DOI: 10.5433/1679-0359.2020v41n6Supl2p3419

Co-supplementation of colostrum powder on performance, intestinal morphology, blood biochemical parameters and antioxidant status of broilers in heat stress

Co-suplementação de pó de colostro no desempenho, morfologia intestinal, parâmetros bioquímicos sanguíneos e status antioxidante de frangos de corte no estresse térmico

Momammad Hussein Gorbannejad Parapary[1]; Ali Nobakht[2*]; Yousef Mehmannavaz[2]

Highlights:
Colostrum is rich in vitamins A (retinol), E (tocopherol) and C (which are considered anti-stress vitamins) and therefore their use in feeding broilers in conditions of thermal stress is likely to benefit the immune system, reducing casualties and improving growth.
Colostrum can be added to poultry ration as a feed additive due to its nutritious and performance-enhancing attributes.
Use of colostrum powder in heat stress condition is recommended, because it can improve broilers performance and carcass traits, without any adverse effects on antioxidant status, blood biochemical and immunity parameters.

Abstract

This experiment was conducted to investigate the effects of different levels of colostrum powder on performance, intestinal morphology, blood biochemical parameters and antioxidant status of broilers in heat stress. In this experiment 224 Ross-308 broiler chicks were used from 1 to 42 days in 5 treatments and 4 replicates (12 birds per replicate) in a completely randomized design. Treatments included: 1) control (without using colostrum), 2) 0.5% of colostrum, 3) 1% of colostrum, 4) 1.5% of colostrum, and 5) 2% of colostrum powder. Colostrum powder was added in first 10 days of broilers breeding period in their diets. Colostrum powder had significant effects on performance, carcass traits and intestinal cells morphology of broilers in heat stress ($P < 0.05$). In grower period the highest amounts of final body weight and body weight gain were obtained with 2% of colostrum powder. Colostrum powder in contrast to control improved the percentages of gizzard, liver, bursa of fabricious, thighs and breast ($P > 0.05$). The highest villies, the lowest crypts and the highest ratio of villies/crypts were obtained with colostrum powder adding ($P > 0.05$). Colostrum powder had no significant effects on blood biochemical parameters and antioxidant status of broilers. The overall resulted showed that in broilers in heat stress condition using colostrum powder up to 2% in starter period has beneficial effects on performance, carcass traits and intestinal morphology of broilers.
Key words: Antioxidant. Broilers. Carcass traits. Heat stress. Performance.

[1] PhD Student of Animal Science, Department of Animal Science, Maragheh Branch, Islamic Azad University, Maragheh, Iran. E-mail: ymailhf@gmail.com
[2] Associated Professor of Animal Science, Department of Animal Science, Maragheh Branch, Islamic Azad University, Maragheh, Iran. E-mail: anobakht20@yahoo.com; mehmannavaz@yahoo.com
[*] Author for correspondence

Received: July 11, 2020 - Approved: Sept. 04, 2020

Resumo

Este experimento foi conduzido para investigar os efeitos de diferentes níveis de colostro em pó no desempenho, morfologia intestinal, parâmetros bioquímicos sanguíneos e status antioxidante de frangos de corte sob estresse térmico. Neste experimento, 224 pintos de corte Ross-308 foram utilizados de 1 a 42 dias em 5 tratamentos e 4 repetições (12 aves por repetição) em um delineamento inteiramente casualizado. Os tratamentos incluíram: 1) controle (sem usar colostro), 2) 0,5% de colostro, 3) 1% de colostro, 4) 1,5% de colostro e 5) 2% de colostro em pó. O colostro em pó foi adicionado nos primeiros 10 dias do período de criação de frangos de corte em suas dietas. O colostro em pó teve efeitos significativos no desempenho, características de carcaça e morfologia das células intestinais de frangos de corte sob estresse térmico ($P < 0,05$). No período de crescimento, os maiores peso corporal final e ganho de peso corporal foram obtidos com 2% de de colostro em pó. O colostro em pó, em contraste com o controle, melhorou as porcentagens de moela, fígado, bolsa de fabricious, coxas e peito ($P > 0,05$). As maiores vilosidades, as menores criptas e a maior proporção de vilosidades/criptas foram obtidas com a adição de colostro em pó ($P > 0,05$). O colostro em pó não teve efeitos significativos nos parâmetros bioquímicos sanguíneos e no status antioxidante de frangos de corte. O resultado geral mostrou que, em frangos de corte sob estresse por calor, utilizando colostro em pó até 2% no período inicial, possui efeitos benéficos no desempenho, características de carcaça e morfologia intestinal dos frangos.

Palavras-chave: Antioxidante. Frangos de corte. Características de carcaça. Estresse térmico. Desempenho.

Introduction

Chickens have a strong tendency to lose weight immediately after hatching, and this has adverse effects on subsequent growth (Prabakar, Pavulraj, Shanmuganathan, Kirubakaran, & Mohana, 2016; Ijiri et al., 2016; Elliott, Branton, Evans & Peebles, 2018). This may be affiliated to nutritional limitations immediately after hatching, and unexpected changes in feed type and adaptation of the gut to rigid feed (Sarlak, Tabeidian, & Gheisari, 2017; Jha, Singh, Yadav, Berrocoso, & Mishra, 2019). Nonetheless, integrating nutrition with the development and growth of chickens after hatching is a challenge. The first days after hatching is a critically important in maintaining and survival of newly hatched chickens (Surai, Fisinin, & Karadas, 2016; Elwan, Elnesr, Xu, Xie, Dong, & Zou, 2019). Substitute the yolk (the endogenous diet) with a solid (exogenous diet) ration causes large metabolic and physiological changes, and resulted to delay in growth rates (Nazem, Amiri, & Tasharrofi, 2019; Wu et al., 2019). Colostrum plays an important nutritional role for neonatal growth and the development in mammals (Wang et al., 2018; Verso et al., 2020). In addition, colostrum can provide nutrients and immunity to the newborn animals (Hammon, Liermann, Frieten, & Koch, 2020). Colostrum can be added to poultry ration as a feed additive due to its nutritious and performance-enhancing attributes (Zhang et al., 2016; Afzal et al., 2017; Del Puerto, Cabrera, & Saadoun, 2017). Colostrum containing the low amount of lactose compared to normal milk, and conversely other compounds such as fat, protein and ash, is higher in it (Szyndler-Nędza, Mucha, & Tyra, 2020; Reyes-Camacho et al., 2020; Gallo et al., 2020). Colostrum is rich in vitamins A (retinol), E (tocopherol) and C (which are considered anti-stress vitamins) and therefore their use in feeding broilers in conditions of thermal stress is likely to benefit the immune system, reducing casualties and improving growth (Y de Vries, Pundir, Mckenzie, Keijer, & Kussmann, 2018; Jrad, Oussaief, Khorchani, & El-Hatmi, 2020). Present experiment carried out to evaluate the effects of different levels of colostrum powder on performance, intestinal morphology, blood biochemical parameters and antioxidant status of broilers in heat stress. Despite

the fact that the study of the colostrum powder in broiler ration is one of the novelties of this study, the study of colostrum powder on heat stress condition has been done for the first time in this study and is novelty of the study.

Material and Methods

A total of 224 male Ross-308 broilers (one-day-old) were sexed and weighed before starting the trial from between 500 birds of both sexes, then were divided into completely randomized design with 5 treatments and 4 replicates (12 birds per replicate). Diets conformed to the advised levels of nutrients, as established by the Ross-308 broiler nutrition specification, and using the UFFDA software program. Ingredients and calculated nutrient contents of broilers diets are shown in Table 1.

Lighting of the saloon in the three first days was continuous and from the fourth day it was changed to 23 hours light and 1 hour dark conditions. Broiler house temperature in the first day was 34°C and from the first week onward, for every two weeks the temperature was reduced by 2°C, and in the sixth week the temperature was reduced to 20°C, and remained at this temperature until the end of experimental period. To create artificial heat stress conditions, broilers (14 – 42 d) were kept 8 hours a day at 32 ± 2 °C. Feed conversion ratio was calculated considering the wastage and specifying the age of chickens.

Table 1
Ingredients and calculated nutrient contents of diets in broilers

Feed ingredients	Feeding periods						
	Starter (1 to 10 d)					Grower (11 to 24 d)	Finisher (25 to 42 d)
Corn	57.66	57.87	57.46	57.98	57.99	63.35	65.93
Soybean meal	37.64	37.01	36.37	35.73	35.11	32.08	28.06
Soybean oil	0.14	0.1	0.69	0.34	0	0.50	2.18
Colostrum powder	0	0.50	1.00	1.50	2.00	0	0
Oyster shell	1.18	1.18	1.19	1.19	1.19	1.07	1.00
Dicalcium phosphate	1.89	1.88	1.87	1.87	1.86	1.63	1.45
Vitamin premix	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Mineral premix	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Sodium chloride	0.3	0.3	0.3	0.3	0.3	0.23	0.23
DL-Methionine	0.29	0.28	0.27	0.26	0.25	0.24	0.22
Lysine—HCl	0.30	0.28	0.25	0.23	0.20	0.25	0.24
Sodium bicarbonate	0.10	0.10	0.10	0.10	0.10	0.15	0.15
Calculated composition							
ME (Mcal/kg)			2.86			2.89	3.00
CP(%)			21.98			20.00	18.50
Calcium (%)			0.917			0.81	0.74
Avail. P (%)			0.458			0.41	0.37
Sodium (%)			0.16			0.15	0.16
Lysine (%)			1.38			1.20	1.09
Met + cys (%)			1.03			0.92	0.86
Met (%)			0.67			0.59	0.55

At the end of the experiment (42 days old), after 6 hours of starvation, 2 birds were selected from each cage that close to the mean weight of the cage and after slaughter, different parts and length of the intestine were evaluated. To measure blood biochemical parameters, samples were centrifuged (at 1000 × g for 20 min) after clotting (2h) to obtain serum and stored at -20ºC prior to analysis. Data were subjected to statistical analysis according to a completely randomized design using the general linear model procedure of SAS (Palangi, & Macit, 2019).

Results

Growth performance

The effects of dietary supplementation with colostrum powder on the growth performance of chickens are shown in Table 2. Weight gain significantly improved in the 2% colostrum powder groups during days 1-24 ($P < 0.05$). However, FCR and FI in experimental broilers was not significantly different from control ($P > 0.05$).

Table 2
Effect of supplementation colostrum powder on weight gain (WG; g/chick/period), feed intake (FI, g/chick/duration), and feed conversion ratio (FCR)

Colostrum powder	0	0.50	1.00	1.50	2.00	SEM	P-Value
WG (1-24)	656.17^{c}	682.24^{ab}	666.96^{bc}	685.83^{ab}	699.21^{a}	8.06	0.0157
WG (25-42)	1184.92	1206.97	1140.00	1192.71	1141.06	38.83	0.6493
FI (1-24)	723.67	744.17	733.12	748.96	745.21	11.14	0.5021
FI (25-42)	2410.83	2443.50	2433.12	2487.33	2385.42	46.35	0.6187
FCR (1-24)	1.102	1.091	1.099	1.092	1.066	0.0164	0.5443
FCR (25-42)	2.045	2.032	2.140	2.089	2.091	0.0703	0.8255

Carcass traits

The effect of using different levels of colostrum powder on carcass traits of broilers at the end of the experimental period is shown in Table 3. Colostrum powder supplementation significantly affected ($P < 0.05$) the Burs, Thigh and Breast.

Table 3
Effect of supplementation colostrum powder on carcass traits of broilers (%)

Colostrum powder	0	0.50	1.00	1.50	2.00	SEM	P-Value
Carcass	73.23	73.17	74.77	74.89	76.17	0.926	0.1712
Abdominal fat	4.31	4.17	4.82	4.24	4.53	0.258	0.4170
Intestine	7.30	6.91	6.85	7.09	7.36	0.341	0.7726
Gizzard	4.41	3.86	4.49	4.29	4.63	0.178	0.0574
Liver	4.66	4.17	4.67	4.28	4.72	0.180	0.1366
Spleen	0.216	0.179	0.205	0.166	0.194	0.0186	0.3695
Burs	0.207^{ab}	0.163^{b}	0.214^{b}	0.274^{a}	0.208^{ab}	0.021	0.0344
Thigh	22.08^{ab}	21.29^{b}	22.33^{ab}	22.11^{ab}	23.09^{a}	0.446	0.0130
Breast	25.65^{ab}	26.57^{ab}	27.41^{a}	23.81^{b}	26.59^{ab}	0.999	0.0167

Morphological characteristics of the intestine

As can be seen in Table 4, supplementation of colostrum powder was affected morphological characters of intestine, and difference between means was statistically significant (P <0.05).

Table 4
Effect of supplementation colostrum powder on small intestine flaps (scale in µm)

Colostrum powder	0	0.50	1.00	1.50	2.00	SEM	P-Value
Villi	1041.25^{ab}	1021.65^{b}	1006.75^{b}	1134.20^{ab}	1210.15^{a}	54.997	0.0878
Crypt	202.25^{a}	168.15^{b}	202.93^{a}	180.82^{ab}	186.09^{ab}	10.40	0.1431
Villi/Crypt	5.160^{b}	6.115^{ab}	5.027^{b}	6.352^{ab}	6.555^{a}	0.4260	0.0698
Gublet	44.35	47.35	41.45	46.85	43.40	5.397	0.9310

Blood parameters

Effect of different levels of colostrum powder on blood biochemical and immunity parameters were presented in Table 5 and 6. None of the biochemical parameters were affected by the experimental treatments.

Table 5
Effect of supplementation colostrum powder on blood biochemical parameters of broiler in 42 day (mg/dL)

Colostrum powder	0	0.50	1.00	1.50	2.00	SEM	P-Value
Glucose	171.50	188.75	203.75	197.25	209.50	12.70	0.2934
Triglyceride	74.25	83.75	85.00	81.00	87.50	5.28	0.4769
Cholesterol	129.00	133.25	128.00	128.25	131.50	8.87	0.9911
HDL	61.25	60.50	57.50	60.25	61.50	2.41	0.7810
LDL	52.50	55.75	53.25	51.50	60.00	10.72	0.9805
Albumin	1.272	1.195	1.177	1.120	1.232	0.062	0.5057
Total Protein	9.675	10.887	12.312	10.837	10.405	0.812	0.2784

Table 6
Effect of supplementation colostrum powder on immunity parameters of broiler in 42 day (mg/dL)

Colostrum powder	0	0.50	1.00	1.50	2.00	SEM	P-Value
DNCB-W12h	0.0400	0.0475	0.0550	0.0395	0.0400	0.01268	0.8585
DNCB-W24h	0.0375	0.0475	0.0650	0.0400	0.0650	0.01609	0.6149
DNCB-W48h	0.0350	0.0500	0.0850	0.0475	0.0575	0.0135	0.1627
PHA- P12h	0.0175	0.0225	0.0250	0.0150	0.0325	0.0063	0.3673
PHA- P24h	0.0175^{b}	0.0275^{b}	0.0550^{a}	0.0300^{b}	0.0300^{b}	0.00736	0.0317
PHA- P48h	0.0175	0.0150	0.0275	0.0275	0.0225	0.00516	0.3441
SRBC1	1.500	1.750	2.000	2.750	2.500	0.3979	0.2029
SRBC2	2.250^{b}	2.250^{b}	2.500^{b}	3.500^{b}	4.250^{a}	0.5204	0.0564

ROS Level and redox status

The antioxidant capacities are presented in Table 7. The production of reactive oxygen species (ROS), such as SOD, GSH-Px and MDA wasn't significant ($P > 0.05$).

Table 7
Effect of supplementation colostrum powder on ROS Level and redox status

Colostrum powder	0	0.50	1.00	1.50	2.00	SEM	P-Value
SOD	22.127	30.470	24.805	26.915	30.312	1.7697	0.1661
GSH-Px	1.9421	2.012	1.847	2.057	2.357	0.2058	0.5016
MDA	0.545	0.575	0.535	0.455	0.435	0.0511	0.2792

Discussion

Growth performance

Commercial poultry are almost inevitably exposed to different stressors (Surai, Kochish, Fisinin, & Kidd, 2019). Even though, the secretion of stress hormones supply birds needs for survival, but they inhibit different functions of the immune system, leading not only to the occurrence of diseases and mortality in chickens and also to their reduced performance (Saeed et al., 2017; Shukla, Kumar, & Sharma, 2017; Kamal, Dey, Mondal, & Chandran, 2018). Mashayekhi, Mazhari and Esmaeilipour (2018) investigated that adding probiotics up to the age of 28 can be helpful in reducing the FCR and increasing weight, that did not match the results obtained in this study. Shah, Patel, Gohil, Blake and Joshi (2019) noted that the probiotic effect on the performance of broilers were improved growth factors, including moderate WG, FCR, average FI, and reduced mortality compared to the control. Because probiotics reduce the pH of the small intestine, thereby making the intestinal environment unfavorable for pathogens and significantly increasing poultry performance.

Carcass traits

Due to the lack of the lactase enzyme in poultry gut, lactose is not absorbed, but is fermented and converted to lactic acid and volatile fatty acids, which may stimulate the colonization of lactobacilli in the gut. Elevated fat concentrations reduce the acidity of the appendix, which reduces the growth of pathogenic bacteria, and is effective in increasing the carcass of chickens.

Kusandi and Djulardi (2011) stated that the weight of immune organs (bursa, liver and spleen) decreased significantly under heat stress, which could be a consequence of reduced feed intake and thus less nutrients for proper growth of these organs, in this experiment supplementation of colostrum powder was increased the bursa organ and improved the immunity.

Morphological characteristics of the intestine

Because of the small intestine is considered to be the major area of absorption from the gastrointestinal tract, examination of the tissue structure of the small intestinal can be important in knowing amount of absorption and performance of broilers. Allahdo et al. (2018) attribute this to longer villi prevent rapid passage, reduces moisture content and reduces FCR, therefore, the higher the height of the villi, leads to greater the absorption capacity of the small intestine. Gomes et al. (2014) concluded that declining performance in stress exposed chicks might be related to alterations in the functions of the

hypothalamic, pituitary, adrenal (HPA) axis, that in present study colostrum may improve this.

Blood parameters

Among the studied parameters for immunity, only PHA- P24h and SRBC2 were affected by experimental treatments ($P < 0.05$). These include glucose (Glu), triglyceride (TG), cholesterol (CHO), high-density lipoprotein (HDL), low-density lipoprotein (LDL), albumin (ALB) and total protein (TP). None of the parameters were significantly different.

ROS Level and redox status

The primary sources of ROS in skeletal muscle is the leakage of electrons from the respiratory chain in mitochondria. Meanwhile, mitochondria are vulnerable to attack by ROS owing to the lipids (phospholipid) and proteins composition of their membranes. None of the parameters were significantly different.

Conclusion

The overall resulted showed that in broilers in heat stress condition using colostrum powder up to 2% in starter period has beneficial effects on performance, carcass traits and intestinal morphology of broilers. Colostrum powder has no adverse effects on poultry performance, carcass traits, intestinal morphology, antioxidant status, blood biochemical and immunity parameters, and can be used to improve poultry ability in stress condition.

Acknowledgement

The article was extracted from the Ph.D. thesis prepared by Momammad Hussein Gorbannejad Parapary, under the guidance of Prof. Dr. Ali Nobakht.

Authors' contributions

MHGP collected the data for this study, YM conducted the statistical analyses, MHGP and AN developed the original hypotheses and designed the experiments, both authors have read and approved the finalized manuscript

Conflict of Interest Declaration

The authors declare that they have no known competing financial interests or personal relationship that could have appeared to influence the work reported in this paper.

References

Afzal, I., Khan, A. A., Khaliq, T., Hamadani, H., Shafi, M., & Raja, T. A. (2017). Effect of bovine colostrum supplemented diets on performance of broiler chicken. *Indian Journal of Poultry Science*, *52*(2), 157-160. doi: 10.5958/0974-8180.2017.00027.7

Allahdo, P., Ghodraty, J., Zarghi, H., Saadatfar, Z., Kermanshahi, H., & Edalatian Dovom, M. R. (2018). Effect of probiotic and vinegar on growth performance, meat yields, immune responses, and small intestine morphology of broiler chickens. *Italian Journal of Animal Science*, *17*(3), 675-685. doi: 10. 1080/1828051X.2018.1424570

Del Puerto, M., Cabrera, M. C., & Saadoun, A. (2017). A note on fatty acids profile of meat from broiler chickens supplemented with inorganic or organic selenium. *International Journal of Food Science*, *7613069,* 8 págs. doi: 10.1155/2017/7613069

Elliott, K. E. C., Branton, S. L., Evans, J. D., & Peebles, E. D. (2018). Early post-hatch survival and humoral immune response of layer chickens when in ovo vaccinated with strain F Mycoplasma gallisepticum. *Poultry Science*, *97*(11), 3860-3869. doi: 10.3382/ps/pey282

Elwan, H. A., Elnesr, S. S., Xu, Q., Xie, C., Dong, X., & Zou, X. (2019). Effects of in ovo methionine-cysteine injection on embryonic development, antioxidant status, IGF-I and tlr4 gene expression, and jejunum histomorphometry in newly hatched broiler chicks exposed to heat stress during incubation. *Animals*, *9*(1), 25. doi: 10.3390/ani9010025

Gallo, S. B., Moretti, D. B., Oliveira, M. C., Santos, F. F. dos, Brochine, L., Micai, G.,... Tedeschi, L. O. (2020). The colostrum composition of sheep fed with high-energy diets supplemented with chromium. *Small Ruminant Research*, *191*, 106177. doi: 10.1016/j.smallrumres.2020.106177

Gomes, A., Quinteiro, W., Fº., Ribeiro, A., Ferraz-de-Paula, V., Pinheiro, M., Baskeville, E., & Palermo, J., Neto. (2014). Overcrowding stress decreases macrophage activity and increases Salmonella Enteritidis invasion in, broiler chickens. *Avian Pathology*, *43*(1), 82-90. doi: 10.1080/03079457.2013.874006

Hammon, H. M., Liermann, W., Frieten, D., & Koch, C. (2020). Importance of colostrum supply and milk feeding intensity on gastrointestinal and systemic development in calves. *Animal*, *14*(S1), s133-s143. doi: 10.1017/S1751731119003148

Ijiri, D., Ishitani, K., El Deep, M. M. H., Kawaguchi, M., Shimamoto, S., Ishimaru, Y., & Ohtsuka, A. (2016). Single injection of clenbuterol into newly hatched chicks decreases abdominal fat pad weight in growing broiler chickens. *Animal Science Journal*, *87*(10), 1298-1303. doi: 10.1111/asj.12541

Jha, R., Singh, A. K., Yadav, S., Berrocoso, J. F. D., & Mishra, B. (2019). Early nutrition programming (in ovo and post-hatch feeding) as a strategy to modulate gut health of poultry. *Frontiers in Veterinary Science*, *6*, 82. doi: 10.3389/fvets.2019.00082

Jrad, Z., Oussaief, O., Khorchani, T., & El-Hatmi, H. (2020). Camel colostrum composition, nutritional value, and nutraceuticals. In Nome dos Editores, *Handbook of research on health and environmental benefits of camel products* (pp. 240-262). IGI Global. doi: 10.4018/978-1-7998-1604-1.ch011

Kamal, R., Dey, A., Mondal, K. G., & Chandran, P. C. (2018). Impact of Environmental Stressors on the Performance of Backyard Poultry. *Proceedings of the National Academy of Sciences, India Section B: Biological Sciences*, *88*(1), 79-84. doi: 10.1007/s40011-016-0741-z

Kusandi, E., & Djulardi, A. (2011). Physiological dynamic of broiler at various environmental temperatures. *International Journal of Poultry Science*, *10*(1), 19-22. Recovered from http://free-journal.umm ac.id/files/file/Physiology_Broiler.pdf

Mashayekhi, H., Mazhari, M., & Esmaeilipour, O. (2018). Eucalyptus leaves powder, antibiotic and probiotic addition to broiler diets: effect on growth performance, immune response, blood components and carcass traits. *Animal: an International Journal of Animal Bioscience*, *12*(10), 2049-2055. doi: 10.1017/S1751731117003731

Nazem, M. N., Amiri, N., & Tasharrofi, S. (2019). Effect of in ovo feeding of amino acids and dextrose solutions on hatchability, body weight, intestinal development and liver glycogen reserves in newborn chicks. *In Veterinary Research Forum*, *10*(4), 323. doi: 10.30466/vrf.2018.69536.1956

Palangi, V., & Macit, M. (2019). In situ crude protein and dry matter ruminal degradability of heat-treated barley. *Revue de Medecine Veterinaire*, 170(7-9), 123-128.

Prabakar, G., Pavulraj, S., Shanmuganathan, S., Kirubakaran, A., & Mohana, N. (2016). Early nutrition and its importance in poultry: a review. *Indian Journal of Animal Nutrition*, *33*(3), 245-252. doi: 10.5958/ 2231-6744.2016.00044.X

Reyes-Camacho, D., Vinyeta, E., Pérez, J. F., Aumiller, T., Criado, L., Palade, L. M.,... Solà-Oriol, D. (2020). Phytogenic actives supplemented in hyperprolific sows: effects on maternal transfer of phytogenic compounds, colostrum and milk features, performance and antioxidant status of sows and their offspring, and piglet intestinal gene expression. *Journal of Animal Science*, *98*(1), skz390. doi: 10.1093/jas/skz390

Saeed, M., Babazadeh, D., Naveed, M., Arain, M. A., Hassan, F. U., & Chao, S. (2017). Reconsidering betaine as a natural anti-heat stress agent in poultry industry: a review. *Tropical Animal Health and Production*, *49*(7), 1329-1338. doi: 10.1007/s11250-017-1355-z

Sarlak, S., Tabeidian, S. A., & Gheisari, A. (2017). Effects of time of initiation of feeding after hatching and diet composition on performance, carcass characteristics, digestive tract development and immune responses of broilers. *Animal Production Science*, *57*(8), 1692-1701. doi: 10.1071/AN15839

Shah, T. M., Patel, J. G., Gohil, T. P., Blake, D. P., & Joshi, C. G. (2019). Host transcriptome and microbiome interaction modulates physiology of full-sibs broilers with divergent feed conversion ratio. *Biofilms and Microbiomes*, *5*(1), 1-13. doi: 10.1038/s41522-019-0096-3

Shukla, P. K., Kumar, A., & Sharma, A. (2017). Stressors and their biochemical indicators in poultry. *International Journal of Agriculture and Biology*, *4*(1), 29. doi: 10.21088/ijab.2454.7964.4118.5

Surai, P. F., Fisinin, V. I., & Karadas, F. (2016). Antioxidant systems in chick embryo development. Part 1. Vitamin E, carotenoids and selenium. *Animal Nutrition*, *2*(1), 1-11. doi: 10.1016/j.aninu.2016.01.001

Surai, P. F., Kochish, I. I., Fisinin, V. I., & Kidd, M. T. (2019). Antioxidant defence systems and oxidative stress in poultry biology: an update. *Antioxidants*, *8*(7), 235. doi: 10.3390/antiox8070235

Szyndler-Nędza, M., Mucha, A., & Tyra, M. (2020). The effect of colostrum lactose content on growth performance of piglets from Polish Large White and Polish Landrace sows. *Livestock Science*, *234*(2020), 103997. doi: 10.1016/j.livsci.2020.103997

Verso, L. L., Matte, J. J., Lapointe, J., Talbot, G., Bissonnette, N., Blais, M.,... Lessard, M. (2020). Impact of birth weight and neonatal nutritional interventions with micronutrients and bovine colostrum on the development of piglet immune response during the peri-weaning period. *Veterinary Immunology and Immunopathology*, *226*(2020), 110072. doi: 10.1016/j.vetimm.2020.110072

Wang, X., Zhu, Y., Feng, C., Lin, G., Wu, G., Li, D., & Wang, J. (2018). Innate differences and colostrum-induced alterations of jejunal mucosal proteins in piglets with intra-uterine growth restriction. *British Journal of Nutrition*, *119*(7), 734-747. doi: 10.1017/S0007114518000375

Wu, S., Guo, W., Li, X., Liu, Y., Li, Y., Lei, X.,... Yang, X. (2019). Paternal chronic folate supplementation induced the transgenerational inheritance of acquired developmental and metabolic changes in chickens. *Proceedings of the Royal Society B, 286*(1910), 20191653. doi: 10.1098/rspb.2019.1653

Y de Vries, J., Pundir, S., Mckenzie, E., Keijer, J., & Kussmann, M. (2018). Maternal circulating vitamin status and colostrum vitamin composition in healthy lactating women A systematic approach. *Nutrients*, *10*(6), 687. doi: 10.3390/nu10060687

Zhang, L., Zhang, L., Zeng, X., Zhou, L., Cao, G., & Yang, C. (2016). Effects of dietary supplementation of probiotic, Clostridium butyricum, on growth performance, immune response, intestinal barrier function, and digestive enzyme activity in broiler chickens challenged with Escherichia coli K88. *Journal of Animal Science and Biotechnology*, *7*(1), 3. doi: 10.1186/s40104-016-0061-4