A mixed pasture sample was taken before the start of the experiment. This sample was lyophilized and the nutrient concentration was subsequently determined. Table 1 presents ingredients and nutrient content of the mixed feed and pasture. The chickens were fed mixed feed starter in days 0–13 of age, grower feed in days 14–27 of age, and finisher feed in days 28–41 of age. The protocol was approved by the Ethical Committee of the Institute of Animal Science. The field part of this experiment was conducted on 0.7 ha of experimental grassland at Netluky village, Czech Republic (150°2'21.344''N, 14°36'51.075''E) (Figure S1). The altitude of the study site was 284 m a.s.l., the average (2009–2012) precipitation in June ranged from 60 to 72 mm, and the mean annual temperature ranged from 16.1 to 18.5°C. The soil was loamy clay. Plant-available P, K, and Mg contents were analyzed according to the Mehlich III method (Mehlich 1984). The dominant species of the existing temporary grassland were *Lolium perenne* (“Merlinda”) and *Festuca pratensis* (“Kolumbus”), with 20% being *Trifolium pratense* (“Violetta” and the intergeneric hybrid “Felina”). The floorless portable pen dimensions were 3.0 × 3.6 × 0.6 m for a total area of 10.8 m^2 per pen. The pen contained hat drinkers connected to a water basin. Feed was provided in trough feeders (length of 100 cm) with chicken access on both sides. After the first full day on pasture, the chickens were moved to visually determine the effects of consumption and waste accumulation on the pasture. After this initial test it was decided to move the portable pen twice daily, once during the morning feeding at 8:00 h and again at 18:00 h. The herbage intake of the chickens was indirectly assessed by compressed sward height (CSH) measurement after each cage movement, employing a rising plate-meter according to Castle (1976). Measurements were taken at 12 locations and were evenly distributed throughout the pasture plot to achieve an average difference. The sward was first measured before placement of the portable pen and once again after the portable pen was relocated to another position. Pasture composition and grazing preference were determined by sampling the cut sward from locations where pen were not placed and from locations where pen had been removed. Samples were collected on 3 separate days spread over the pasturing period in June, 2013. Before chicken grazing, four samples of sward biomass were collected three times per field experiment (on 6th, 12th and 18th of June, 2013). Average results are shown in Table 5. For the forage chemical analysis, samples were dried at 85°C (Table 6). Soil quality was determined by taking soil samples in the pastured area prior to and after chicken grazing to determine the level of nutrients. To determine pH/KCl and macro-nutrients content, four samples (each consisting of three subsamples) were collected in a 60 m line at a 0–8 cm depth and plant residues were removed. At 42 days of age, 10 male chickens (with an average final weight of 3.15 kg) from each dietary treatment were slaughtered, and the breast muscles were dissected, measured for pH, and used in a sensory evaluation. Meat was stored at –70°C until analysis.

Analyses. For the sensory evaluation, the procedure described by Dolezalova et al. (2010) was applied. Chicken breasts with skin were evaluated by a panel of ten selected assessors that were trained according to ISO 8586-1:2012. The evaluation was performed in a sensory laboratory equipped with booths. The samples were coded, cooked at 180°C for 1 h, and served at 50°C. The appearance and odour of the samples were scored, followed by flavour and overall acceptability. A nine-point scale was used for assessment (1 – very desirable, 9 – very undesirable). The pH of the soil and the breast meat (24 h *post mortem*) were measured using a pH meter (type 3520; Jenway, Stone, UK). Before the chemical analysis, the meat was thawed at 4°C for 48 h. To determine the α-tocopherol content of the feed, lyophilized pasture vegetation, and skinless breast muscle, each sample was homogenized and vitamin E was determined in accordance with the EN 12822 (2000) European standard for high-performance liquid chromatography (HPLC), using a diode-array detector (VP series; Shimadzu, Kyoto, Japan). The samples were subjected to alkaline saponification with 60% potassium hydroxide followed by appropriate extraction with diethyl ether. The standard used was

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α-tocopherol (purity ≥ 97.0%) (Sigma-Aldrich, St. Louis, USA). For determination of the cholesterol content in meat, lipids were saponified, and the unsaponified matter was extracted with diethyl ether in accordance with ISO 3596:2011). Silyl derivatives were prepared using TMCS and HMDS silylation reagents (Sigma-Aldrich) and quantified on a gas chromatograph equipped with a SAC-5 capillary column (Supelco, Bellefonte, USA) that was operated isothermally at 285°C. Meat colour parameters (L^* = lightness, a^* = redness, b^* = yellowness) were determined using a Minolta CR-300 colorimeter (Minolta, Osaka, Japan). The lipid oxidation in the minced samples of breast meat that were stored at 4°C for 0 or 5 days was measured by the thiobarbituric acid method of Piette and Raymond (1999). Thiobarbituric acid-reactive substances (TBARS) were expressed in mg of malondialdehyde per kg of muscle. The harvested biomass was immediately weighed, and the percentage of dry matter was determined after 48 h of drying at 85°C. Dry matter was extracted using the Mehlich III method (Mehlich 1984), and plant-available Ca, P, K, and Mg contents were determined using ICP-OES. These minerals were determined after microwave mineralization in HNO_3 : HCl = 6 : 1, using inductively coupled plasma atomic emission spectroscopy (ICP-OES IRIS Intrepid II XSP Duo; THERMO Elemental, Franklin, USA). The soil samples were air dried, ground in a mortar, and sieved to 2 mm after removing living roots. To increase solubility of phosphorous forms bound on Al, soil samples were extracted using an acidic solution, Mehlich III (Mehlich 1984) with ammonium fluoride. Acidic reaction of the solution was adjusted by acetic and nitric acid. Total nitrogen (Nt) in both biomass and soil was determined after burning the sample at 850°C using a thermal conductivity detector (Nitrogen Analyzer TruSpec N; LECO Elemental, Franklin, USA). Oxidizable carbon (Cox) was determined after acidic oxidation of organic soil content and reduction of Cr^{VI} to Cr^{III} spectrophotometrically (SPEKOL 11; Carl Zeiss Jena, Jena, Germany).

In the statistical analyses, the mean of four samples per plot was used. Other analyses of the mixed feed, pasture (dry matter, crude protein, crude fibre, calcium, and phosphorus) and meat (dry matter and fat) were performed using standard AOAC (2005) procedures.

The data were statistically analyzed using the General Linear Models (GLM) procedure of SAS (Statistical Analysis System, Version 9.2, 2003). Differences between the treatment means were evaluated with a t-test and considered significant at $P < 0.05$. The results were presented as the means and standard errors of the mean (SEM).

Table 2. Growth traits

Item	Control	Grazing	SEM
Body weight (g)			
Day 0	47	48	0.2
Day 21	1178	1173	18
Day 28	1865	1870	47
Day 35	2588	2570	93
Day 42	3176	3140	114
Feed : gain (g : g)			
Days 0–21	1.40	1.30	
Days 0–42	1.85	1.80[1]	
Mortality			
Days 0–21 (%)	0.96	0.00	
Days 0–42 (%)	3.84	2.88	

[1]feed mixture only

RESULTS

The weight difference between groups of live chickens was not significant. Chicken mortality in the grazing group was by 25% lower than that in the control group (Table 2). Mortality, however, was generally low (3.84% in the control group). Average pasture vegetation intake, as measured by the CSH method, was 1 g dry matter (DM) per chick/day. After 19 days of grazing, the α-tocopherol concentration in the chicken breast meat approximately doubled (Table 3) and the breast meat redness also increased ($P < 0.009$). There was no significant effect of grazing on the dry matter, fat, cholesterol or pH of meat. However, the lightness and yellowness values in the breast meat of the

Table 3. The α-tocopherol content in mixed feed, lyophilized pasture, and breast meat (mg/kg DM)

Item	Control	Grazing	SEM	P
Mixed feed	34.7	35.2		
Pasture		68.4		
Breast meat	15.2[b]	29.7[a]	0.59	< 0.001

[a,b]values with different superscripts were significantly different

doi: 10.17221/7974-CJAS

Table 4. Breast meat traits

Item	Control	Grazing	SEM	*P*
Dry matter (%)	25.9	26.2	1.52	ns
Fat (%)	10.5	12.6	1.07	ns
Cholesterol (mg/kg)	680	665	5.2	ns
pH	5.8	6.0	0.04	ns
Lightness (L*)	66.1[a]	61.7[b]	1.01	0.026
Redness (a*)	0.3[b]	1.9[a]	0.34	0.009
Yellowness (b*)	9.1[a]	6.7[b]	0.43	0.003
TBARS				
Day 0	0.22	0.17	0.020	ns
Day 5	0.36[a]	0.23[b]	0.030	0.013

ns = not significant, TBARS = thiobarbituric acid reactive substances in raw meat and meat stored at 4°C for 5 days (TBARS values are presented in mg malondialdehyde/kg of meat)
[a,b]values with different superscripts were significantly different

Table 5. Sward composition

Sward composition (%)	Before grazing	After grazing	Grazing preference
Grass leaf	29	31	26
Grass stem	11	11	9
Grass flower	0	0	0
Grass dead material	38	51	30
Clover leaf	11	3	17
Clover leafstalk	4	1	7
Clover flower	0	0	0
Clover stolon	5	2	8
Clover dead material	2	1	3

pasture group decreased ($P < 0.026$ and $P < 0.003$, respectively), as did the concentration of oxidation products (Table 4). After storage at 4°C for 5 days, the production of TBARS in the breast meat of the pasture group was lower ($P = 0.013$) than in the meat of control chickens (Table 4). The average value of meat flavour for the pasture treatment was 5.08, which was an improvement of 9% over that of the control group ($P = 0.014$). Other sensory traits were not significantly affected. The chickens preferred grass to clover, as indicated by the grazing preference results: dead grass material, grass leaf, and grass stem represented 65% of the total pasture intake, as shown in Table 5. Pasture concentration of K, Ca, P, Mg, and N increased non-significantly over time. The soil concentration of these minerals decreased non-significantly (Tables 6 and 7); P and K decreased by 20% and Ca and Mg decreased by 9%.

DISCUSSION

The initial stocking density of birds on pasture was 0.11 m^2 with a total floorless portable pen area of 10.8 m^2. The stocking density at the end of the experiment (at 42 days of age) in the coop reached 27 kg on 1 m^2. The stocking density takes into account death during the experiment (3 chickens were crushed when the coop was shifted). Lower stocking densities were achieved in studies by Sun et al. (2013) (0.15 m^2/bird and 14.7 kg/m^2) and Ponte et al. (2008) (0.26 m^2/bird and only 8.2 kg/m^2) at the end of the experimental periods. However, in both cases, different genotypes (reared until 60 and 56 days of age) were used. Furthermore, the shelters used in these studies were moved less frequently than those in our experiment. The final weight of live grass-fed chickens usually decreases, and differences in live weight increase with longer duration time. Birds in both experimental groups had similar average body weight, which was most likely related to their short grazing period. However, there are some reported cases of body weight remaining unchanged, even after longer grazing periods, from that of indoor-reared control groups (e.g. body weights of 3.37 and 3.39 kg at 63 days of age (Fanatico et al. 2009), and body weights of 4.40 and 4.41 kg at 65 days of age for cockerels of a fast-growing genotype (Mikulski et al. 2011)). In these cases, feed composition, pasture quality, space, or climatic factors could have affected the results, too.

The average pasture intake, as measured using the indirect CSH method, was lower than the

Table 6. Quality of herbage collected three times during the field experiment

Item (g/kg)	June 2013			SEM	*P*
	6th	12th	18th		
K	23.6	22.6	26.1	0.86	ns
Ca	8.0	8.4	10.5	0.09	ns
Mg	1.8	2.0	2.1	0.13	ns
P	3.6	4.0	4.0	0.10	ns
N	21.8	24.0	22.9	1.03	ns

ns = not significant

doi: 10.17221/7974-CJAS

Table 7. Soil chemical properties before and after chicken grazing

Item	Before grazing	After grazing	SEM	*P*
pH	6.7	6.7	0.10	ns
P (mg/kg)	127.7	101.5	8.01	ns
K (mg/kg)	295.4	240.6	13.65	ns
Ca (mg/kg)	3540	3249	202.0	ns
Mg (mg/kg)	211.0	193.9	4.32	ns
C_{ox} (%)	22	21	0.10	ns
Nt (%)	0.198	0.182	0.0500	ns

C_{ox} = oxidizable carbon, Nt = total nitrogen, ns = not significant

results of other authors. Other authors' results vary by hundreds of percent, which may be due to pasture re-growth, botanical composition or quality, as well as the method of measurement. Another reason may be the inaccuracy of data. Ponte et al. (2008) found that in chickens reared on pasture for meat production, pasture represented approximately 2.5% of the total feed intake. Pasture intake represented 4 g DM per chick daily, which was four times more than that estimated by CSH. Lorenz and Grashorn (2012) concluded that chicken and hen pasture intake was 2–5 g DM daily, on the basis of postmortem examinations conducted at the end of their experiment. The intake of pasture was lower in chickens than in hens. According to Lorenz and Grashorn (2012), the intake of pasture accounts for 10–15% of the total feed intake. It is possible that this finding may include a number of individual components of the original dry matter. Singh and Cowieson (2013) estimated, on the basis of *n*-alkane concentrations in the pasture and digesta, that pasture intake varied from 3.7 to 4.3% of the total feed intake and represented 1.55–1.58 g of grass per chick per 1 h. In the present study, pasture treatment produced breast meat with significantly greater redness and flavour score and lower yellowness. Similar effects have since been found in a study of broiler meat production by Sun et al. (2013), and a study by Ponte et al. (2008) demonstrated that the intake of legumes on the pasture can contribute favourably to chicken meat sensory attributes.

The α-tocopherol content of pasture measured in this study was 68 mg/kg DM. Information about tocopherol content in fresh forage is not consistent (Kalac 2012). Larsen et al. (2012) reported that the concentrations of α-tocopherol in various grasses and legumes vary considerably with plant maturity and, to a lesser extent, with species. They reported a concentration of 36 mg in 1 kg DM lucerne mix. Kalber et al. (2011) found 3–7 mg of α-tocophero per kg DM in various plants. In contrast, Pavlata et al. (2008) reported 80–200 mg of α-tocopherol per kg DM in fresh forage. The almost doubled concentration of vitamin E in breast muscle after 19 days of pasture indicates that there is a good bioavailability of vitamin E in the pasture. Although meat does not represent a very important source of vitamin E in human nutrition, its strong antioxidative properties can improve the oxidative stability and shelf life of meat and meat products. Surai (2003) identified that vitamin E, as the main breaking antioxidant in biological systems, prevents free radical damage in tissues and is essential for improving the oxidative stability of broiler meat (Grau et al. 2001). A similar phenomenon was observed by Englmaierova et al. (2011), who demonstrated that the addition of vitamin E at 50 mg/kg decreased TBARS production in meat stored at 4°C. TBARS production decreased by 41% after 3 days of storage. In the present study, TBARS production decreased in pasture-reared chicken breast muscle by 36%, compared to that of the indoor-reared control chickens (stored at 4°C for 5 days). This result corresponds with a dietary vitamin E supplement of 50 mg/kg. A positive effect of vitamin E on beef shelf life was also observed (Gatellier et al. 2004). Higher oxidative stability of the lipids of pasture-reared chicken breast meat is consistent with the findings of Skrivan and Englmaierova (2014) regarding the eggs of pasture-reared hens.

Non-significant changes in the mineral concentrations of herbage during pasture, as well as in the soil before and after pasture, are most likely related to the recent origin (i.e. one year) of pasture in the area and the short duration of the experiment. Long-term poultry pasture increases nutrient concentration in both herbage and soil (McGinley et al. 2004; Glatz et al. 2005; Hilimire et al. 2012).

This study demonstrates the use of a mobile system of meat chicken pasture. The free ranging of chickens on pasture increased the oxidative

doi: 10.17221/7974-CJAS

stability of breast meat, mainly by increasing its vitamin E concentration. However, this management practice is not without drawbacks. Future research should focus on the effects of stocking density, rotation, and time between pen relocations on herbage quality, animal health, and the optimization of soil nutrient concentrations (specifically phosphorous). Particular attention is needed to better understand the effects of pasture-rearing meat chickens on soil N and P dynamics.

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Received: 2014–10–08
Accepted after corrections: 2014–12–04

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