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Citation for published version:
Veldkamp, T, Hocking, PM & Vinco, LJ 2017, 'Effect of crude protein concentration and dietary electrolyte balance on litter quality, foot pad dermatitis, growth performance and processing yields in two medium heavy turkey hybrids' British Poultry Science, vol 58, no. 5, pp. 557-568. DOI: 10.1080/00071668.2017.1349296

Digital Object Identifier (DOI):
10.1080/00071668.2017.1349296

Link:
Link to publication record in Edinburgh Research Explorer

Document Version:
Peer reviewed version

Published In:
British Poultry Science

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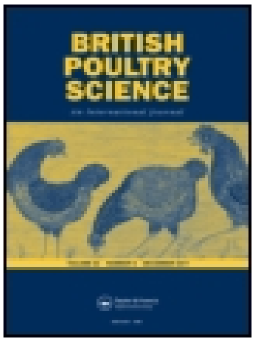

British Poultry Science

ISSN: 0007-1668 (Print) 1466-1799 (Online) Journal homepage: http://www.tandfonline.com/loi/cbps20

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To cite this article: T. Veldkamp, P.M. Hocking & L. J. Vinco (2017): Effect of crude protein concentration and dietary electrolyte balance on litter quality, foot pad dermatitis, growth performance and processing yields in two medium heavy turkey hybrids, British Poultry Science, DOI: 10.1080/00071668.2017.1349296

To link to this article: http://dx.doi.org/10.1080/00071668.2017.1349296

Accepted author version posted online: 04 Jul 2017.

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CBPS-2017-060

Ed. Kjaer, June 2017;

Publisher: Taylor & Francis

Journal: *British Poultry Science*

DOI: 10.1080/00071668.2017.1349296

Effect of crude protein concentration and dietary electrolyte balance on litter quality, foot pad dermatitis, growth performance and processing yields in two medium heavy turkey hybrids

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Running Head: Nutrition and FPD in turkeys

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Accepted for publication 18th May 2017

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Abstract. 1. An experiment was conducted to investigate the effect of crude protein (CP) concentration and dietary electrolyte balance (DEB) on growth performance, processing yields, litter quality and foot pad dermatitis (FPD) in male turkeys from two commercial hybrids. Soya bean meal was replaced by vegetable protein sources selected for lower K concentrations to lower DEB in order to improve litter quality and subsequent quality of foot pads.

2. Effects of CP on litter friability and wetness were not consistent during the production period. FPD in turkeys fed on diets with low CP was significantly lower than FPD in turkeys fed on diets with high CP until 84 days. Growth performance was adversely affected at low CP. Processing yields were not affected by CP.

3. Litter was significantly dryer in pens of turkeys fed on diets with low DEB than in pens of turkeys fed on diets with high DEB. FPD in turkeys fed on diets with low DEB was significantly lower than in turkeys fed on diets with high DEB. Growth performance and processing yields were adversely affected at low DEB.

4. FPD in turkey hybrid A was higher than in turkey hybrid B at 28 days of age. Thereafter, no differences in FPD between turkey hybrids were observed. Growth performance and processing yields were not affected by turkey hybrid.

5. Overall, a significant interaction effect of CP x DEB was observed for FCR: in turkeys fed on the high DEB treatment, FCR of turkeys fed on the high CP diets was

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lower than FCR of turkeys fed on the low CP (LCP) diets whereas on the low DEB treatment, FCR was not affected by CP treatment.

6. It was concluded that litter quality can be improved and FPD may be decreased in turkeys fed on diets containing lower CP and DEB levels.

Keywords: genotype, dermatitis, soya bean, litter moisture, potassium

INTRODUCTION

Footpad dermatitis is very common in commercial turkey flocks and is a potential economic and welfare problem in intensive production systems (Berg, 1998). In a field study in Germany, Bergmann *et al*. (2013) determined the prevalence and severity of foot pad alterations of turkey poults up to 5 weeks of age, starting as early as 3 d of age. Prevalence and severity increased from 3 d to 5 weeks of age; 27.3% (d 3 to d 5; male/female: 39.1/25.0%) and 63.3% (d 22 to d. 35: 61.3/65.7%). Mayne *et al*. (2007) also reported that histopathologic alterations of the foot pads can occur at an early age and can proceed to fully developed lesions in a period of 3 weeks in commercial turkeys. Clearly, alterations of the foot pads of turkeys can already occur at young ages. External signs of FPD have been observed under test conditions in the second week of life (Berk 2007; Berk, 2009; Schumacher *et al*., 2012). Multiple factors such as poor litter condition, especially high litter moisture (Martland, 1984; Clark *et al*., 2002; Spindler, 2007; Mayne *et al*., 2007; Wu and Hocking, 2011) and chemical irritants bound to litter (Martland, 1984), have been linked to FPD. Litter quality is affected by many factors such as stocking density, air temperature and humidity, ventilation, season, consistency and amount of excreta, and drinker design

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(Veldkamp, 2011). Reduced activity and disrupted behavioural sequences are associated with high FPD scores in turkeys kept on wet litter (Hocking and Wu, 2013; Sinclair *et al*., 2015). Weber Wyneken *et al*. (2015) observed a linear relationship between FPD and litter moisture above a breakpoint of 49% litter moisture. All factors which will cause wet and caked litter are a risk factor for FPD.

Wet excreta and subsequently wet litter may be affected by diet composition. The protein requirement of turkeys is high and therefore high proportions of soya bean meal are included in their diets. Soya bean meal contains high levels of potassium which adversely affect the consistency of the excreta. High dietary sodium and potassium concentrations may result in excessive water intake resulting in wet litter (Eichner *et al*., 2007). Soya bean meal-based diets have relatively high α-galactoside concentration (above 2%), which also increases the risk of FPD in turkeys (Jankowski *et al*., 2009) whereas maize gluten meal, potato protein, rapeseed meal and sunflower seed meal have lower α-galactoside concentrations. Use of other vegetable protein sources selected for lower K concentrations compared to soya bean meal will result in a lower dietary electrolyte balance (DEB) and may improve litter quality and subsequently quality of foot pads.

Diets with high CP concentrations may also cause an increase in water intake and wet litter as the surplus nitrogen that is not accreted in the body has to be excreted. This process requires extra water, increase in the water/feed ratio and results in wet litter. This was demonstrated in an experiment with broilers in which high levels of dietary crude protein stimulated water intake in young broilers (Marks and Pesti, 1984). More recently it was found that increasing dietary balanced protein concentration stimulated water intake in a dose dependent manner (Huang *et al*. 2011). Lowering the crude protein concentration in diets in combination with

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supplementation of free amino acids may decrease the moisture concentration in excreta and subsequently in the litter and may result in a lower incidence and severity of FPD in turkeys.

Hocking and Wu (2013) concluded that heavier lines of turkeys had higher mean FPD scores that developed earlier than those in a traditional line, but the effect was relatively small in young turkeys. Hybrid differences in susceptibility to FPD in commercial hybrids with similar growth performance may occur and two widely used medium heavy turkey hybrids were compared in the present experiment.

The objective of the current study was to evaluate the effect of crude protein concentration and dietary electrolyte balance on litter quality, foot pad dermatitis, growth performance and processing yields in male turkeys of two commercial turkey hybrids in the period from 0 to 134 days of age.

MATERIALS AND METHODS

Birds and housing

All procedures including the use of birds, management and care were in compliance with the European parliament and the European Council Directive regulations on the protection of animals used for scientific purposes (2010/63/EU). A 2 x 2 x 2 factorial block arrangement of 8 dietary treatments was used to evaluate the effects of dietary electrolyte balance (DEB) and crude protein (CP) concentration on growth performance, processing yields, litter quality and foot pad dermatitis in two commercial turkey hybrids in the period from 0 to 134 days of age. An open-sided turkey barn of 96 x 12.3 meters was used for the experiment. The pens were located

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in 2 rows of 32 pens (3 m wide and 4 m deep) with 30 birds per pen (density 2.5 turkeys per m^2). In total, 1920 male turkeys (960 turkey hybrid A and 960 turkey hybrid B) were used in the study. Ages of parent stock of hybrid A and B were 53 weeks and 54 weeks, respectively. All turkeys were obtained from a commercial hatchery and were treated with an infrared beak treatment (Novatech) in the hatchery. Day-old turkey poults were placed in 16 pens with 120 birds per pen (density 10 turkeys per m^2) until 28 days of age (2 pens per treatment). In this period pens were heated by gas brooders. Turkeys were weighed and divided randomly among all 64 pens at 28 days of age. All turkeys remained within the same treatment group after distribution at 28 days of age. Housing, management, feeding and husbandry conditions were representative for a modern commercial operation in Europe. Water and feed for the turkeys was available *ad libitum*. One day prior to placement of the turkeys the rooms were pre-heated according to the temperature recommendations of the breeding companies. Lighting schedule was 16 h light and 8 h dark. White wood shavings were used as litter material and 130 kg were added to each pen prior to the start of the experiment (10 kg/m^2). During the production period an equal amount of wood shavings was added for 7 times to each pen (175 kg in total). Furthermore, litter was tilled with a garden cultivator in all pens when required, based on the assessment of the pen with the worst litter conditions.

Experimental diets

Feed was provided according to a five phase feeding programme in four-week periods. Four experimental diets per feeding phase were provided to both turkey hybrids as summarised in Table 1.

Table 1 near here

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Diets were formulated to be isocaloric for the 5 phases (0-28, 28-56, 56-84, 84-112 and 112-134 days of age) and containing per phase 290 vs. 260, 270 vs. 240, 230 vs. 200, 200 vs. 170, 175 vs. 145 g CP/kg, respectively; and DEB (240 vs. 130 mEq/kg) in all phases. Feed formulation was based on analysed nutrient concentrations (dry matter, crude protein, crude fat, crude fibre, starch, sugar, Na, K, Cl, Ca and P) of the feed ingredients: maize, soyabean meal, fish meal, maize gluten meal, peas, potato protein, rapeseed meal and sunflower meal. Free amino acids (L-Lysine HCl, DL-Methionine, L-Threonine, L-Tryptophan and L-Arginine) were supplemented to the diets to meet the birds' digestible amino acid requirements according to Aviagen Nutritional Recommendations for B.U.T. Commerical Turkeys (2009). Diets were formulated with the software program Bestmix®. Matrix coefficient values in this program are based on CVB (2007). Amino acid concentrations in the matrix were corrected for differences between analysed and matrix values for dry matter and crude protein. Diets with a low electrolyte balance (LEB) were formulated by full exchange of soya bean meal by maize gluten meal, peas, potato protein, rapeseed meal and sunflower seed meal. Sodium chloride, sodium-bicarbonate and potassium-bicarbonate were used for adjusting DEB levels in the experimental diets. Diets were provided as 2.3 mm pellets (0-28 days of age), 3.0 mm pellets (28-56 days of age) and 4.0 mm pellets (56-134 days of age). The composition and the analysed nutrient concentrations of the experimental diets are presented in Table 2.

Table 2 a,b,c near here

Observations

Visual litter quality was determined at 28, 56, 84, 112 and 134 days of age by a panel of three assessors on a 10-point scale (Table 3). Scores for friability of the litter layer

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varied from score 1 = complete caked litter to score 10 = friable litter, no caked litter particles. Scores for wetness of the litter layer ranged from score 1 = wet litter (defined as water appearing over the total area when pressure was applied to the litter) to score 10 = very dry litter (only observed at start). Litter moisture was determined according to the method used by Mayne *et al*. (2007). At 28, 56, 84, 112 and 134 days of age a sample of litter was obtained from the full depth of the litter from a position 30 cm from each wall forming the corner of the pen. The 4 samples from each pen were pooled and thoroughly mixed. A subsample of about 100 g was placed in a weighed plastic container and reweighed to obtain the weight of fresh litter. The samples were dried in an oven at 60ºC for 2 weeks and reweighed. The proportion of moisture in the sample was calculated from the loss in weight of the fresh sample. Foot pad dermatitis was determined at 28, 56, 84, 112 and 134 days of age in the turkey house by a panel of three assessors according the standard European foot pad dermatitis scoring system as described by Hocking *et al*. (2008). Twelve turkeys per pen were randomly selected and individually marked with leg bands at 28 days of age and these turkeys were assessed for foot pad dermatitis during the trial.

Table 3 near here

Body weight gain and feed intake were recorded at 0, 28, 56, 84, 112 and 134 days of age in the turkey house and feed conversion ratio (FCR) was calculated in these periods. Dead or culled turkeys were weighed, *post mortem* gross necropsy was performed and the age, weight and cause of mortality were recorded. Body weight gain of dead or culled turkeys was included in the calculation of FCR. Processing yields of 5 turkeys per pen (body weight of selected turkeys was close to mean body weight of pen) were obtained at 134 days of age in the slaughterplant. Feed withdrawal on farm was 6 h, loading took 1 h and the journey to slaughter took 1 h.

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Birds were processed within an hour after arrival to the slaughterplant to determine processing yields consisting of wing tips, wings and two phalanges, shoulder with skin, thighs, breast without skin and residual carcass. All carcass parts include bones. Yield determination was made after air-chilling

Laboratory analysis and calculations

Prior to feed production, the feed ingredients: maize, soyabean meal, maize gluten meal, peas, potato protein, rapeseed meal and sunflower meal were analysed for dry matter, crude protein, crude fat, crude fibre, starch, sugar, Na, K, Cl, Ca and P. During production of the diets 3 kg samples of each experimental diet were collected and analysed in the lab for dry matter, crude protein, crude fat, crude fibre, starch, sugar, Na, K, Cl, Ca and P. Samples of feed ingredients and experimental diets were ground in a centrifugal mill fitted with a 1 mm screen. Dry matter, crude protein, crude fat, crude fibre, starch, sugar, Na, K, Cl, Ca and P were analysed by methods 10032, 10005, 10112, 10061, 10484, 10138, 10040, 10040, 10008, 10040 and 10040 respectively (NutriControl B.V. Analytical Services, NEN-EN-ISO/IEC 17025:2005, reg. no. L 053).

Bird welfare

The health of the turkeys was inspected on a daily basis and severely affected birds were humanely killed. All turkeys were slaughtered at the end of the experiment in a commercial slaughter plant.

Statistical analysis

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The data were analysed as a completely randomised block design using Genstat version 17.1 (VSN International, Hemel Hempsted, UK). The *P*-value of the treatment effect and the LSD (least significant difference, $P = 0.05$) were provided per response parameter. Treatment effects with a *P*-value ≤0.05 were considered to be statistically significant. Data transformation to achieve normality and homogeneity of variance was $\log_e$ for mortality. Transformed data for mortality are presented as back-transformed means. Only means of main effects and means of significant interaction effects ($P < 0.05$) are presented in the tables.

RESULTS

The analysed concentrations of macro-nutrients in the experimental diets were according to expectations (Table 2a, 2b and 2c) in all feeding phases. Calculated DEB with analysed concentrations of Na, K and Cl was lower than the intended DEB from matrix values.

The effects of different dietary treatments on litter quality are presented in Table 4a. Friability was not affected by CP in the period up to 112 days of age. Scores for litter wetness in pens with turkeys fed on HCP diets were higher than in pens with turkeys fed on LCP diets which implies that the litter in pens with turkeys fed on HCP diets was dryer than on LCP diets. A significant interaction effect ($P < 0.05$) of dietary treatments on friability and wetness was observed at the end of the growth period at 134 d. Higher scores for HCP compared to LCP were only observed in HEB diets. Scores for friability and wetness of litter in pens with turkeys fed on HEB diets were lower than in pens with turkeys fed on LEB diets during the entire production period. Visual scores for friability and wetness of litter were not affected

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by turkey hybrid. Litter moisture as presented in Table 4b was also determined by laboratory analysis. Litter moisture in pens with turkeys fed on HEB diets was higher than in pens with turkeys fed on LEB diets at 28, 56 and 134 d of age ($P <$ 0.05). Litter moisture determined by laboratory analysis was not affected by CP or turkey hybrid.

The effects of different dietary treatments on foot pad dermatitis (FPD) score are presented in Table 5. Mean scores of FPD in turkeys fed on HCP diets were significantly higher ($P < 0.001$) than in turkeys fed on LCP diets at 28, 56 and 84 d of age. The FPD score in turkeys fed on HEB diets was significantly higher ($P <$ 0.001) than in turkeys fed on LEB diets at 28, 56, 84 and 134 d of age. The FPD score of hybrid A turkeys was significantly higher ($P = 0.020$) than the FPD score of hybrid B turkeys at 28 d of age. After 28 days of age no significant effect of turkey hybrid on FPD was observed.

Table 5 near here

The effects of different dietary treatments on growth performance of turkeys in the period from 0 to 28 days of age are presented in Table 6. Body weight of turkey poults at arrival was 63 g and general health status was good. Growth performance of turkeys was not affected by dietary CP concentration or turkey hybrid ($P > 0.05$). High dietary electrolyte balance (HEB) resulted in a significantly higher feed intake and body weight gain than low electrolyte balance (LEB). A significant interaction effect of CP x DEB was observed for feed intake and FCR ($P = 0.026$ and $P =$ 0.034, respectively). At high DEB, feed intake and FCR of turkeys fed on HCP diets was lower than turkeys fed on LCP diets (feed intake 51.9 g/d vs. 53.7 g/d; feed conversion ratio 1.34 vs. 1.39). However, at low DEB, feed intake and feed conversion of turkeys fed on HCP diets were higher than turkeys fed on LCP diets (feed intake 43.0 g/d vs. 40.8 g/d and feed conversion ratio 1.23 vs. 1.19). A

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significant interaction effect of CP x turkey hybrid was also observed for feed intake and feed conversion ratio (P = 0.017 and P = 0.002, respectively). Within hybrid A feed intake of turkeys fed on HCP diets was not significantly different from feed intake of turkeys fed on LCP diets, whereas within hybrid B, feed intake of turkeys fed on HCP diets was higher than turkeys fed on LCP diets (48.3 g/d vs. 45.9 g/d). Feed conversion ratio of hybrid A turkeys fed on HCP diets was lower than turkeys fed on LCP diets (1.22 vs. 1.31) whereas FCR of hybrid B turkeys fed on HCP diets was higher than on LCP diets (1.34 vs. 1.26). Furthermore, a significant interaction effect of DEB x turkey hybrid was observed for feed intake and FCR (P = 0.023 and P = 0.005, respectively). The difference in effect of HEB and LEB diets on feed intake and FCR in hybrid A turkeys was larger than in hybrid B turkeys. Within hybrid A turkeys feed intake and FCR of turkeys fed on HEB diets was higher than turkeys fed on LEB diets (feed intake 54.1 g/d vs. 41.2 g/d and FCR 1.38 vs. 1.15). Within hybrid B feed intake and FCR of turkeys fed on HEB diets was also higher than turkeys fed on LEB diets (feed intake 51.5 g/d vs. 42.6 g/d and FCR 1.35 vs. 1.26) but the difference in feed intake and FCR between turkeys fed on HEB and LEB diets was smaller. So the effects of DEB on feed intake and FCR were more pronounced in hybrid A than in hybrid B turkeys.

Table 6 near here

The effects of different dietary treatments on growth performance of turkeys in the period from 28 to 134 days of age are presented in Table 7. High electrolyte balance (HEB) resulted in a significantly higher feed intake and body weight gain than low electrolyte balance (LEB) (feed intake 435 g vs. 420 g; P < 0.001, body weight gain 172 g/d vs. 166 g/d; P < 0.001). Feed conversion ratio was not affected by DEB treatment. Growth performance was not affected by turkey hybrid. A significant interaction effect of CP x DEB was observed for FCR (P = 0.042): in

Table 7 near here

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turkeys fed on the HEB treatment, FCR of turkeys fed on the HCP diets was lower than FCR of turkeys fed on the LCP diets (2.48 vs. 2.57) whereas on the LEB treatment, FCR was not affected by CP treatment.

The effects of different dietary treatments on processing yields are presented in Table 8. Processing yields were not affected by dietary CP. The HEB treatment resulted in a higher body weight of processed turkeys, a higher percentage carcass yield and breast without skin, and a lower percentage of wing tips and residual carcass. Turkey hybrid did not affect processing yields.

Table 8 near here

DISCUSSION

The aim of the experiment was to investigate the effect of crude protein concentration and dietary electrolyte balance on litter quality, foot pad dermatitis, growth performance and processing yields on male turkeys. Soya bean meal was exchanged completely by vegetable protein sources selected for lower K concentrations in order to lower dietary electrolyte balance to improve litter quality and quality of foot pads. Soya bean meal also has relatively high α-galactoside concentration (above 2%), which also increases the risk of FPD in turkeys (Jankowski *et al*., 2009). Due to the complete exchange of soya bean meal by vegetable protein sources selected for lower K concentrations, the treatment of dietary electrolyte balance was confounded with the treatment of dietary protein sources. In peas, potato protein, rapeseed meal and sunflower seed meal, potassium concentrations were lower than in soya bean meal (10.0, 0.2, 12.6, 15.0 vs. 22.2 g/kg, respectively) according to CVB (2012). Analysed potassium concentrations in the experimental diets were lower and analysed chloride concentrations were higher

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than calculated concentrations based on matrix values. Intended levels of DEB were 240 and 130 mEq/kg whereas overall DEB levels calculated with analysed Na, K and Cl resulted in 221 and 113 mEq/kg, respectively. However, the intended difference between high and low DEB of 110 mEq/kg was realised. All used vegetable protein sources such as maize gluten meal, peas, potato protein, rapeseed meal and sunflower seed meal are used in turkey rations on common basis at conservative levels to avoid possible adverse effects of potentially detrimental constituents such as anti-proteases, glucosinolates, haemagglutinins, phytic acid and tannins. Castell *et al*. (1996) suggested a limit for use of peas in turkey diets at 250 g/kg. No limits were found in the literature for use of potato protein in turkey diets. Mikulski *et al*. (2012) observed that an increase in the inclusion rate of rapeseed meal in turkey diets caused a linear increase in FCR, which was significantly higher in the group fed on diets with 180 g/kg of rapeseed meal. Feed conversion ratios of turkeys fed on diets containing 60 g/kg or 120 g/kg were not different from those of controls. Sunflower seed meal contains higher concentrations of crude fibre and lignin as compared to soya bean meal. Jankowski *et al*. (2011) exchanged soya bean meal (and part of wheat) by sunflower seed meal at different concentrations in turkey diets and observed that body weight of turkeys fed on diets containing 140 g/kg and 210 g/kg of sunflower seed meal was 4 % and 6% lower, respectively, than in those receiving the soya bean meal-based diets in young turkeys from 0 to 8 weeks of age. There is limited data on feeding peas to turkeys, although Savage *et al*. (1986) found that there were no significant differences in growth rate, feed efficiency or meat quality from including peas at levels from 25 percent in the starter feed to 55 percent in the finisher feeds. For this experiment, inclusion levels were set for peas at 100 g/kg, potato protein at a maximum of 65 g/kg, rapeseed meal at a maximum of 80 g/kg and

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sunflower seed meal at a maximum of 110 g/kg. The aim was to formulate the low electrolyte balance diets without soya bean meal and inclusion of alternative vegetable protein sources at the same inclusion levels for high crude protein (HCP) diets as well as for low crude protein (LCP) diets. In this way differences in response of turkeys to HCP and LCP diets could not be attributed to differences in inclusion level of alternative protein sources per se. The analysed concentrations of macro-nutrients in all experimental diets were according to expectations in all feeding phases in the current experiment.

The experimental design was split into two parts. In the period from day 0 to day 28, the 8 treatment combinations were allocated amongst 16 pens to be in line with the normal stocking density used on a commercial basis during the rearing period. From 28 to 134 days of age, the 8 treatment combinations were allocated amongst 64 pens. Therefore, the results were presented separately for the rearing period and the growing period. At 28 days of age, all turkeys were weighed and placed randomly in the final pens according to the assignment of treatments to pens. All turkeys remained within the same treatment group. Body weights of turkeys at 28 days in Table 6 and Table 7 are not similar due to selection and culling of some turkeys with suboptimal health.

Litter quality and foot pad dermatitis

Visual observation showed that litter in pens with turkeys fed on HCP diets was dryer than in pens with turkeys fed on LCP diets. A significant interaction effect ($P < 0.05$) of dietary treatments on friability and wetness was observed at the end of the growth period at 134 d. Dryer litter in pens with turkeys fed on HCP diets compared to LCP diets was only observed in combination with HEB diets. Litter was less

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friable and dry in pens with turkeys fed on HEB diets than in pens with turkeys fed on LEB diets during the entire production period. This means that litter in pens with turkeys fed on HEB diets was more caked and wetter than litter in pens with turkeys fed on LEB diets. The adverse effect of HEB diets on litter moisture was also confirmed by laboratory analysis of litter moisture as litter moisture in pens with turkeys fed HEB diets was in general higher than in pens with turkeys fed LEB diets. Friability and wetness of litter were not affected by turkey hybrid.

In general, FPD scores in the current experiment were comparable with scores in studies by Jankowski *et al*. (2012a), Jankowski *et al*. (2013) and Vermette *et al*. (2016) using also the scoring method of Hocking *et al*. (2008).

Mean scores of FPD in turkeys fed on HCP diets were significantly higher ($P < 0.001$) than in turkeys fed on LCP diets at 28, 56 and 84 d of age. The FPD score in turkeys fed on HEB diets was significantly higher ($P < 0.001$) than in turkeys fed on LEB diets at 28, 56, 84 and 134 d of age. A relation between wet litter and FPD has been demonstrated in the literature (Martland [1984; 1985]; Mayne *et al*., 2007; Wu and Hocking, 2011; Weber Wyneken *et al*., 2015). Eichner *et al*. (2007) observed that a higher water intake occurred in birds fed on diets containing 8.00–9.00 g K/kg and 2.00 g Na/kg compared with diets containing 7.00 g K/kg and 2.00 g Na/kg and the excreta moisture was highly correlated with dietary K concentration. The results of the current experiment confirmed the positive effect of lowering CP and DEB levels in diets on litter quality and subsequently a reduction of FPD in turkeys. DEB levels in the current experiment were reduced by decreasing the K content of diets. Some research findings (Jankowski *et al*., 2012a; Jankowski *et al*., 2012b; Lichtorowicz *et al*., 2012) indicate that FPD severity in turkeys is affected by increasing dietary NaCl levels, and not only by DEB values. An increase in the NaCl

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content of diets from 0.5 to 2.5 g/kg (Jankowski *et al*., 2012a) or from 1.3 to 5.1 g/kg (Jankowski *et al*., 2012b), including a simultaneous increase in Na and Cl, did not change DEB values but intensified FPD symptoms (Lichtorowicz *et al*., 2012). On the other hand, an increase in DEB values, caused by replacing NaCl with sodium sulphate or sodium carbonate, had no effect on litter moisture content and the severity of FPD symptoms in turkeys (Jankowski *et al*., 2012).

Growth performance

Body weight of day-old turkey poults was 63 g for both turkey hybrids. Parent stock of both hybrids were selected for similar age to exclude effects of age of parent stock on quality of turkey poults. Ages of parent stock of hybrid A and B were 53 weeks and 54 weeks, respectively.

During the rearing period, growth performance of turkeys was not affected by dietary CP concentration so the amino acid requirement of young turkeys was met at 30 g/kg lower CP concentrations in diets adjusted for first limiting amino acids. L-lysine HCl, DL-methionine, L-threonine, L-tryptophan and L-arginine were supplemented according to breeder recommendations to meet the birds' digestible amino acid requirements. Growth performance was not affected by turkey hybrid. The optimal dietary electrolyte balance for turkeys is not well established, however a few studies have been conducted to evaluate different levels of DEB on growth performance of growing turkeys. The results from these studies are inconsistent regarding the impact on FCR. Brake *et al*. (1994) reported a significant increase in FCR of turkey males (8 to 20 weeks of age) by raising the DEB level from 150 to 250 mEq/kg of diet, whereas Kidd and Kerr (1998) reported a significant decrease in FCR of Large White males (8 to 20 weeks of age) by raising the DEB level from 148

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to 202 mEq/kg of diet. Veldkamp *et al*. (2000) found no significant difference in FCR of turkey toms (4 to 20 weeks of age) with DEB ranging from 164 to 254 mEq/kg of diet. Murakami *et al*. (2000) suggested that a low electrolyte balance in diets in which 100 g/kg of fishmeal was exchanged with soybean meal may have contributed to the reduced performance in broilers. In the current experiment, however, a main effect of dietary electrolyte balance was observed on growth performance. High dietary electrolyte balance resulted in a significantly higher feed intake ($P < 0.001$) and body weight gain ($P = 0.004$) than low dietary electrolyte balance. Pellet durability in diets with low electrolyte balance visually appeared to be higher than diets with high electrolyte balance. Diets with low electrolyte balance contained peas. Peas are an excellent binder for the manufacturing of high quality pellets. Probably the durability and hardness of pellets of the low electrolyte balance diets was too high which hampered feed intake of turkeys. It was observed that feed that is too hard can cause sorting phenomena by the animals. The animals search for pellets less hard and reject the others. Interaction effects of CP x DEB have been observed for feed intake and FCR ($P = 0.026$ and $P = 0.034$, respectively). At high DEB, feed intake and FCR of turkeys fed on HCP diets was lower than turkeys fed on LCP diets. However, at low DEB, feed intake and feed conversion of turkeys fed on HCP diets was higher than turkeys fed on LCP diets. This may implicate that turkeys may adjust their feed intake to protein supply via the diet in order to meet their amino acid requirements. The increased feed intake and feed conversion ratio in LEB diets in the current study might also be caused by an overestimation of the ME value and/or amino acid digestibility of the alternative feed ingredients such as maize gluten meal, peas, potato protein, rapeseed meal and sunflower meal for young turkeys.

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A significant interaction effect of CP x turkey hybrid was observed for feed intake and feed conversion ratio (*P* = 0.017 and *P* = 0.002, respectively). Within hybrid A, feed intake of turkeys fed on HCP diets was not significantly different from feed intake of turkeys fed on LCP diets, whereas within hybrid B, feed intake of turkeys fed on HCP diets was higher than turkeys fed on LCP diets (48.3 vs. 45.9 g/d). Feed conversion ratio of hybrid A turkeys fed on HCP diets was lower than turkeys fed on LCP diets (1.22 vs. 1.31) whereas FCR of hybrid B turkeys fed on HCP diets was higher than on LCP diets (1.34 vs. 1.26). This demonstrates that amino acid requirements are different in young turkeys of hybrid A and hybrid B. Furthermore, a significant interaction effect of DEB x turkey hybrid was observed for feed intake and FCR (*P* = 0.023 and *P* = 0.005, respectively). Within hybrid A, feed intake and FCR of turkeys fed on HEB diets was higher than turkeys fed on LEB diets whereas within hybrid B, feed intake and FCR of turkeys fed on HEB diets was also higher than turkeys fed on LEB diets but the difference in feed intake and FCR between turkeys fed on HEB and LEB diets was smaller. The effects of DEB on feed intake and FCR were therefore more pronounced in hybrid A than in hybrid B turkeys.

During the growth period, high electrolyte balance (HEB) resulted in a significantly higher feed intake and body weight gain than low electrolyte balance (LEB) (feed intake 435 g/d vs. 420 g/d; $P < 0.001$, body weight gain 172 g/d vs. 166 g/d; $P < 0.001$) whereas FCR was not affected by DEB treatment. A significant interaction effect of CP x DEB was observed for FCR (*P* = 0.042). In turkeys fed on the HEB treatment, FCR of turkeys fed on the HCP diets was lower than FCR of turkeys fed on the LCP diets (2.48 vs. 2.57) whereas on the LEB treatment, FCR was not affected by CP treatment. The lack of a significant effect on FCR in LEB diets in

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the growing period might be caused by an overestimation of the ME value and/or amino acid digestibility of the alternative feed ingredients such as maize gluten meal, peas, potato protein, rapeseed meal and sunflower meal. A lack of metabolic energy to use the amino acids for protein accretion may have occurred in the LEB diets such that the turkeys were not able to utilise the extra available amino acids in the HCP x LEB diets for protein accretion.

Processing yields

Processing yields were not affected by dietary CP whereas the HEB treatment resulted in a higher body weight of processed turkeys, a higher percentage carcass yield and a higher percentage breast without skin and a lower percentage wing tip and percentage residual carcass. Turkey hybrid did not affect processing yields. A positive correlation between body weight gain and percentage breast muscles is generally known in turkey production.

Disclosure statement

No potential conflict of interest was reported by the authors.

ACKNOWLEDGEMENTS

The experiment was funded by the Ministry of Economic Affairs, The Netherlands as part of the FP7 ERA-Net ANIHWA, “Coordination of European Research on Animal Health and Welfare” project TURKEYWELFARE [number 182]. The authors acknowledge also the cooperation with industrial partners: Aviagen Turkeys, Chester UK; Unaitalia (Italian Meat and Egg Association), Rome Italy and Società

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Agricola La Pellegrina (Gruppo Veronesi), Verona Italy. The Roslin Institute contribution was supported by a core strategic grant (BB/J004316/1) and a project grant (BB/L012022/1).

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Table 1. *Experimental treatments with description of intended crude protein concentration and dietary electrolyte balance per feeding phase provided to two turkey hybrids*

Treatment	Crude protein concentration (g/kg)					Electrolyte balance (mEq/kg)	Turkey hybrid
Code[1]	Phase I	Phase II	Phase III	Phase IV	Phase V		
HCP-HEB-A	290	270	230	200	175	240	A
LCP-HEB-A	260	240	200	170	145	240	A
HCP-LEB-A	290	270	230	200	175	130	A
LCP-LEB-A	260	240	200	170	145	130	A
HCP-HEB-B	290	270	230	200	175	240	B
LCP-HEB-B	260	240	200	170	145	240	B
HCP-LEB-B	290	270	230	200	175	130	B
LCP-LEB-B	260	240	200	170	145	130	B

[1]HCP = high crude protein concentration, LCP = low crude protein concentration, HEB = high dietary electrolyte balance, LEB = low dietary electrolyte balance, A = turkey hybrid A, B = turkey hybrid B.

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Table 2a. *Composition of experimental diets in period 0 to 4 weeks*

Item		0 to 4 weeks			
		HCP-HEB	LCP-HEB	HCP-LEB	LCP-LEB
Ingredient, g/kg					
Maize		411.2	471.4	380.7	447.7
Soya bean meal		399.7	392.9	0.0	0.0
Maize gluten meal		90.0	30.0	169.3	109.0
Peas		0.0	0.0	100.0	100.0
Potato protein		0.0	0.0	65.0	65.0
Rapeseed meal		0.0	0.0	79.9	75.0
Sunflower seed meal		0.0	0.0	110.0	105.0
Soya oil		32.4	33.9	18.8	17.9
Limestone (fine)		15.3	15.2	15.7	15.6
Mono-Calcium phosphate		29.6	30.1	31.4	32.0
Sodium chloride		3.4	3.1	1.2	0.2
Sodium bicarbonate		0.0	0.5	2.4	4.0
Potassium bicarbonate		0.0	0.1	1.3	0.0
Premix[1], incl phytase		5.0	5.0	5.0	5.0
L-Lysine HCl		6.1	6.9	9.8	10.5
DL-Methionine		3.2	4.5	2.0	3.3
L-Threonine		1.5	2.6	1.2	2.3
L-Tryptophan		0.1	0.2	0.6	0.8
L-Arginine		2.5	3.6	5.7	6.7
Calculated composition, g/kg					
CP		290	260	290	260
ME	MJ/kg	11.8	11.8	11.8	11.8
Calcium		13.5	13.5	13.5	13.5
Phosphorus		11.5	11.5	11.8	11.7
Available phosphorus		7.6	7.6	7.6	7.6
Na		1.5	1.5	1.5	1.5
K		10.8	10.8	6.4	5.9
Cl		3.6	3.6	3.5	3.0
DEB[2]	mEq/kg	240	240	130	130
dLYS		16.6	16.6	16.6	16.6
dMET		7.3	7.8	7.2	7.7
dCYS		3.7	3.2	3.8	3.3
dM+C		11.0	11.0	11.0	11.0
dTHR		10.3	10.3	10.3	10.3
dTRP		2.7	2.7	2.7	2.7
dARG		18.2	18.2	18.2	18.2
dVAL		11.4	10.0	11.7	10.4
Analysed composition, g/kg					

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CP		287	259	289	257
Crude fat		61	60	53	52
Crude fibre		20	20	47	41
Starch		297	320	335	359
Sugar		46	47	29	24
Calcium		12.4	12.7	13.2	13.0
Phosphorus		11.2	11.2	12.2	11.9
Na		1.5	1.5	1.4	1.5
K		9.9	10.0	6.5	5.6
Cl		4.1	4.2	4.3	4.0
DEB[2]	mEq/kg	204	205	108	95

[1] Supplied the following per kg of feed: retinol acetate, 5.2 mg; cholecalciferol, 125 µg; DL-a-tocopheryl acetate, 100 mg; menadione, 5 mg; thiamin, 5 mg; riboflavin, 8 mg; d-pantothenic acid, 25 mg; niacin, 75 mg; biotin, 300 µg, cobalamin, 20 µg; folic acid, 3 mg; pyridoxine, 7 mg; choline chloride, 400 mg; Fe (as Fe(II)Sulphate), 50 mg; Cu (as copper sulphate), 20 mg; Zn (as zinc sulphate), 100 mg; Mn (as Mn(II)Oxide, 120 mg; I (as K-iodide), 2 mg; Se (as Na-Selenite), 200 µg; Monensin (Elancoban 200) 80 mg; Natuphos 10000 G (BASF), 50 mg.

[2] DEB was calculated as Na + K – CL in mEq/kg.

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Table 2b. *Composition of experimental diets in period 4 to 8 weeks and 8 to 12 weeks*

Item		4 to 8 weeks				8 to 12 weeks			
		HCP-HEB	LCP-HEB	HCP-LEB	LCP-LEB	HCP-HEB	LCP-HEB	HCP-LEB	LCP-LEB
Ingredient, g/kg									
Maize		461.4	518.7	427.2	490.3	552.9	607.3	508.6	565.7
Soya bean meal		352.5	351.5	0.0	0.0	283.0	298.9	0.0	0.0
Maize gluten meal		96.6	32.9	167.8	93.8	77.7	2.4	121.4	55.8
Peas		0.0	0.0	100.0	100.0	0.0	0.0	100.0	100.0
Potato protein		0.0	0.0	55.0	65.0	0.0	0.0	48.9	50.0
Rapeseed meal		0.0	0.0	65.0	60.0	0.0	0.0	50.0	50.0
Sunflower seed meal		0.0	0.0	100.0	100.0	0.0	0.0	90.0	90.0
Soy oil		30.6	33.4	18.5	20.8	27.9	32.9	21.7	24.9
Limestone (fine)		15.3	15.2	15.7	15.6	14.5	14.3	14.8	14.7
Mono-Calcium phosphate		25.2	25.6	26.8	27.3	23.0	23.2	24.2	24.6
Sodium chloride		2.6	2.5	0.9	1.0	3.3	1.3	1.3	1.2
Sodium bicarbonate		1.4	1.6	3.4	3.3	0.5	3.4	3.0	3.1
Potassium bicarbonate		0.0	0.0	0.0	0.0	4.2	0.0	0.1	0.0
Premix[1], incl. phytase		5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
L-Lysine HCl		4.7	5.4	8.1	8.2	4.1	4.3	6.2	6.8
DL-Methionine		2.7	4.0	1.6	2.9	2.5	3.9	1.7	3.0
L-Threonine		0.6	1.7	0.4	1.3	0.3	1.3	0.0	1.0
L-Tryptophan		0.0	0.1	0.5	0.6	0.0	0.1	0.3	0.5
L-Arginine		1.4	2.4	4.1	4.9	1.1	1.7	2.8	3.7
Calculated composition, g/kg									
CP		270	240	270	240	230	200	230	200
ME	MJ/kg	12.0	12.0	12.0	12.0	12.2	12.2	12.2	12.2
Calcium		12.5	12.5	12.5	12.5	11.5	11.5	11.5	11.5
Phosphorus		10.3	10.2	10.5	10.4	9.4	9.4	9.6	9.5
Available phosphorus		6.7	6.7	6.7	6.7	6.1	6.1	6.1	6.1
Na		1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
K		9.9	10.0	5.6	5.7	10.2	9.0	5.4	5.5
Cl		3.0	3.0	2.9	3.1	3.2	2.2	2.8	2.9
DEB[2]	mEq/kg	240	240	130	130	240	240	130	130
dLYS		14.4	14.4	14.4	14.4	12.0	12.0	12.0	12.0
dMET		6.7	7.2	6.6	7.1	5.9	6.5	5.9	6.4
dCYS		3.5	3.0	3.6	3.1	3.1	2.5	3.1	2.6
dM+C		10.2	10.2	10.2	10.2	9.0	9.0	9.0	9.0
dTHR		8.9	8.9	8.9	8.9	7.3	7.3	7.3	7.3
dTRP		2.4	2.4	2.4	2.4	2.0	2.0	2.0	2.0
dARG		15.8	15.8	15.8	15.8	13.2	13.2	13.2	13.2
dVAL		10.7	9.3	11.0	9.8	9.1	7.8	9.5	8.1
Analysed composition, g/kg									

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CP		269	242	265	239	234	201	232	202
Crude fat		60	62	54	55	61	64	58	59
Crude fibre		18	19	39	40	20	22	36	37
Starch		324	353	362	382	382	395	398	424
Sugar		43	43	24	25	35	39	23	23
Calcium		11.7	11.6	12.1	12.1	10.9	11.0	11.4	11.5
Phosphorus		10.1	10.1	10.6	10.7	8.5	8.5	9.0	9.1
Na		1.5	1.5	1.6	1.5	1.6	1.5	1.6	1.4
K		9.2	9.3	5.2	5.4	9.8	8.6	5.3	5.4
Cl		3.1	3.3	3.4	3.7	3.3	2.2	3.1	3.3
DEB[2]	mEq/kg	218	211	106	100	226	223	118	110

[1] Supplied the following per kg of feed: retinol acetate, 3.4 mg; cholecalciferol, 75 µg; DL-a-tocopheryl acetate, 80 mg; menadione, 3 mg; thiamin, 1 mg; vitamin B2, 6 mg; d-pantothenic acid, 15 mg; niacin, 50 mg; biotin, 300 µg, cobalamin, 20 µg; folic acid 2 mg, pyridoxine, 5 mg; choline chloride, 150 mg; Fe (as Fe(II)Sulphate), 20 mg; Cu (as copper sulphate), 20 mg; Zn (as zinc sulphate), 70 mg; Mn (as Mn(II)Oxide, 100 mg; I (as K-iodide), 2 mg; Se (as Na-Selenite), 200 µg; Monensin (Elancoban 200), 70 mg; Natuphos 10000 G (BASF), 50 mg.

[2] DEB was calculated as Na + K – CL in mEq/kg.

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Table 2c. *Composition of experimental diets in period 12 to 16 weeks and 16 weeks to slaughter date*

Item		12 to 16 weeks				16 weeks to slaughter date			
		HCP-HEB	LCP-HEB	HCP-LEB	LCP-LEB	HCP-HEB	LCP-HEB	HCP-LEB	LCP-LEB
Ingredient, g/kg									
Maize		663.8	690.9	557.5	615.7	733.2	734.4	609.2	682.5
Soya bean meal		173.6	235.0	0.0	0.0	105.8	137.0	0.0	0.0
Maize gluten meal		104.2	0.0	119.2	46.8	107.5	0.0	97.3	0.0
Peas		0.0	0.0	100.0	100.0	0.0	0.0	100.0	100.0
Potato protein		0.0	0.0	13.2	20.0	0.0	0.0	3.1	35.2
Rapeseed meal		0.0	0.0	50.0	50.0	0.0	0.0	32.9	21.4
Sunflower seed meal		0.0	0.0	90.0	90.0	0.0	50.0	90.0	90.0
Soy oil		5.7	23.2	22.6	26.3	0.4	27.9	25.5	27.6
Limestone (fine)		12.7	12.2	12.5	12.3	12.0	11.4	11.7	11.5
Mono-Calcium phosphate		17.7	17.5	17.5	18.0	14.2	13.8	13.5	14.3
Sodium chloride		0.6	2.2	1.2	1.4	0.6	1.2	1.2	1.9
Sodium bicarbonate		4.2	2.1	3.1	2.9	4.2	3.5	3.3	2.4
Potassium bicarbonate		5.6	4.1	0.0	0.0	9.3	6.8	0.0	0.0
Premix[1], incl. phytase		5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
L-Lysine HCl		4.3	3.2	5.6	5.8	4.6	4.1	5.0	3.9
DL-Methionine		1.2	2.8	0.8	2.2	1.4	2.8	1.3	2.6
L-Threonine		0.0	0.8	0.0	0.9	0.0	0.9	0.0	0.4
L-Tryptophan		0.1	0.0	0.3	0.4	0.3	0.2	0.3	0.2
L-Arginine		1.3	1.0	1.5	2.3	1.5	1.0	0.7	1.1
Calculated composition, g/kg									
CP		200	170	200	170	175	145	175	145
ME	MJ/kg	12.3	12.3	12.3	12.3	12.5	12.5	12.5	12.5
Calcium		9.4	9.4	9.4	9.4	8.2	8.2	8.2	8.2
Phosphorus		7.7	7.7	8.2	8.1	6.5	6.8	7.0	6.9
Available phosphorus		4.9	4.9	4.9	4.9	4.1	4.1	4.1	4.1
Na		1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
K		8.6	9.4	5.2	5.4	8.8	9.0	5.0	5.3
Cl		1.8	2.5	2.6	2.7	1.9	2.2	2.4	2.7
DEB[2]	mEq/kg	240	240	130	130	240	240	130	130
dLYS		9.6	9.6	9.6	9.6	8.2	8.2	8.2	8.2
dMET		4.5	5.1	4.5	5.0	4.4	5.0	4.4	5.0
dCYS		2.8	2.2	2.8	2.3	2.5	1.9	2.5	1.9
dM+C		7.3	7.3	7.3	7.3	6.9	6.9	6.9	6.9
dTHR		5.9	5.9	5.9	5.9	5.0	5.0	5.0	5.0
dTRP		1.6	1.6	1.6	1.6	1.4	1.4	1.4	1.4
dARG		10.6	10.6	10.6	10.6	8.9	8.9	8.9	8.9
dVAL		7.8	6.6	7.9	6.6	6.7	5.5	6.8	6.0

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Analysed composition, g/kg									
CP		203	178	200	173	178	147	184	144
Crude fat		42	55	58	61	51	61	66	65
Crude fibre		18	18	38	38	18	29	40	38
Starch		463	458	438	456	474	475	432	479
Sugar		29	34	24	26	28	28	24	26
Calcium		9.7	8.8	9.3	9.4	8.1	8.2	8.4	8.2
Phosphorus		7.7	7.4	8.0	8.0	6.2	6.4	6.8	6.6
Na		1.5	1.4	1.5	1.6	1.5	1.5	1.5	1.5
K		8.5	8.3	4.9	5.1	8.6	10.4	5.0	5.2
Cl		1.9	1.7	2.6	3.0	1.7	3.5	2.3	2.6
DEB[2]	mEq/kg	229	224	120	116	239	234	130	127

[1] Supplied the following per kg of feed: retinol acetate, 2.75 mg; cholecalciferol, 50 µg ; DL-a-tocopheryl acetate, 50 mg; menadione, 3 mg; thiamin, 1 mg; vitamin B2, 6 mg; d-pantothenic acid, 15 mg; niacin, 40 mg; biotin, 200 µg, cobalamin, 20 µg; folic acid, 2 mg; pyridoxine, 3 mg; choline chloride, 100 mg; Fe (as Fe(II)Sulphate), 20 mg; Cu (as copper sulphate), 20 mg; Zn (as zinc sulphate), 70 mg; Mn (as Mn(II)Oxide, 100 mg; I (as K-iodide), 2 mg; Se (as Na-Selenite), 200 µg; Natuphos 10000 G (BASF), 50 mg.

[2] DEB was calculated as Na + K – CL in mEq/kg.

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Table 3. *Description of the visual litter scores for friability and wetness*

Score	Friability description	Wetness description
1	Completely caked	Wet litter, total area, water is appearing by pressure on the litter
2	80-90 % area caked	Wet litter, beneath drinking line, water is appearing by pressure on the litter
3	70-80 % area caked	Wet litter, beneath drinking line, no water is appearing by pressure on the litter
4	60-70 % area caked	Wet litter, dark coloured. Litter can be pressed into ball-shape
5	50-60 % area caked	Wet litter, dark coloured. Ridges occur beneath the drinking line
6	40 % area caked	Almost dry litter, small ridges beneath drinking line. Litter between drinking line and feeders is still friable
7	30 % area caked	Almost dry litter, dark coloured beneath drinking line and in other areas light coloured, ridge formation beneath drinking lines just started
8	10 % area caked	Almost dry litter, light coloured, no ridges beneath drinking line
9	Friable litter, small caked areas	Dry litter, light coloured
10	Friable litter, no caked areas	Very dry litter (only observed at start)

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Table 4a. *Visual scores of friability and wetness of litter at different ages*

			Friability[2]				Wetness[3]			
			Age (d)				Age (d)			
Crude protein[1]	Electrolyte balance[1]	Turkey hybrid	56	84	112	134	56	84	112	134
HCP			8.7	5.6	4.4	4.2^{a}	4.8	4.3	3.8	3.8^{a}
LCP			8.7	6.0	4.3	3.8^{b}	4.9	4.7	3.6	3.5^{b}
	HEB		8.2^{b}	5.4^{b}	4.2^{b}	3.8	4.3^{b}	4.1^{b}	3.4^{b}	3.4^{b}
	LEB		9.2^{a}	6.3^{a}	4.5^{a}	4.1	5.5^{a}	4.9^{a}	3.9^{a}	3.9^{a}
		A	8.6	5.9	4.4	3.9	4.9	4.5	3.8	3.7
		B	8.8	5.7	4.3	4.0	4.9	4.5	3.6	3.7
HCP	HEB		8.1	5.3	4.4^{a}	4.3^{a}	4.3	3.9	3.6	3.8^{a}
LCP	HEB		8.3	5.4	4.0^{b}	3.4^{b}	4.4	4.2	3.3	3.1^{b}
HCP	LEB		9.3	5.9	4.4^{a}	4.0^{a}	5.4	4.6	3.9	3.9^{a}
LCP	LEB		9.1	6.6	4.6^{a}	4.1^{a}	5.5	5.3	4.0	3.9^{a}
Source of variation										
Crude protein			1.00	0.107	0.457	**0.003**	0.494	0.053	0.341	**0.022**
sed			0.11	0.23	0.13	0.13	0.14	0.22	0.13	0.13
Electrolyte Balance			**<.001**	**<.001**	**0.008**	0.097	**<.001**	**<.001**	**<.001**	**<.001**
sed			0.11	0.23	0.13	0.13	0.14	0.22	0.13	0.13
Turkey hybrid			0.242	0.280	0.218	0.810	0.819	0.778	0.156	0.639
sed			0.11	0.23	0.13	0.13	014	0.22	0.13	0.13
Crude protein x Electrolyte Balance			0.242	0.280	0.029	**<.001**	0.819	0.399	0.060	**0.022**
sed			0.15	0.32	0.18	0.18	0.19	0.31	0.18	0.19

[a,b] Values in the same column with no common superscript differ significantly at $P < 0.05$.

[1]HCP = high crude protein concentration, LCP = low crude protein concentration, HEB = high dietary electrolyte balance, LEB = low dietary electrolyte balance.

[2]Scores for friability of the litter layer varied from score 1 = complete caked litter to score 10 = friable litter, no caked litter particles.

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[3]Scores for wetness of the litter layer ranged from score 1 = wet litter (defined as water appearing over the total area when pressure was applied to the litter) to score 10 = very dry litter (only observed at start).

Table 4b. *Litter moisture of litter at different ages*

			Litter moisture (%)				
Crude protein[1]	Electrolyte Balance[1]	Turkey hybrid	28	56	84	112	134
HCP			26.1	33.1	48.4	50.9	56.1
LCP			23.0	30.4	48.0	52.5	57.2
	HEB		26.6^{a}	34.5^{a}	47.6	51.7	57.6^{a}
	LEB		22.5^{b}	29.0^{b}	48.8	51.7	55.6^{b}
		A	24.2	31.3	47.3	51.5	56.8
		B	24.8	32.2	49.1	51.9	56.5
Source of variation							
Crude protein			0.131	0.153	0.787	0.248	0.235
sed			1.80	1.90	1.70	1.40	0.97
Electrolyte Balance			**0.053**	**0.006**	0.506	0.981	**0.044**
sed			1.80	1.90	1.70	1.40	0.97
Turkey hybrid			0.751	0.609	0.296	0.789	0.719
sed			1.80	1.90	1.70	1.40	0.97

[a,b] Values in the same column with no common superscript differ significantly at $P < 0.05$.

[1]HCP = high crude protein concentration, LCP = low crude protein concentration, HEB = high dietary electrolyte balance, LEB = low dietary electrolyte balance.

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Table 5. *Foot pad dermatitis score at different ages according to the method described by Hocking et al. (2008)*[1]

			Age, days				
Crude protein[2]	Electrolyte Balance[1]	Turkey hybrid	28	56	84	112	134
HCP			0.36[a]	0.81[a]	1.58[a]	2.40	3.06
LCP			0.14[b]	0.59[b]	1.35[b]	2.45	3.09
	HEB		0.38[a]	0.97[a]	1.66[a]	2.45	3.24[a]
	LEB		0.12[b]	0.43[b]	1.27[b]	2.39	2.92[b]
		A	0.29[a]	0.70	1.45	2.39	3.01
		B	0.21[b]	0.70	1.47	2.45	3.15
Source of variation							
Crude protein			**<.001**	**<.001**	**<.001**	0.499	0.760
sed			0.035	0.061	0.053	0.069	0.090
Electrolyte balance			**<.001**	**<.001**	**<.001**	0.379	**<.001**
sed			0.035	0.061	0.053	0.069	0.090
Turkey hybrid			**0.020**	0.966	0.703	0.399	0.114
sed			0.035	0.061	0.053	0.069	0.090

[a,b] Values in the same column with no common superscript differ significantly at $P < 0.05$.

[1] Score 0 - 4; Score 0: No external signs of FPD. The skin of the foot pad feels soft to the touch and no swelling or necrosis is evident; Score 4: Swelling is evident and the total foot pad size is enlarged. Reticulate scales are pronounced, increased in number and separated from each other. The amount of necrosis extends to more than half of the foot pad.

[2]HCP = high crude protein concentration, LCP = low crude protein concentration, HEB = high dietary electrolyte balance, LEB = low dietary electrolyte balance.

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Table 6. *Growth performance in the period from 0 to 28 days of age*

Crude protein[1]	Electrolyte balance[1]	Turkey hybrid	Body weight 28 d g	Body weight gain 0-28 d g/d	Feed intake 0-28 d g/d	FCR 0-28 d	Mortality 0-28 d %
HCP			1099	37.0	47.5	1.28	5.9
LCP			1087	36.6	47.2	1.29	3.3
	HEB		1149^{c}	38.8^{c}	52.8^{c}	1.36^{c}	3.4
	LEB		1037^{d}	34.8^{d}	41.9^{d}	1.21^{d}	5.8
		A	1113	37.5	47.6	1.27	4.5
		B	1073	36.1	47.1	1.30	4.6
HCP	HEB		1152	38.9	51.9^{c}	1.34^{c}	4.1
LCP	HEB		1146	38.7	53.7^{c}	1.39^{c}	2.7
HCP	LEB		1047	35.2	43.0^{d}	1.23^{d}	7.6
LCP	LEB		1028	34.5	40.8^{d}	1.19^{d}	3.9
HCP		A	1129	38.1	46.7^{dc}	1.22^{d}	5.7
LCP		A	1098	37.0	48.6^{c}	1.31^{cb}	3.4
HCP		B	1070	36.0	48.3^{c}	1.34^{b}	6.0
LCP		B	1076	36.2	45.9^{d}	1.26^{dc}	3.2
	HEB	A	1163	39.3	54.1^{b}	1.38^{b}	4.3
	LEB	A	1063	35.7	41.2^{d}	1.15^{d}	4.8
	HEB	B	1134	38.3	51.5^{c}	1.35^{b}	2.5
	LEB	B	1011	33.9	42.6^{d}	1.26^{c}	6.7
HCP	HEB	A	1180	39.9	53.1^{ba}	1.33^{b}	5.4
LCP	HEB	A	1147	38.7	55.1^{a}	1.42^{a}	3.2
HCP	LEB	A	1079	36.3	40.2^{d}	1.11^{d}	6.1
LCP	LEB	A	1048	35.2	42.1^{d}	1.20^{c}	3.5
HCP	HEB	B	1124	37.9	50.8^{b}	1.34^{b}	2.8
LCP	HEB	B	1145	38.6	52.3^{ba}	1.35^{ba}	2.1
HCP	LEB	B	1016	34.0	45.8^{c}	1.34^{ba}	9.2
LCP	LEB	B	1007	33.7	39.5^{d}	1.18^{dc}	4.3
Source of variation							
Crude protein			0.650	0.651	0.753	0.742	0.110
sed			26.8	0.96	0.69	0.017	1.18
Electrolyte Balance			**0.004**	**0.004**	**<.001**	**<.001**	0.083
sed			26.8	0.96	0.69	0.017	1.18
Turkey hybrid			0.175	0.176	0.448	0.063	0.871

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sed	26.8	0.96	0.69	0.017	1.18
Crude protein x Electrolyte Balance	0.806	0.807	**0.026**	**0.034**	0.509
seds	37.9	1.35	0.98	0.025	1.67
Crude protein x Turkey hybrid	0.504	0.510	**0.017**	**0.002**	0.784
sed	37.9	1.35	0.98	0.025	1.67
Electrolyte Balance x Turkey hybrid	0.682	0.680	**0.023**	**0.005**	0.175
sed	37.9	1.35	0.98	0.025	1.67
Crude protein x Electrolyte Balance x Turkey hybrid	0.778	0.776	**0.027**	**0.035**	0.802
sed	53.7	1.91	1.38	0.035	2.36

[a,b,c,d] Values in the same column with no common superscript differ significantly at $P < 0.05$.

[1]HCP = high crude protein concentration, LCP = low crude protein concentration, HEB = high dietary electrolyte balance, LEB = low dietary electrolyte balance.

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Table 7. *Growth performance in the period from 28 to 134 days of age*

Crude protein[1]	Electrolyte Balance[1]	Turkey hybrid	Body weight 28 d g	Body weight 134 d g	Daily Body weight gain 28-134 d g	Daily Feed intake 28-134 d g	FCR 28-134 d	Mortality 28-134 d %
HCP			1107	^{b}19061	169	424	2.50	^{c} 6.3
LCP			1080	^{c}18932	168	431	2.56	^{b} 7.2
	HEB		1164	^{b}19405	^{b}172	^{b}435	^{b}2.53	6.1
	LEB		1023	^{c}18588	^{c}166	^{c}420	^{c}2.53	7.4
		A	1130	^{b}19084	169	430	2.54	7.1
		B	1057	^{c}18910	168	425	2.52	6.4
HCP	HEB		1164	^{a}19515	173	430	2.48	^{c} 6.1
LCP	HEB		1164	^{a}19296	171	440	2.57	^{a} 6.1
HCP	LEB		1051	^{b} 18608	166	418	2.52	^{c} ^{b} 6.4
LCP	LEB		996	^{c} 18568	166	422	2.54	^{b} ^{a} 8.4
Source of variation								
Crude protein			**<.001**	0.235	0.336	0.053	**0.002**	0.663
sed			**7.6**	107.6	1.0	3.4	**0.017**	1.06
Electrolyte Balance			**<.001**	**<.001**	**<.001**	**<.001**	0.762	0.108
sed			**7.6**	**107.6**	**1.0**	**3.4**	0.017	1.06
Turkey hybrid			**<.001**	0.112	0.340	0.143	0.382	0.593
sed			**7.6**	107.6	1.0	3.4	0.017	1.06
Crude protein x Electrolyte Balance			**<.001**	0.410	0.268	0.369	**0.042**	0.305
sed			**10.8**	152.2	1.4	4.8	**0.023**	1.50

[a,b,c] Values in the same column with no common superscript differ significantly at $P < 0.05$.

[1]HCP = high crude protein concentration, LCP = low crude protein concentration, HEB = high dietary electrolyte balance, LEB = low dietary electrolyte balance.

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Table 8. *Processing yields of turkeys at different dietary treatments at 134 days of age in the slaughterplant*

Crude protein[1]	Electrolyte Balance[1]	Turkey hybrid	Body weight processed turkeys (kg)	Carcass yield (%)	Wing tips (%)	Wings and two phalanges (%)	Thighs (%)	Breast without skin (%)	Shoulder with skin (%)	Residual carcass (%)
HCP			19.71	74.2	1.13	10.1	32.9	32.1	2.1	21.8
LCP			19.67	73.9	1.12	10.1	33.1	31.9	2.1	21.7
	HEB		20.26[a]	74.4[a]	1.11[b]	10.0	32.9	32.5[a]	2.1	21.4[b]
	LEB		19.13[b]	73.7[b]	1.14[a]	10.1	33.0	31.6[b]	2.1	22.1[a]
		A	19.67	74.1	1.11	10.1	33.0	32.0	2.1	21.9
		B	19.72	74.0	1.14	10.1	33.0	32.1	2.1	21.7
Source of variation										
Crude protein			0.820	0.233	0.515	0.784	0.084	0.310	0.218	0.601
sed			0.174	0.23	0.012	0.06	0.11	0.17	0.02	0.12
Electrolyte Balance			**<.001**	**0.003**	**0.002**	0.183	0.393	**<.001**	0.218	**<.001**
sed			0.174	0.23	0.012	0.06	0.11	0.17	0.02	0.12
Turkey hybrid			0.796	0.579	0.066	0.973	0.801	0.541	0.289	0.152
sed			0.174	0.23	0.012	0.06	0.11	0.17	0.02	0.12

[a,b] Values in the same column with no common superscript differ significantly at $P < 0.05$.

[1]HCP = high crude protein concentration, LCP = low crude protein concentration, HEB = high dietary electrolyte balance, LEB = low dietary electrolyte balance.

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