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The Effect of Buriti Oil (*Mauritia flexuosa* L.) as Feed Additive on the Organic and Inorganic Materials Digestibility on Heat Stress Exposed Broilers

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ABSTRACT

Heat stress due to high environmental conditions can affect the digestibility of organic and inorganic broilers. Buriti oil (*Mauritia flexuosa* L.) contains antioxidants that can suppress Reactive Oxygen Species (ROS) thereby reducing the negative effects of heat stress. This study aims to determine the effect of adding buriti oil to the ration on the organic and inorganic matter of digestibility in broiler exposed to heat stress. This research was experimental and the method used is the completely randomized design method (CRD). The treatment be carried out on 20 broiler aged 22-35 days who are kept in individual cages. Broiler in the treatment group were given heat stress induction using gasolec up to a temperature 35 ± 10°C for 4 hours every day. Broiler were randomly selected in 4 treatment groups divided into K- (temperature 27 ± 2°C + complete feed), K+ (exposure to temperature 35 ± 1°C + complete feed), P1 (exposure to temperature 35 ± 1°C + complete feed + 2% buriti oil total feed gram /head /day) and P2 (exposure to temperature 35 ± 1°C + complete feed + 4% buriti oil total feed gram /head /day). This treatment was studied for 22-35 days and tested for normality using ANOVA with a significance level ($p<0.05$). The results showed a significant value ($p<0.05$) between control and treatment on the organic and inorganic matter of digestibility.

Keywords: Broiler, Buriti oil, Digestibility, Heat stress, Inorganic matter, Organic matter

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Introduction

Cage management is an important factor in the process of raising broiler chickens (Shields and Greger, 2013). The cage is a place to live for broiler chickens because the life and reproduction processes are carried out there, the comfortable conditions of the cage make the productivity of broiler chickens maximum (Hariono *et al.*, 2023). Temperature and humidity are also important factors in broiler chicken productivity. The optimal temperature and humidity to support the growth of broiler chickens is around 26-27°C and 50-70% (Kpomasse *et al.*, 2021). High environmental temperatures can cause heat stress in broiler chickens which has a negative impact in the form of reducing feed consumption, growth rate and body weight of broiler chickens, causing large losses (Lara and Rostagno, 2013).

Excessive heat exposure can cause heat stress in broiler chickens (Wasti *et al.*, 2020). Heat stress is a condition that causes changes in the body's biological functions such as decreased feed consumption, disruption of protein metabolism, energy and mineral balance, enzymatic reactions and hormonal secretion (Rostagno, 2020). Environmental stress is very detrimental for broiler chickens, this will show changes in behavior in broiler chickens, including increased expiratory frequency, frequent raising of the wings, moving less and spending more time resting (Lara and Rostagno, 2013). Broiler chickens that experience stress also experience panting and spend more time drinking, this causes the volume of water in the intestine to increase and enzyme dilution occurs so that the enzymatic digestion process takes longer (Mancinelli *et al.*, 2023).

Heat stress reactions can increase the formation of Reactive Oxygen Species (ROS) (Medina *et al.*, 2021). High ROS can affect the growth metabolism of broiler chickens, phosphorus is a mineral compound that has important nutrients for biological processes and physiological functions of the body such as supporting growth performance and livestock production (Surai *et al.*, 2019). Balanced calcium and phosphorus in the ration can reduce the production of intestinal calcium fitrate complex bonds which will increase the amount of phosphorus thereby helping absorption in the small intestine (Xu *et al.*, 2020). The solution that can be provided is in the form of synthetic and herbal feed additives (Righi *et al.*, 2021).

Feed additives are materials that do not include food substances that are added in small amounts, these materials can come from herbal and synthetic materials (Ayalew *et al.*, 2022). Broiler chicken farmers have now started using feed additives to trigger growth factors in broiler chickens, both with herbal ingredients and synthetic ingredients that have been produced by feed companies. Currently, feed additives derived from herbal ingredients are still very underused at the farmer level because breeders are looking for things that are instant and easy to obtain (Alem, 2024). Herbal plants that have the potential to have active compounds that can influence heat stress in broiler chickens are the buriti plant (*Mauritia flexuosa* L.).

The research results of Marcelino *et al.* (2022) concluded that the content of buriti oil derived from buriti fruit proves the high quality of flavonoids, alpha tocopherol, β-carotene, palmitic acid and oleic acid. The antioxidant content in buriti oil can play a role in suppressing ROS production so that the oxidative stress of a cell will decrease along with decreasing ROS production (de Souza Aquino *et al.*, 2023). High ROS can affect the metabolism of broiler chickens, digestibility of feed will decrease if ROS increases so that antioxidant compounds in buriti oil are needed to suppress and reduce the action of ROS (Desbruslais and Wealleans, 2022).

The latest research regarding the provision of herbal feed additives which have the best effect in reducing the negative impacts of heat stress has not been carried out much. This research was conducted to determine the herbal feed additive from buriti oil as an antioxidant that can reduce heat stress.

Materials and methods

Research design

This research was carried out from December 2020 to January 2021 in several places, namely sample treatment was carried out at Slamet Hariyadi Farm, Jl. Gandrung, Cungking Neighborhood, Mojopanggung Village, Giri District, Banyuwangi Regency. Making feed and mixing it with buriti oil is carried out at the Animal Feed Laboratory of the Off-Main Campus Study Program (PSDKU) Airlangga University in Banyuwangi.

The sample used in this study was 20 broiler chickens which were divided into four treatments with 5 broiler chickens in each treatment. The treatment was carried out using Cobb strain broiler chickens. Broiler chickens in the starter phase were reared for 14 days, the adaptation period was carried out at the age of 15-21 days and the finisher phase at the age of 22-35 days as research treatment.

Broiler chicken rearing

Maintenance of 102 Day Old Chicks (DOC) reared at the age of 1-14 days. The cage has been cleaned and sprayed with disinfectant before the DOC arrives, then prepare the technical management of the cage with a temperature of 30-32°C, relative humidity of 60-70%, floor temperature of 28-30°C, minimal ventilation, even light from lamps in the cage, and appropriate placement of food and drinking water as well as installation of litter that has been covered with newspaper. Broiler chickens aged 1-14 days are reared with complete feed and drinking water ad libitum.

Mixing feed ingredients

Mixing feed ingredients includes mixing the main ingredients with micro ingredients. Mixing complete feed with buriti oil begins with taking the buriti oil using a syringe according to the specified dose then transferring it into a spray bottle, then spraying evenly on the feed that has been spread in the basin and mixing so that the feed is mixed homogeneously with the buriti oil.

Mixing the feed is carried out before the feed is given, namely at 6.00 am and 4.00 pm for broiler chickens for 14 days, this aims to ensure that the feed mixed with buriti oil does not evaporate. The feed mixed with buriti oil has 2 different concentrations, namely group P1 at 2% of the total feeding grams/head/day, while P2 is 4% of the total feeding grams/head/day and at the same time groups (K- and K+ = 0%) is also prepared. The provision of nutrients in broiler chicken feed is adjusted to the age period of finisher phase broiler chickens (2909 kcal / kg ME; 20.21% CP) weeks 3-4. Proximate analysis of feed was carried out in the control group and treatment group.

Treatment

The broiler chickens were moved to individual treatment cages (20 cm × 35 cm × 35 cm) at the age of 14 days complete with feed and water containers. Before the broiler chickens were moved, 20 birds were graded by looking at the body weight in the range of 750-800 grams. At the age of 22 days (7 days after the adaptation period), the environmental temperature of the broiler chickens was controlled according to the treatment group. Exposure to heat stress in groups K+, P1 and P2 started from 10.00 am to 14.00 afternoon. Research by Mancinelli *et al.* (2023) stated that broiler chickens exposed to heat stress of 35°C and humidity above 60% for 4 hours can disrupt broiler chicken body homeostasis. The treatments used in this research are,

K-: Broiler maintenance is carried out at a temperature of 27 ± 2°C without heat stress induction and is given complete feed.

K+: Broiler rearing with induced heat stress of 35°C ± 1°C and fed complete feed.

P1: Broiler rearing with induced heat stress of 35°C ± 1°C and feeding mixed with buriti oil with a concentration of 2% of total feed grams/head/day.

P2: Maintenance of broilers with induced heat stress of 35°C ± 1°C and feeding mixed with buriti oil with a concentration of 4% of total feed grams/head/day.

Stool collection

Stool collection was carried out for 14 days (days 22-35). Fecal samples from 20 broilers were put into plastic clips separately and then labeled with paper according to the treatment given. Stool samples are stored in the freezer at -15°C to prevent spoilage. Feces stored in the freezer are dried using an oven at 60°C for 12-24 hours, after which they are weighed using a scale. The dried feces from each treatment were taken at 50% of the dry weight and subjected to proximate analysis (Apáez-Barrios *et al.*, 2023).

Retrieval of remaining feed

Remaining feed was collected for 14 days. Feed is collected from the feed bin and what falls on the floor of the cage. The remaining feed is then weighed and put in plastic. The remaining feed weight data is used to calculate digestibility values (Fan *et al.*, 2017).

Proximate analysis of feed and feces

The proximate test is a chemical analysis method to determine the nutritional content of the samples being tested, such as fish, feed, and feces samples, which is generally carried out in the laboratory (Ajibare *et al.*, 2023). Proximate tests on feed ingredients and broiler feces were carried out in the UPT laboratory for Quality Testing and Development of Marine and Fishery Products in Banyuwangi. Proximate analysis of treatment feed using BR2 feed produced by PT Japfa Comfeed, 10 grams of which were taken as samples in testing protein, ash, fat and water content. A proximate test on 5 grams of feces from each treatment sample was carried out to test the water content and ash content. The feces samples were taken after drying using an oven.

Calculation of digestibility

Calculation of digestibility uses a formula with data taken from the total collection during the period of fecal sample collection and feed consumption carried out for 14 days. Determination of the digestibility of dry matter and organic matter is carried out using proximate analysis tests.

Data analysis

The data obtained will be tested using Univariate Analysis of Variance and followed by Duncan's test if there is a significant difference ($p<0.05$).

Result

Digestibility of organic materials

The average digestibility of organic matter in Cobb broiler strains treated with buriti oil (*Mauritia flexuosa* L.) and exposed to heat stress for each treatment can be seen in table 1.

Table 1. Average digestibility of organic matter

Treatment	Mean (%) ± SD
K-	$64.80^b \pm 1.304$
K+	$62.40^a \pm 1.672$
P1	$64.20^b \pm 0.894$
P2	$64.40^b \pm 1.468$

Note: Different superscripts in the same column indicate a significant difference ($p<0.05$)

The results of the ANOVA test showed that the data were normally distributed and the administration of buriti oil to broilers exposed to heat stress showed significant differences ($p<0.05$) between treatment groups, so it was continued with the Duncan test. Based on the results of research on organic matter in broilers given buriti oil and exposed to heat stress in the K- group, it was 64.80 ± 1.304%, there was a significant difference with the K+ group, 62.40 ± 1.672% and the P1 group, 64.20 ± 0.894% different from the P2 group by 64.40 ± 1.468%. The K+ group showed significant differences with the P1 and P2 groups, while the K- group showed no significant differences with the P1 and P2 groups (Figure 1).

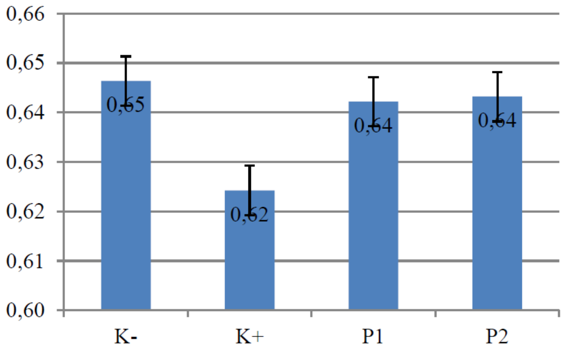

Figure 1. Diagram of the average digestibility of organic matter

Digestibility of inorganic materials

The average digestibility of inorganic materials in Cobb broiler strains treated with buriti oil (*Mauritia flexuosa* L.) and exposed to heat stress for each treatment can be seen in table 2.

Table 2. Average digestibility of inorganic materials

Treatment	Mean (%) ± SD
K-	53.20^{b} ± 2.280
K+	48.60^{a} ± 2.074
P1	54.80^{b} ± 1.095
P2	55.20^{b} ± 0.837

Note: Different superscripts in the same column indicate a significant difference ($p<0.05$)

The results of the ANOVA test showed that the data tested was normally distributed with the results showing significant differences ($p<0.05$) between the treatment groups, so further tests could be carried out using the Duncan test. Based on the results of research on inorganic materials in broilers given buriti oil and exposed to heat stress in the K- group, it was 53.20 ± 2.280%, showing a significant difference with the K+ group, 48.60 ± 2.074% and the P1 group, 54.80 ± 1.095% significantly different from the P2 group of 55.20 ± 0.837%. The K+ group showed significant differences with groups P1 and P2, while the K- group showed no significant differences with groups P1 and P2 (Figure 2).

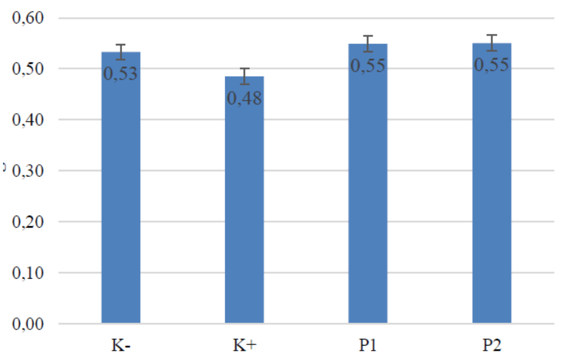

Figure 2. Diagram of the average digestibility of inorganic materials

Discussion

Digestibility of organic materials

Digestibility is a reflection of the amount of nutrients in the feed that can be utilized by livestock. The level of digestibility of the feed ingredient indicates how much the feed ingredient contains food substances that can be digested in the digestive tract (Atchade *et al.*, 2019). The digestibility level of feed quality is divided into three categories, namely low digestibility value of 50-60%, medium digestibility value of 60-70% and high digestibility value in the range of more than 70%. The digestibility of a ration is influenced by palatability, environmental temperature and rate of digestion, level of feeding, physical form of feed ingredients, crude fiber content of feed ingredients, nutritional deficiencies, feed composition, processing of feed ingredients, the influence of combined feed ingredients and digestive tract disorders even if not consistent (Llonch *et al.*, 2018).

The results of data analysis showed that the addition of buriti oil (*Mauritia flexuosa* L.) feed additive at a dose of 2% and 4% of the total feed gram/head/day at P1 and P2 caused a significant difference between the control group and the treatment group ($p<0.05$) on the digestibility value of organic matter. According to Mariam *et al.* (2023) explained that the digestibility of organic matter will increase if the digestibility of dry matter increases. This happens because most of the dry matter comes from organic matter so that factors that influence the level of dry matter digestibility will also influence the digestibility of organic matter. The nutritional value of organic material components must be adjusted to the needs of each animal in order to achieve optimal organic material digestibility (Pomar *et al.*, 2021). The research results of Beckford *et al.* (2020) reported that feed consumption will decrease if broiler chickens are at a temperature higher than the comfort zone, this is done to reduce heat production in the broiler chicken's body.

Heat stress is one of the factors that causes a decrease in the digestibility of organic materials as a result of high environmental temperatures (Nawab *et al.,* 2018). Broiler chickens experience heat stress causing reduced feed consumption and increased drinking water consumption so that endothermic body heat formation is reduced, lack of feed consumption can cause nutritional needs for basic life and growth to decrease and can reduce the activation of digestive enzymes so that enzyme secretion becomes low (Lara and Rostagno, 2013). Montilla *et al.* (2014) stated that the source of oxidative stress is due to high environmental temperatures due to exposure to heat stress. Oxidative stress is an imbalance between a lack of antioxidants and high production of free radicals in the body.

Antioxidants in buriti oil can prevent the formation of free radical ions due to the loss of peroxide produced by cells so that it has the potential to produce free radical ions which can damage nutritional elements in the form of vitamins and other ingredients (Lobo *et al.,* 2010). Antioxidant compounds such as flavonoids can increase fluid production in the intestinal villi and increase the permeability of intestinal cell walls, thereby maintaining homeostasis of the intestinal epithelium which can improve the digestive process and absorption of food nutrients in the digestive tract (Verediano *et al.,* 2021). The flavonoid compound content in herbal plants works to protect the mucosal walls of the small intestine so that it can increase the absorption of nutrients in animal feed (Panche *et al.,* 2016). Nutrient absorption in the intestine is closely related to the intestinal villi, according to Prihambodo *et al.* (2021) flavonoids can increase the height of broiler duodenal villi, causing the absorption surface area to be wider and nutrient absorption to be more optimal. Optimal nutrient absorption can increase the digestibility of organic material in broiler chickens (Zhang *et al.,* 2023).

The tocopherol content in buriti oil is a natural antioxidant that forms vitamin E which acts as a natural antioxidant that destroys free radicals and oxygen molecules and prevents membrane peroxidation of unsaturated fatty acids (Rizvi *et al.,* 2014). According to Reboul (2017), 20-80% of tocopherol is absorbed in the upper part of the small intestine in the form of micelles, the formation of which depends on bile salts and pancreatic lipase. Tocopherol absorption is carried out by dissolving it in a mixture of bile salt micelles which are absorbed in the small intestine and secreted into the circulation of the lymphatic system (Jesch and Carr, 2017).

Digestibility of inorganic materials

Analysis of research data on the effect of giving feed mixed with buriti oil and exposed to heat stress showed a significant difference ($p<0.05$) on the digestibility value of inorganic materials. Buriti oil as an antioxidant indirectly affects the digestibility of inorganic materials, the flavonoid and tocopherol content in buriti oil is able to bind toxic free radicals in the bloodstream so that the body's metabolism can run well (Marcelino *et al.,* 2022). Metabolism that runs well triggers the mineral content in buriti oil such as phosphorus and iodine to work optimally. Zaffarin *et al.* (2020) stated that tocopherol is absorbed together with dietary fat which has an important role as a carrier in the digestive process and absorption of nutrients in the body. Nutrient absorption is closely related to the villi, the increase in intestinal villi which occurs due to the effects of flavonoid compounds causes the level of absorption of food substances to become wider and the absorption of phosphorus and iodine becomes optimal (Kiela and Ghishan, 2016).

Giannone *et al.* (2023) defines all forms of biological responses that pose a threat and disrupt homeostasis in animals can be categorized as heat stress. Exposure to heat stress can be minimized through feed and drinking water with antioxidants which have the ability to ward off free radicals (Liang *et al.,* 2022). Lobo *et al.* (2010) explains that antioxidant compounds are substances that the body needs to neutralize free radicals and prevent damage caused by free radicals to normal cells, proteins and fats. Antioxidant compounds have a molecular structure that can provide electrons to free radical molecules without interfering with their function and can break the chain reaction of free radicals (Pham-Huy *et al.,* 2008). Antioxidants also work to inhibit pro-inflammatory cytokines which influence the reduction of livestock appetite (Al-Khayri *et al.,* 2022). Low feed consumption due to decreased appetite can inhibit chicken body weight growth (te Pas *et al.,* 2020). The content of antioxidant compounds such as flavonoids and vitamin E in herbal plants plays an important role in protecting the intestinal surface (Ullah *et al.,* 2020).

Phosphorus is a mineral compound that has important nutrients for biological processes and physiological functions of the body, such as supporting growth performance and livestock production (Serna and Bergwitz, 2020). According to Wagner (2024), balanced phosphorus in the diet can reduce the production of calcium phosphate and calcium-phytate bonds in the intestine, thereby increasing the amount of phosphorus available for absorption in the intestine. Sensoy (2021) explains that phosphorus also has an important role in facilitating the digestive process so that it runs effectively. This is done by phosphorus by stimulating digestion to increase absorption of vitamins and minerals. Phosphorus in livestock bodies is in the form of phospholipids as a structural component of cell walls and also as organic phosphate which plays a role in storing or releasing energy in the form of Adenine Triphosphate (Serna and Bergwitz, 2020).

Iodine is an inorganic compound in buriti oil which functions as a constituent of hormones produced by the thyroid gland which play a role in the level of oxidation and protein synthesis in all body cells (Sorrenti *et al.*, 2021). The hormones produced have an active role in digestive mechanisms, thermoregulation, growth, muscle function, endurance and livestock reproduction (da Silva Rosa *et al.*, 2020). According to Krela-Kaźmierczak *et al.* (2021) stated that iodine in the poultry body is easily absorbed by the digestive tract, iodine requirements in poultry are influenced by growth, gender and physiological condition. Słupczyńska *et al.* (2023) stated that iodine deficiency for poultry is very dangerous because the iodine content affects thyroid function because most of the cell metabolism in the chicken's body is regulated by the thyroid gland.

Conclusion

Based on the research conducted, it can be concluded that the addition of buriti oil (*Mauritia flexuosa* L.) to the ration can increase the digestibility of organic and inorganic materials in broiler chickens exposed to heat stress.

References

Ajibare AO, Ayeku PO, Udoh FE. Proximate Composition and Sensory Evaluation of Catfish (*Clarias gariepinus*) Smoked with Different Materials. Aquat Food Stud. 2023; 3(2): AFS193.

Al-Khayri JM, Sahana GR, Nagella P, Joseph BV, Alessa FM, Al-Mssallem MQ. Flavonoids as Potential Anti-Inflammatory Molecules: A Review. Molecules. 2022; 27(9): 2901.

Alem WT. Effect of herbal extracts in animal nutrition as feed additives. Heliyon. 2024; 10(3): e24973.

Apáez-Barrios J, Ocampo-López J, Soto-Simental S, Aguilar-Raymundo VG, Ayala-Martínez M. Dietary Supplementation with *Pithecellobium dulce* (Roxb) Benth Fruits to Fattening Rabbits. Animals (Basel). 2023; 13(20): 3249.

Atchade GST, Houndonougbo FM, Chrysostome CAAM, Mensah GA. Digestibility of feeds in broiler chicken (*Galus galus linnaeus*, 1758) in Africa: a review. Int J Biol Chem Sci. 2019; 13(2): 1127–1139.

Ayalew H, Zhang H, Wang J, Wu S, Qiu K, Qi G, Tekeste A, Wassie T, Chanie D. Potential Feed Additives as Antibiotic Alternatives in Broiler Production. Front Vet Sci. 2022; 9(1): 916473.

Beckford RC, Ellestad LE, Proszkowiec-Weglarz M, Farley L, Brady K, Angel R, Liu HC, Porter TE. Effects of heat stress on performance, blood chemistry, and hypothalamic and pituitary mRNA expression in broiler chickens. Poult Sci. 2020; 99(12): 6317–6325.

da Silva Rosa SC, Nayak N, Caymo AM, Gordon JW. Mechanisms of muscle insulin resistance and the cross-talk with liver and adipose tissue. Physiol Rep. 2020; 8(19): e14607.

de Souza Aquino J, Batista KS, Araujo-Silva G, Dos Santos DC, de Brito NJN, López JA, da Silva JA, das Graças Almeida M, Pincheira CG, Magnani M, de Pontes Pessoa DCN, Stamford TLM. Antioxidant and Lipid-Lowering Effects of Buriti Oil (*Mauritia flexuosa* L.) Administered to Iron-Overloaded Rats. Molecules. 2023; 28(6): 2585.

Desbruslais A, Wealleans AL. Oxidation in Poultry Feed: Impact on the Bird and the Efficacy of Dietary Antioxidant Mitigation Strategies. Poultry. 2022; 1(4): 246–277.

Fan YF, Yang YY, Yang P, Xia T, Ma YX. Available energy content, nutrients digestibility of chili meal and effects on performance of growing pigs. Anim Feed Sci Technol. 2017; 229(1): 97–105.

Giannone C, Bovo M, Ceccarelli M, Torreggiani D, Tassinari P. Review of the Heat Stress-Induced Responses in Dairy Cattle. Animals. 2023; 13(22): 3451.

Hariono, Afnan R, Sumiati, Fadilah R. The Effect of Wind Chill in Closed House on Broiler Performance. J Anim Prod Process Technol. 2023; 11(1): 34–40.

Jesch ED, Carr TP. Food Ingredients That Inhibit Cholesterol Absorption. Prev Nutr Food Sci. 2017; 22(2): 67–80.

Kiela PR, Ghishan FK. Physiology of Intestinal Absorption and Secretion. Best Pract Res Clin Gastroenterol. 2016; 30(2): 145–159.

Kpomasse CC, Oke OE, Houndonougbo FM, Tona K. Broiler production challenges in the tropics: A review. Vet Med Sci. 2021; 7(3): 831–842.

Krela-Kaźmierczak I, Czarnywojtek A, Skoracka K, Rychter AM, Ratajczak AE, Szymczak-

Tomczak A, Ruchała M, Dobrowolska A. Is There an Ideal Diet to Protect against Iodine Deficiency? Nutrients. 2021; 13(2): 513.

Lara LJ, Rostagno MH. Impact of Heat Stress on Poultry Production. Animals (Basel). 2013; 3(2): 356–369.

Liang ZL, Chen F, Park S, Balasubramanian B, Liu WC. Impacts of Heat Stress on Rabbit Immune Function, Endocrine, Blood Biochemical Changes, Antioxidant Capacity and Production Performance, and the Potential Mitigation Strategies of Nutritional Intervention. Front Vet Sci. 2022; 9(1): 906084.

Llonch P, Mainau E, Ipharraguerre IR, Bargo F, Tedó G, Blanch M, Manteca X. Chicken or the Egg: The Reciprocal Association Between Feeding Behavior and Animal Welfare and Their Impact on Productivity in Dairy Cows. Front Vet Sci. 2018; 5(1): 305.

Lobo V, Patil A, Phatak A, Chandra N. Free radicals, antioxidants and functional foods: Impact on human health. Pharmacogn Rev. 2010; 4(8): 118–126.

Mancinelli AC, Baldi G, Soglia F, Mattioli S, Sirri F, Petracci M, Castellini C, Zampiga M. Impact of chronic heat stress on behavior, oxidative status and meat quality traits of fast-growing broiler chickens. Front Physiol. 2023; 14(1): 1242094.

Marcelino G, Hiane PA, Pott A, de Oliveira Filiú WF, Caires ARL, Michels FS, Júnior MRM, Santos NMS, Nunes ÂA, Oliveira LCS, Cortes MR, Maldonade IR, Cavalheiro LF, Nazário CED, Santana LF, Di Pietro Fernandes C, Negrão FJ, Tatara MB, de Faria BB, Asato MA, de Cássia Freitas K, Bogo D, do Nascimento VA, de Cássia Avellaneda Guimarães R. Characterization of Buriti (Mauritia flexuosa) Pulp Oil and the Effect of Its Supplementation in an In Vivo Experimental Model. Nutrients. 2022; 14(12): 2547.

Mariam M, Natsir A, Syahrir S. Consumption and Digestibility Studies in Goats Fed with Complete Feed Corn Tumpi and Red Dragon Fruit Peel Flour (*Hylocereus* sp.). Hasanuddin J. Anim. Sci. 2023; 5(1): 10–17.

Medina E, Kim SH, Yun M, Choi WG. Recapitulation of the Function and Role of ROS Generated in Response to Heat Stress in Plants. Plants (Basel). 2021; 10(2): 371.

Montilla SI, Johnson TP, Pearce SC, Gardan-Salmon D, Gabler NK, Ross JW, Rhoads RP, Baumgard LH, Lonergan SM, Selsby JT. Heat stress causes oxidative stress but not inflammatory signaling in porcine skeletal muscle. Temperature (Austin). 2014; 1(1): 42–50.

Nawab A, Ibtisham F, Li G, Kieser B, Wu J, Liu W, Zhao Y, Nawab Y, Li K, Xiao M, An L. Heat stress in poultry production: Mitigation strategies to overcome the future challenges facing the global poultry industry. J Therm Biol. 2018; 78(1): 131–139.

Panche AN, Diwan AD, Chandra SR. Flavonoids: an overview. J Nutr Sci. 2016; 5(1): e47.

Pham-Huy LA, He H, Pham-Huy C. Free radicals, antioxidants in disease and health. Int J Biomed Sci. 2008; 4(2): 89–96.

Pomar C, Andretta I, Remus A. Feeding Strategies to Reduce Nutrient Losses and Improve the Sustainability of Growing Pigs. Front Vet Sci. 2021; 8(1): 742220.

Prihambodo TR, Sholikin MM, Qomariyah N, Jayanegara A, Batubara I, Utomo DB, Nahrowi N. Effects of dietary flavonoids on performance, blood constituents, carcass composition and small intestinal morphology of broilers: a meta-analysis. Anim Biosci. 2021; 34(3): 434–442.

Reboul E. Vitamin E Bioavailability: Mechanisms of Intestinal Absorption in the Spotlight. Antioxidants (Basel). 2017; 6(4): 95.

Righi F, Pitino R, Manuelian CL, Simoni M, Quarantelli A, De Marchi M, Tsiplakou E. Plant Feed Additives as Natural Alternatives to the Use of Synthetic Antioxidant Vitamins on Poultry Performances, Health, and Oxidative Status: A Review of the Literature in the Last 20 Years. Antioxidants. 2021; 10(5): 659.

Rizvi S, Raza ST, Ahmed F, Ahmad A, Abbas S, Mahdi F. The role of vitamin e in human health and some diseases. Sultan Qaboos Univ Med J. 2014; 14(2): e157–e165.

Rostagno MH. Effects of heat stress on the gut health of poultry. J Anim Sci. 2020; 98(4): skaa090.

Sensoy I. A review on the food digestion in the digestive tract and the used in vitro models. Curr Res Food Sci. 2021; 4(1): 308–319.

Serna J, Bergwitz C. Importance of Dietary Phosphorus for Bone Metabolism and Healthy Aging. Nutrients. 2020; 12(10): 3001.

Shields S, Greger M. Animal Welfare and Food Safety Aspects of Confining Broiler Chickens to Cages. Animals (Basel). 2013; 3(2): 386–400.

Słupczyńska M, Jamroz D, Orda J, Wiliczkiewicz A, Kuropka P, Król B. The Thyroid Hormone and Immunoglobulin Concentrations in Blood Serum and Thyroid Gland Morphology in Young Hens Fed with Different Diets, Sources, and Levels of Iodine Supply. Animals. 2023; 13(1): 158.

Sorrenti S, Baldini E, Pironi D, Lauro A, D'Orazi V, Tartaglia F, Tripodi D, Lori E, Gagliardi F, Praticò M, Illuminati G, D'Andrea V, Palumbo P, Ulisse S. Iodine: Its Role in Thyroid Hormone Biosynthesis and Beyond. Nutrients. 2021; 13(12): 4469.

Surai PF, Kochish II, Fisinin VI, Kidd MT. Antioxidant Defence Systems and Oxidative Stress in Poultry Biology: An Update. Antioxidants (Basel). 2019; 8(7): 235.

te Pas MFW, Borg R, Buddiger NJH, Wood BJ, Rebel JMJ, van Krimpen MM, Calus MPL, Park JE, Schokker D. Regulating appetite in broilers for improving body and muscle development - A review. J Anim Physiol Anim Nutr (Berl). 2020; 104(6): 1819–1834.

Ullah A, Munir S, Badshah SL, Khan N, Ghani L, Poulson BG, Emwas AH, Jaremko M. Important Flavonoids and Their Role as a Therapeutic Agent. Molecules. 2020; 25(22): 5243.

Verediano TA, Martino HSD, Paes MCD, Tako E. Effects of Anthocyanin on Intestinal Health: A Systematic Review. Nutrients. 2021; 13(4): 1331.

Wagner CA. The basics of phosphate metabolism. Nephrol Dial Transplant. 2024; 39(2): 190–201.

Wasti S, Sah N, Mishra B. Impact of Heat Stress on Poultry Health and Performances, and Potential Mitigation Strategies. Animals (Basel). 2020; 10(8): 1266.

Xu Y, Ye J, Zhou D, Su L. Research progress on applications of calcium derived from marine organisms. Sci Rep. 2020; 10(1): 18425.

Zaffarin ASM, Ng SF, Ng MH, Hassan H, Alias E. Pharmacology and Pharmacokinetics of Vitamin E: Nanoformulations to Enhance Bioavailability. Int J Nanomedicine. 2020; 15(1): 9961–9974.

Zhang C, Hao E, Chen X, Huang C, Liu G, Chen H, Wang D, Shi L, Xuan F, Chang D, Chen Y. Dietary Fiber Level Improve Growth Performance, Nutrient Digestibility, Immune and Intestinal Morphology of Broilers from Day 22 to 42. Animals (Basel). 2023; 13(7): 1227.