https://doi.org/10.34101/actaagrar/73/1626

Impact of chronic heat stress on digestibility of nutrients and performance of meat type ducks

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SUMMARY

The aim of the study is to determine the effect of vitamin and mineral supplement under permanently high environmental temperature (30±1 °C) on the digestibility of nutrients, performance and furthermore the composition of duck meat in the growing period. A total of four hundred mixed sex 14 days old Cherry Valley type hybrid ducks were used for the study. Two experimental diets were formulated in the study (control and vitamin E, C and zinc supplemented diet). Based on the results the following conclusions were drown: the antioxidant defence system plays an important role in the reduction of heat stress generated lipid peroxidation process. Feed additives which have direct or indirect antioxidant effects can reduce the negative effects of heat stress on the ducks performance and meat composition. Digestibility of nutrients (Dry Matter, Crude Protein, Crude Fat) was not affected by antioxidant supplementation under chronic heat stress (30±1 °C). The performance was affected significantly by Vitamin C and E and zinc supplementation under heat stress (P<0.05). In the treated group the daily weight gain (dWG) increased and the feed conversion ratio (FCR) was improved significantly (P<0.05). The energy and protein conversion was decreased also significantly (P<0.05).

Keywords: *heat stress, meat type duck, nutrient digestibility, performance, chemical composition of meat*

ÖSSZEFOGLALÁS

A közlemény célja, hogy bemutassa a vitamin- és ásványianyag-kiegészítés hatását tartós hőstressz (30±1 °C) során a kacsa nevelési időszakában a táplálóanyagok emészthetőségére, a termelési paraméterekre, valamint a hús kémiai összetételére. A kísérletbe összesen 400 vegyes ivarú előnevelt (14 napos) Cherry Valley hibrid kacsa került beállításra. A kísérletben két kezelést alkalmaztunk (kontroll valamint C és E vitamin, továbbá cink kiegészítés). A vizsgálataink alapján az alábbi fontosabb megállapításokat tettük: az antioxidáns védelmi rendszernek kiemelkedő szerepe van a hősokk okozta lipidperoxidáció csökkentésében. Alkalmazhatók olyan takarmány kiegészítők, melyek direkt vagy indirekt antioxidáns tulajdonságúak, ezáltal csökkentik a hőstressz káros hatásait a termelési paraméterekre és a hús összetételre. Hőstressz során a táplálóanyagok emészthetőségét (szárazanyag, nyers fehérje, nyers zsír) nem befolyásolta az antioxidáns kiegészítés. A termelési paraméterek szignifikánsan javultak C és E vitamin, valamint cinkkiegészítés hatására hőstressz során (P<0,05). A kezelt csoportban szignifikánsan javult a napi súlygyarapodás, a fajlagos takarmányértékesítés, valamint a fajlagos energia- és fehérjeértékesítés szignifikáns csökkenést mutatott (P<0,05).

Kulcsszavak: *hőstressz, hús típusú kacsa, táplálóanyagok emészthetősége, termelési paraméterek, hús kémiai összetétele*

INTRODUCTION

Nowadays the climate change has an effect both on everyday life, and also on the agriculture and food production. The higher environmental temperature may have more serious consequences: it changes the energy and nutrient metabolism of the animals, the antioxidant status could be impaired greatly, the resistance capacity decreases and the product quality is deteriorating on a final row (Babinszky et al. 2011). The negative effects of high environmental temperature could be reduced by genetic or keeping technology devices, but these methods are expensive and not in all cases are adequate. This is the reason why intensive researches are going on with different nutrition tools. Based on the scientific findings feed additives which have direct or indirect antioxidant effects can be used in general: Vitamin C, A, E alone or with other micro minerals, for example chrome and/or zinc (Horváth et al. 2016c).

The demand for poultry meat is increasing; the importance of duck meat is rising, although there is not much relevant data about their nutrition. Hungary is leading in production and costuming, the duck production is about 4.3 million, which is increasing by 30% each year. Successful and economic production is possible with intensive nutrition and concentrated nutrient content beside a temperature being equal to the animal's thermoneutral zone (Cherry and Morris 2008.). The thermoneutral zone of ducklings are 26.5–29.5 °C, but their temperature range decrease 3 °C weekly, reaching 18–20 °C at the end of the growing period (FASS 2010).

Free radicals are formed due to heat stress, which is part of the general protection mechanism. The antioxidant-prooxidant balance can be damaged in chronic phase, shifted to the prooxidant processes. The recovery is done by the so-called Three Level Antioxidant System. The first is the direct enzymatic pathway, free radicals are neutralized by enzymes e.g. Superoxide-dismutase enzyme (SOD). The second is the small molecule antioxidant group, which compounds are participated in detoxification and regeneration reactions. One of the most important antioxidant is Vitamin C. Vitamin E also plays an important role with strong antioxidant quality. The third level is activated when damaged proteins have to be repaired and/or removed from the cells. Damaged protein amount is increasing due to heat stress and heat shock protein synthesis begins. The most known heat stress protein is heat shock protein 70 (HsP70) which is located in the cytoplasm. (Horváth et al. 2016b). The antioxidant defence system plays an important role in the reduction of the heat stress generated lipid peroxidation process. Many studies prove that under short or long term heat stress the antioxidant system of broilers is damaged (Yang et al. 2010, Akbarian et al. 2015). According to our previous study we found the same results in ducks under chronic heat stress (Horváth et al. 2016a).

There are very limited and inconsequence number of scientific results on the digestibility of nutrients, production parameters and chemical composition of meat under heat stress in ducks. Long term heat stress has proved negative effects on the digestibility of nutrients in broilers (Hai et al. 2000, Daghir 2009). In contrast with these data Sahin and Kucuk (2001) find higher digestibility of nutrients with Vitamin C and E supplementation in diet under chronic heat stress (34 °C). However Laganá et al. (2007) could not detect any negative effect on the digestibility of nutrients when the environmental temperature was inconstant (25–32 °C).

Production parameters are also affected by chronic heat. Feed additives with antioxidant effect can be used to improve the performance of ducks. Vitamin C and E supplement in diets reduced the deterioration of daily weight gain (dWG) and feed conversion ratio (FCR) (Sahin and Kucuk 2001, Attia et al. 2011, Horváth et al. 2016a). Scientific findings on the chemical composition of duck meat under heat stress are limited; most of the experiments were done under thermoneutral conditions (Galal et al. 2011, Heo et al. 2015).

In summary the literature findings it can be conclude that there are very limited relevant information and hardly enough systematic studies are available about the negative effects on the antioxidant status, energy turnover, digestibility of the nutrients, production parameters and chemical composition of meat under long term heat stress in meat type ducks.

Therefor the aim of the study is to determine the effect of vitamin C and E and mineral (Zn) supplement in the diet under permanently high environmental temperature (30±1 °C) on the digestibility of nutrients, performance and furthermore the chemical composition of duck meat in the growing period.

MATERIALS AND METHODS

The experimental procedures were approved by University of Debrecen Animal Care Committee (Debrecen, Hungary).

Birds

A total of four hundred mixed sex 14 days old Cherry Valley type hybrid ducks were used for the study. The ducklings were fed by same compound feed for 14 days, before the start of the experiment at the Tranzitker Company's farm. The ducklings at the age of 14 days were placed to the animal house. The experiment started at 14 days of age and lasted for 42 days. The feed and water were available ad libitum.

Housing

In the animal house 10 pens were placed. Ducks were weighted and equally distributed among two groups of five replicate (3.30×1.5 m) consisted of 20 birds. The floor pens were housed in environmentally controlled rooms. The average room temperature was maintained at 30±1 °C for 24 hours every day and the relative humidity was 65±5%. The temperature was monitored twelve times daily at different locations of the animal house. The lighting schedule of 23L:1D (2 lux) was provided (Cherry and Morris 2008). Ducks were kept in floor pens covered with straw for beddings. This experiment was repeated once more in same circumstances (2×200 ducks=400 ducks).

Dietary treatments, composition of diets and calculated nutrient content

Two experimental diets were formulated in the study. The experimental diets *(Table 1)* were prepared by making a control diet, which can be used in normal environmental temperature (near to thermoneutral zone) and experimental diet (supplemented with Vitamin C and E and zinc). The composition and calculated nutrient contents of diets can be seen is *Table 1*.

Table 1.

Composition and calculated nutrient contents of control and high-oxidant diets

Composition (%)	Diets	
	Control	Experiment
Corn	25.0	35.03
Wheat	20.0	10.0
Triticale	25.52	20.0
Ext. Soy meal (CP: 46%)	3.62	10.64
Full fat soya	5.0	5.0
Ext. sunflower granulate	13.47	10.24
Wheat meal	3.0	6.0
Others	4.39*	3.09**
Calculated nutrient content (100 g dry matter)	Diets	
	Control	Experiment
AMEn poultry (MJ per kg)	12.3	12.0
C. protein (%)	18.4	19.8
C. fiber (%)	5.0	5.0
Lysine (%)	1.0	1.1
Methionine (%)	0.50	0.52
Ca (%)	0.65	0.68
Vitamin A (IU)	10000	10000
Vitamin D3 (IU)	4000	4000
Vitamin E (mg per kg)	40	190
Vitamin C (mg per kg)	25	200
Se (mg per kg)	0.4	0.4
Zn (mg per kg)	100	110

Note: *Amino Acid supplementation: L-Lysine HCl, DL-Methionine, L-Threonine; Sunflower oil; Limestone; MCP; Salt; $NaHCO_3$; premix. ** Amino acid supplementation: L-Lysine HCl, DL-Methionine, L-Threonine; Limestone; MCP; Salt; $NaHCO_3$; premix

Measurements

Digestibility trial

One duck from each pen was randomly euthanized by cervical dislocation at day 42. Digesta was collected from the distal duodenum to the ileocecal junction (the entire ileum) according to Jin et al. (2000). The samples were placed in plastic holders and stored on -20 °C until laboratory analysis (n=20).

Performance trial

The live weight (LW) of the ducks was measured at day 14 and 42. The dWG was calculated individually. The daily feed intake (FI) was also recorded by each pen. The FCR and the energy and protein conversion was also calculated (n=200).

Meat analysis

One duck from each pen was randomly euthanized by cervical dislocation at day 42. The skinny leg and breast meat of the ducks was collected individually in plastic bags. The samples were stored on -20 °C until laboratory analysis (n=20).

Chemical Analysis

Diet

The nutrient and mineral content of the feed was determinated using standard procedures of Proximate Analysis (AOAC 2016). The diet samples were analysed for dry matter (DM), nitrogen (N), crude fat (CF), crude fiber and ash. Dry matter of diets was determined by oven-drying 4 h at 103 °C (MSZ ISO 6496:2001) and ash by complete combustion (550 °C for 24 h) (MSZ ISO 5984:1992). Nitrogen content was determined by Kjeldahl method (MSZ EN ISO 5983:1:2005). Crude lipids were measured by Soxtec extract (TECATOR-Soxtec 1998).

Digestibility

The digestibility of nutrients in the small intestine was determined by post mortem digestibility trial using SiO_2 as indicator (5 ducks/treatment). The digesta samples were analysed using standard procedures of Proximate Analysis (AOAC 2016). The following measurements were done: DM, CP, CF content of the digesta. The following formula was used to calculate the apparent digestibility of nutrients (Elbers et al. 1989):

$$K_1 = 100 - 100 \times \frac{I_F}{I_D \times F} \times \frac{N_D}{N_F}$$

where: K_1 = either nutrient apparent digestibility (%); I_F = Indicator in Feed (%); N_D = Nutrient content of Digesta (%); I_D = Indicator in Digesta (%); N_F = Nutrient content of Feed (%); F = Indicator Recovery Factor.

Meat

The meat samples were analysed for DM, protein, fat and ash using standard procedures of Proximate Analysis (AOAC 2016).

Statistical Analysis

The experimental data were analysed by General Lineal Modell of SAS (version 9.3; SAS Inst. Inc., Cary, NC) using the following general model:

$$Y_{jjk} = \mu + t_i + r_j + (t \times r)_{ij} + e_{ijk}$$

where: Y – Dependent variable; μ – Overall mean; t – Treatment (i=2); r – Repeat (j=2); k × i – Interaction between treatment and repeat; e – Residual error.

Tukey's multiple comparison test was conducted at a significance level of P< 0.05 (SAS 9.3.) Repeat and treatment repeat interactions were ignored, because these effects for trait were found non-significant.

RESULTS

Digestibility of nutrients

The digestibility coefficients are summarized in *Table 2*. As it can be seen the nutrient digestibility of ducks was not affected by the raised vitamin and mineral supplementation under long term heat stress. The digestibility of DM, CP and CF did not change significantly (P>0.05).

Table 2.

Effect of antioxidant supplement on nutrient digestibility of ducks under long term heat stress

Nutrient digestibility (%)	Treatments		RMSE**
	Control group*	Treated group*	
Dry matter	78.5	80.3	1.8
Crude protein	74.2	75.8	2.7
Crude fat	35.7	37.6	20.4

Note: *Treatments are defined in section 2.3. **Root mean square error.

Growth performance

In *Table 3* the effect of antioxidant supplementation on the performance of ducks can be seen. In the treated group (diet supplemented with vitamin C and E and with zinc) the dWG increased and the FCR improved significantly (P<0.05). The energy and protein conversion was decreased also significantly (P<0.05).

Table 3.

Effect of antioxidant supplement on performance of ducks under long term heat stress (n=200)

Items	Treatments		RMSE**
	Control group*	Treated group*	
Daily Weight Gain (g per bird)	44[a]	53[b]	9
Feed intake (kg per pen per 28 days)	63[a]	69[b]	3.5
Feed intake (calculated) (g per bird per 28 days)	3150	3450	-
Feed Conversion Ratio (kg per kg WG)	2.7[a]	2.2[b]	0.2
Energy Conversion Ratio (MJ AMEn per kg WG)	333.2[a]	267.6[b]	27.8
Protein Conversion Ratio (g protein per kg WG)	443[a]	393[b]	42

Note: *Treatments are defined in section 2.3. **Root mean square error. [a,b] Different superscripts in the same row indicate significant differences between groups at P<0.05 level.

Meat chemical composition

As it can be seen in *Table 4* the DM and ash content was not affected by the higher vitamin C and E and zinc content of diet under heat stress. The protein content was higher in the treated group but not significantly (P>0.05). Fat decreased in the treated group but also not significantly (P>0.05).

Table 4.

Effect of antioxidant supplement on leg meat composition of ducks under long term heat stress

Meat composition (leg) (%)	Treatments		RMSE**
	Control group*	Treated group*	
Dry matter	23.8	23.5	0.8
Protein	19.9	20.3	2.5
Fat	2.5	1.9	2.6
Ash	1.1	1.1	0.4

Note: *Treatments are defined in section 2.3. **Root mean square error.

The breast meat was also analysed to examine the difference in the chemical composition between the control and treated group. *Table 5* shows a similar tendency to the results of the leg meat. The DM and ash was not affected by the supplementation under heat stress. The protein content increased but not significantly (P>0.05). Fat decreased but not significantly in treated group (P>0.05).

Table 5.

Effect of antioxidant supplement on breast meat composition of ducks under long term heat stress

Meat composition (breast) (%)	Treatments		RMSE**
	Control group*	Treated group*	
Dry matter	23.5	23.4	0.8
Protein	21.3	21.5	0.8
Fat	0.6	0.5	0.5
Ash	1.3	1.3	0.6

Note: *Treatments are defined in section 2.3. **Root mean square error.

DISCUSSION

Based on different experiments carried out under heat stress it was found that heat stress has negative effects on nutrient digestibility (Hai et al. 2000, Daghir 2009). However, it should be noticed that there are limited and inconsequence number of scientific results on the digestibility of nutrients in ducks under heat stress. Digestibility of DM under heat stress in broilers can be very various: from 66% (Bonett et al. 1997) to 73% (Seven and Seven 2011). Our results show that digestibility of DM in control (78.5%) and treatment (80.3%) group are both higher than in the literature. The digestibility of crude protein is range from 67% (Bonnett et al. 1997, Seven and Seven 2011) to 80–84% (Hosseini and Afsar 2016) in the literature. In general Vitamin C addition under heat stress improves the digestibility of nutrients although in our study it was not expressive. In our study the digestibility of CP is ranged between the results of Seven and Seven (2011) and Hosseini and Afsar (2016) in both treatments. Digestibility of crude protein was not affected by supplementation. In general it can be said that the digestibility values are appropriate for the digestibility of ducks (Seven and Seven 2011).

Feed additives which have direct or indirect antioxidant effect can be used to protect the animals against the negative effects of heat stress. Vitamin C has improved the performance under heat stress in broilers (Attia et al. 2011). Vitamin C and E used together also increased the dWG and the FCR under heat stress in broilers (Sahin and Kucuk 2001). Zinc is a necessary element for growth and development and also for immuncompetance. It also plays a role in carbohydrate and energy metabolism; protein synthesis and catabolism. Under heat stress these systems are damaged, but with zinc supplementation the negative effects can be reduced (Kucuk et al. 2003). In our study we used two treatments. The control group was fed with a diet required to nutrient content in the thermoneutral zone. The experimental group was fed with diet supplemented with vitamin (Vitamin C and E) and mineral (zinc). The results showed same effects as the scientific papers: the production parameters were affected by higher vitamin and mineral supplementation under heat stress. In the treated group the dWG increased and the FCR improved significantly (P<0.05). The energy and protein conversion was decreased also significantly (P<0.05).

The chemical composition of duck breast in different experiments determined as 20–21% protein, 1.5–3.6% fat and 0.9–1.8% ash content under thermoneutral conditions and without supplementation (Galal et al. 2011, Heo et al. 2015). Aksit el al. (2006) and Tankson et al. (2001) reported that heat treatment caused reductions in protein content of the carcass. In our study the protein content of duck leg (19.9%) and breast meat (21.3%) decreased but not significantly without antioxidant supplementation under long term heat stress(P>0.05). We got the same results of protein content in the treated group as in the previously mentioned studies under normal environmental temperature (leg: 20.3%; breast: 21.5%). Our results show that in treated group the fat content was lower (leg: 1.9%; breast: 0.5%) than control group (leg: 2.5%; breast: 0.5%); antioxidant supplementation has improved the fat content of duck meat. Ash content did not change, although the feed was supplemented with high dose of vitamins and zinc. Higher dose of Vitamin (C, E) and mineral (Zn) supplementation under heat stress has improved effects on the chemical composition of duck meat, especially on protein and fat content.

CONCLUSION

Based on the results the following conclusions can be drown:

- The antioxidant defence system plays an important role in the reduction of heat stress generated lipid peroxidation process. Feed additives which have direct or indirect antioxidant effects can reduce the negative effects of heat stress on the ducks performance and meat composition.
- Digestibility of nutrients (DM, CP, CF) was not affected by antioxidant supplementation under chronic heat stress (30±1 °C).

– The performance of ducks was affected significantly by vitamin C and E and zinc supplementation under chronic heat stress. In the treated group the daily weight gain increased and the feed conversion ratio was improved significantly when the diet contains 190 mg kg^{-1} Vitamin E, 200 mg kg^{-1} Vitamin C and 110 mg kg^{-1} zinc. The energy and protein conversion was decreased also significantly.

ACKNOWLEDGMENT

This study was supported in part by Hungarian Research Fund (TÁMOP 4.2.2D-15/1). The authors gratefully acknowledge the generous sponsorship of Tranzitker Trading Company, Debrecen, Hungary (www.tranzitker.hu).

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