Brazilian Journal of Poultry Science
Revista Brasileira de Ciência Avícola

ISSN 1516-635X 2023 / v.25 / n.2 / 001-006

http://dx.doi.org/10.1590/1806-9061-2022-1717

Technical Note

Evaluation of Pelleting Mealworm (Tenebrio Molitor) Powder with Chokeberry By-product Meal To improve Duck Production and Meat Quality Traits

■Author(s)

Choi IH[I] https://orcid.org/0000-0002-4354-2745

[I] Division of Companion Animal Science, Joongbu University, Geumsan- gun, 32713, South Korea.

■Mail Address

Corresponding author e-mail address
In Hag Choi
Division of Companion Animal Science,
Joongbu University, Geumsan-gun, 32713,
South Korea.
Phone: +82-41-750-6284
Email: wicw@chol.com

■Keywords

Chokeberry by-product meal; Duck production; meat quality traits; pelleting; *Tenebrio molitor* powder.

Submitted: 26/August/2022
Approved: 30/January/2023

ABSTRACT

This study aimed to evaluate the effects of dietary supplementation pelleted Tenebrio molitor (TM) powder with chokeberry by-product (CBP) meal on duck production and meat quality traits. A total of 180 0-day-old Pekin ducks were allocated randomly between three dietary groups viz., control, Treatment 1, and Treatment 2, with three pens per group and twenty birds per pen, characterized by increasing levels of pelleted TM powder with CBP meal in concentration of 0%, 1.5%, and 3%, respectively, and reared until 42 days of age in a completely randomized design. On day 42, the ducks were sacrificed, and breast and thigh muscles were used for meat quality evaluations. Feeding pelleted TM powder with CBP meal resulted in a significant difference in final body weight, weight gain and feed conversion ratio (p<0.05). Additionally, a significant difference was observed in the pH of the breast meat samples (p<0.05). As the only significant difference between the breast and thigh meat, 1,1-diphenyl-2-picryhydrazyl radical scavenging was influenced significantly by the dietary inclusion of pelleted TM powder with CBP meal (p<0.05). However, the values of thiobarbituric acid reactive substances and meat color in both breast and thigh meat were insignificant (p>0.05) different among all groups. To conclude, the inclusion of up to 3 % of pelleted TM powder with CBP meal in the diets of ducks did improve the growth production and antioxidant characteristics effects, which could decrease TBARS and reflected by changes in 1,1-diphenyl-2- picrylhydrazyl free DPPH radical scavenging values.

INTRODUCTION

Increasing demand for animal products is related to rapid human population growth and urbanization. Animal feeding and nutrition play an essential role in animal production, including economic and social roles, thus providing multiple functions (Yosef *et al.*, 2022). They are part of an animal product-system chain between crop cultivation and the production and processing of protein-rich animal products (Yosef *et al.*, 2022). In particular, as feed accounts for 60-70% of the total cost in poultry production, any operation to optimize feed efficiency or reduce the feed cost may lead to a reduction in feed ingredient prices or the total cost of production (Thirumalaisamy *et al.*, 2016). Pelleting provides for one such way of optimizing feed efficiency while reducing the feed cost. In addition, it also offers an effective way of mixing insect powders and meals of plant origin. Using insects has been considered an alternative source of conventional protein feed to soybean meal and fish meal or decomposition abilities from animal wastes (Choi, 2022). Especially, other studies have shown the positive effects of using insects as animal diets on poultry production and meat quality or antioxidant (Ojewola *et al.*, 2002; Choi *et al.*, 2021a, b, c;

Jeong *et al.*, 2022). *Tenebrio molitor* (TM), well-known mealworm, represents one of the most interesting edible insects studied as feed and food as it can be easily reared and maintained at early stages and also due to its larval size (Ghaly & Alkoaik, 2009; Morales-Ramos *et al.*, 2012). Chokeberry is cultivated mainly in the east-south of Europe as an industrial crop and has been traditionally used in North America as medicine (Seidemann, 1993; Kokotkiewicz *et al.*, 2010). Due to its antioxidant and beneficial effects on vitamin action, chokeberry has become even more popular in recent years (Denev *et al.*, 2012). In addition, chokeberry is used as an ingredient in juices, wines, and jams and as a coloring agent and nutritional supplement (Kulling & Rawel, 2008). However, the disposal of chokeberry waste is a major environmental problem. Pelleting of chokeberry by-product (CBP) meal reduces food waste and helps in recycling in poultry industries thereby offering a solution to the problem of chokeberry waste disposals. In this context, the use of pelleted TM powder with CBP meal offers a method for improving poultry production and meat quality by decreasing feed wastage (Jeong *et al.*, 2022). In the present study, the effects of dietary supplementation of pelleted TM powder and CBP meal on growth characteristics and meat quality in Pekin ducks was investigated. Thus, the results presented in this study provide pelleting as an alternative technique for mixing insect powder and CBP meal in duck diets.

MATERIALS AND METHODS

Sample preparation

Tenebrio molitor (TM) powder was obtained from Modnilove (Ulju, South Korea). Chokeberry by product was provided by Yusim Farming Asscociation (Yeongju, Korea). To prepare a CBP meal, the wet CBP was air-dried for seven days and kept away from urban traffic to ensure appropriate protection against environmental contamination, followed by hot-air drying at 60°C for 24 h (Kim *et al.*, 2010). After drying, the CBP was ground, sieved, and drilled with 1-mm trapezoid holes. TM powder and chokeberry meal were thoroughly mixed in the ration of 7:3, and pellets were prepared to form a mixture of TM powder and chokeberry meal using a pelleting mill (Kum Kang Eng., Daegu, South Korea).

Animal Husbandry

The protocol for the animal trial complied with the animal care guidelines of animal policy by the Gilhong farm (Geochang, South Korea). A total of 180 0-day-old Pekin ducks were allocated randomly into three groups (n = 45) viz., Control, Treatment 1 and Treatment 2 fed pelleted TM powder with CBP meal in concentration of 0%, 1.5%, and 3%, respectively, with three replicate pens of twenty birds each in a completely randomized design. The basal diets were used during the starter (0-21 d, 21.0% CP, 0.4% Ca, and 1.5% P) and grower phases (22-42 d, 17.0% CP, 0.4% Ca, and 1.0% P). All ducks were maintained under an age-appropriate temperature, light schedule, ventilation and humidity, with water and diet available *ad libitum*. To determine final body weight (FBW), body weight gain (BWG), feed intake (FI), and feed conversion ratio (FCR), ducks were weighed at 0 d and 42 d of age, with feed weighed regularly every seven days.

Slaughter processing

At 42 d of age, 36 ducks with four ducks per pen were selected for slaughter processing, following 12 h fasting. The selected ducks were transported to the slaughterhouse to be electrically stunned and slaughtered by a ventral cut of neck blood vessels. After bleeding, carcasses were scalded at 60 °C for 2 min, plucked, and eviscerated manually. Duck breast and thigh samples were cleared of all skin, subcutaneous fat, and visible connective tissue, placed in a resealable plastic bag, and immediately stored at 4 °C.

Meat quality traits

Meat samples were measured for pH, thiobarbituric acid reactive substances (TBARS), 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical scavenging activity, and meat color. Muscle pH was analyzed for homogenates of 10 g sample in 90 mL of distilled water using a pH-meter (Mettlerr Toledo Co, MP 230, Greifensee, Switzerland). A TBARS assay was performed according to the method described by Sinnhuber and Yu (1977). The absorbance was measured at 532 nm by spectrophotometer (UV-mini-1240, Shimadzu, Japan). The results were calculated as milligrams of malonaldehyde per kilogram of meat. The DPPH radical scavenging activity of meat samples was determined according to the method described by Blois (1958). Absorbance was measured with a UV-visible spectrophoto meter (UV-mini-1240, Shi madzu Corp., Kyoto, Japan) set at 515 nm. Scavenging activity was calculated based on the change in absorbance. The ascorbic acid and α-tocopherol (Sigma, St. Louis, MO, USA) were used as the positive control. Meat color (CIE L*a* b*) was measured from five random locations of the sample surface using a Minolta Chromameter (CR-

300, Minolta Co., Japan), calibrated with a white plate (Y=93.5, x=0.3132, y=0.3198).

Statistical Analysis

The data were analyzed by standard analysis of variance (ANOVA) using SAS GLM procedures (SAS Institute Inc., 2002) with the pen used as the experimental unit. Duncan's multiple range procedures considering $p<0.05$ as significant were used for comparisons among means.

RESULTS

Table 1 showed the effects of pelleted TM powder with CBP meal on the growth production of ducks after six weeks. Dietary supplementation of pellets of TM powder with CBP meal resulted in significant differences in FBW, BWG and FCR ($p<0.05$), in the absence of differences in the initial body weight and feed intake between the control and treatment groups in Pekin ducks. Compared with the control groups, the T1 and T2 treatments displayed better duck production measured in terms of FBW, BWG and FCR. In addition, a diet containing 1.5% and 3% pelleted TM powder with CBP meal (T1 and T2) to ducks resulted in a similar tendency for growth performance.

Effects of pelleted TM powder with CBP meal on meat quality traits of ducks at 42 days are presented in Table 2. A significant difference was observed in pH values in the breast meat samples ($p<0.05$). As for the meat quality traits of the thigh meat, pH was not significantly ($p>0.05$) different among all groups. TBARS values in the breast and thigh meat were unaffected by the inclusion of pelleted TM powder with CBP meal ($p>0.05$). As the only difference between the breast and thigh meat, DPPH radical scavenging was influenced significantly by the dietary inclusion of pelleted TM powder with CBP meal ($p<0.05$). The meat color in the breast and thigh meat were not affected by dietary supplementation of pelleted TM powder with CBP meal ($p>0.05$).

Table 1 – Effects of pelleted TM powder with CBP meal on duck production after 42 days.

Item[1]	Initial body weight (g)	Final body weight (g)	Body weight gain (g)	Feed intake (g)	Feed:gain ratio
Control	45.29	3,619.59[b]	3,574.31[b]	6,788.98	1.90[a]
T1	44.68	3,695.65[ab]	3,650.98[ab]	6,699.06	1.83[b]
T2	46.15	3,712.53[a]	3,666.38[a]	6,711.31	1.83[b]
SEM[2]	0.39	18.96	18.82	20.89	0.02
p-value	0.3415	0.0405	0.0482	0.1628	0.0218

[a-b]Mean in the same column with no common superscript are significantly different ($p<0.05$).

[1]Control: basal diet; T1: basal diet + 1.5% pelleted TM powder with CBP meal; T2: basal diet + 3% pelleted TM powder with chokeberry meal.

[2]Values are expressed as mean ± standard error.

Abbreviations: TM, Tenebrio molitor; CBP, Chokeberry by-porduct; T1, Treatment 1; T2, Treatment 2; Sem. Standard error of mean.

Table 2 – Effects of pelleted TM powder with CBP meal on meat quality traits of ducks at 42 days.

Item[1]	pH	TBARS (mg MDA/kg)	DPPH radical scavenging (%)	Meat color		
				L (lightness)	A (redness)	B (yellowness)
Control	6.10[a]	0.66	74.67[b]	50.48	10.43	5.16
T1	5.94[b]	0.50	78.10[ab]	52.18	10.85	4.17
T2	5.83[b]	0.53	81.83[a]	48.77	9.75	4.52
SEM[2]	0.05	0.03	1.33	0.71	0.39	0.39
p-value	0.0123	0.1369	0.0400	0.1363	0.5886	0.6442
Control	6.23	0.60	79.06[b]	44.54	8.49	4.03
T1	6.14	0.45	82.22[ab]	46.78	7.92	3.10
T2	6.33	0.38	83.10[a]	44.91	7.41	3.38
SEM[2]	0.04	0.04	0.82	0.52	0.26	0.21
p-value	0.2969	0.0642	0.0361	0.1733	0.2773	0.1962

[a-b]Mean in the same columns with no common superscript are significantly different ($p<0.05$).

[1]Control: basal diet; T1: basal diet + 1.5% pelleted TM powder with CBP meal; T2: basal diet + 3% pelleted TM powder with CBP meal.

[2]Values are expressed as mean ± standard error.

Abbreviations: TM, *Tenebrio molitor*; CBP, Chokeberry by-product; T1, Treatment 1; T2, Treatment 2; Sem. Standard error of mean.

DISCUSSION

Overall, our results were consistent with the results reported by Elahi *et al.* (2020), herein feeding 4% mealworm meals to Ross 308 male broiler chickens resulted in increased body weight, average daily gain, and FCR in the starter phase. Hussain *et al.* (2017) reported that chickens fed a diet containing 3% mealworm meals, showed increase in weight gain and dressing percentage, including feed cost and economic profit. In terms of using chokeberry, Lee *et al.* (2018) used the level of 1% chokeberry powder in the diet of ducks and found improvement in the weight gain and the feed:gain ratio. However, no study has so far evaluated the impact of a pelleting combination of TM powder and CBP meal on the growth performance of Pekin ducks. Based on these results, a wide range of alternative feedstuffs is available for these two feed materials (*Tenebrio molitor* powder and chokeberry by-product meal) in duck production systems. In addition, the duck feed industry requires a constant supply of any newer feed resource with consistent quality while making the best use of constantly changing raw materials (Thirumalaisamy *et al.*, 2016). In other words, there is an opportunity for on-farm mixing feeds with locally available alternative feedstuffs. In the present study, the possible mechanisms for improving the growth performance of ducks could be a result of two reasons: 1) pelleting effects (high digestibility) that the ducks receive a balanced supply of nutrients (Abdollahi *et al.*, 2019), and 2) the interaction of bioactive compounds (for example, phenolic constituents) present in TM powder and CBP meal (Kulling & Rawel, 2008). Consequently, it is hypothesized that there is possibly evidence from the current study for a pelleting and bioactive effect of a mixture of TM powder and CBP meal in ducks.

For meat quality traits, the pH values of the breast and thigh meat obtained in the present trial showed different patterns. The pH values of the breast meat were decreased by increasing pelleted TM powder with CBP meal compared with control. In general, the decline in meat pH is due to the change in glycogen decomposition rate caused by the formation of lactate (Bendall, 1960), which could be ascribed to the rapid growth and hypertrophy of muscles in ducks by an interaction effect of pelleted TM powder and CBP meal, especially in the breast as described by Popova *et al.* (2020) and Fernández-López *et al.* (2005). It has also been reported that broiler quails fed diets containing 15% black soldier fly meal result in a decrease in meat pH, suggesting that the addition of TM powder and CBP meal to diets can directly influence the pH of meat (Cullere *et al.*, 2016; Kim *et al.*, 2016). On the other hand, the pH values in thigh meat were similar among groups. However, the majority of the studies in poultry did not observe the change in the meat pH using TM. It might have resulted from using moderate to high levels of yellow meal worm in the diet (Cullere *et al.*, 2016; Secci *et al.*, 2018). The TBARS results of the breast meat were the lowest in T1, followed by T2 and control. In addition, the reduction in the TBARS results of the thigh meat was in the following order: T2 > T1 > Control. The data obtained from the current study suggested that the reason for reducing the TBARS content in both breast and thigh meat was chiefly related to a pelleting effect or the effective antioxidants that are transferred from feed to animal tissue by TM powder and CBP meal (Kulling & Rawel, 2008; Jeong, 2022). The DPPH radical scavenging in both breast and thigh meat of ducks as antioxidant effectiveness decreased in the order: Control > T1 > T2. Our observation is consistent with previous studies on broiler chickens using *Hermetia illucens* and *Protaetia brevitarsis seulensis* powder as dietary supplements (Choi *et al.*, 2021c). According to Jeong (2022), adding of 1.5% and 3% *Ptecticus tenebrifer* to duck diets improved DPPH radical scavenging values compared with the controls. A further possible reason for DDPH effects has been that the supplementation of pelleted TM powder with CBP meal results in the presence of biologically active substances (antioxidants effect) that also may interact. The overall color traits obtained in our study are similar to those reported by Schiavone *et al.* (2019), wherein dietary supplementation of *Hermetia illucens* meal did not affect the meat color in the breast or thigh meat of broiler. In general, the color of food and meat products are a crucial attribute considered by consumers and used as an economic index of foodstuff (Qiao *et al.*, 2001). However, the cause for the lack of change in meat color in response to the dietary supplementation of pellets of TM powder with chokeberry meal remains unexplained.

In conclusion, the results of the present study provide meaningful and innovative information on the effects of supplementation of partially pelleted TM powder with CBP meal in duck diets. The dietary inclusion of 1.5% and 3% pelleted TM powder with CBP meal increased final body weight, body weight gain, and feed:gain ratio. The comparable results, in terms of meat quality traits and antioxidant effects, between the pelleted TM powder with CBP meal and the control group demonstrated a decrease in TBARS and an increase in DPPH radical scavenging in the

breast and thigh meat of ducks. Future research is still needed to investigate the effect of pelleted TM powder with CBP meal on duck breast and thigh meat colors, including various meat quality traits.

ACKNOWLEDGMENTS

This paper was supported by Joongbu University Research & Development Fund, in 2022.

REFERENCES

Abdollahi MR, Zaefarian F, Ravindran V. Maximising the benefits of pelleting diets for modern broilers. Animal Production Science 2019;59:2023-8.

Bendall JR. The structure and function of muscle. New York: Academic Press; 1960. v.2, p.243-309.

Blois MS. Antioxidant determinations by the use of a stable free radical. Nature 1958;26:1199-200.

Choi IH. Decomposition abilities and characteristics of pig manure using three insect larvae. Entomological Research 2022;52:439-44.

Choi IH, Choi SU, Son JS, Jang WW, Chung TH. Antioxidant and cytoprotective effects of enzyme extracted constituents of *Protaetia brevitarsis seulensis* powder. Entomological Research 2021a;51:90-94.

Choi IH, Chung TH. Effects of *Protaetia brevitarsis seulensis* powder dietary inclusion level on antioxidant activities of broiler breast meat during storage. Entomological Research 2021b;51:369-73.

Choi SU, Choi IH, Chung TH. Investigation of breast meat traits of broilers fed different amounts of *Hermetia illucens* and *Protaetia brevitarsis seulensis* powder. Entomological Research 2021c;51:343-348.

Cullere M, Tasoniero G, Giaccone V, Miotti-Scapin R, Claeys E, De Smet S, *et al.* Black soldier fly as dietary protein source for broiler quails:apparent digestibility, excreta microbial load, feed choice, performance, carcass and meat traits. Animal 2016;10:1923-30.

Denev PN, Kratchanov CG, Ciz M, Lojeck A, Kratchanov CG. Bioavailability and antioxidant activity of black chokeberry (*Aronia melanocarpa*) polyphenols:*in vitro* and *in vivo* evidences and possible mechanisms of action:A Review. Comprehensive Reviews in Food Science and Food Safety 2012;11:471-89.

Elahi U, Wang J, Ma YB, Wu SG, Wu J, Qi GH, *et al.* Evaluation of yellow mealworm meal as a protein feedstuff in the diet of broiler chicks. Animals 2020;10:224.

Fernández-López J, Zhi N, Aleson-Carbonell L, Perez-Alvarez JA, Kuri V. Antioxidant and antibacterial of natural extracts:Application in beef meatballs. Meat Sci 2005;69:371-80.

Ghaly AE, Alkoaik FN. The yellow mealworm as a novel source of protein. American Journal of Agricultural and Biological Sciences 2009;4:319-31.

Hussain I, Khan S, Sultan A, Naila Chand N, Khan R, *et al.* Meal worm (*Tenebrio molitor*) as potential alternative source of protein supplementation in broiler. International Journal of Biosciences 2017;10:255-62.

Jeong YW. Growth performance and meat quality traits of Pekin ducks fed with different amounts of pelleted Ptecticus tenebrifer. Entomological Research 2022;52:334-8.

Kim HW, Setyabrata D, Lee YJ, Jones OG, Kim YHB. Pre-treated mealworm larvae and silkworm pupae as a novel protein ingredient in emulsion sausages. Innovative Food Science and Emerging Technologies 2016;38:116-23.

Kim YJ, Nahm BA, Choi IH. An evaluation of the antioxidant and antimicrobial effectiveness of different forms of garlic and BHA in emulsion-type sausages during refrigerated storage. Journal of Muscle Foods 2010;21:813-25.

Kokotkiewicz A, Jaremicz Z, Luczkiewicz M. Aronia plants: a review of traditional use, biological activities, and perspectives for modern medicine. Journal of Medicinal Food 2010;13:255-69.

Kulling SE, Rawel HM. Chokeberry (*Aronia melanocarpa*) a review on the characteristic components and potential health effects. Planta Medica 2008;74:1625-34.

Lee GD, Shin JH, Choi IH. Growth performance and fatty acid profiles of ducks feed a diet supplemented with aronia (*Aronia Melanocarpa*) powder. Brazilian Journal of Poultry Science 2018:20:193-6.

Morales-Ramos JA, Rojas, MG, Kay S, Shapiro-Ilan DI, Tedders WL. Impact of adult weight, density, and age on reproduction of *Tenebrio molitor* (*Coleoptera:Tenebrionidae*). Journal of Entomological Science 2012;47:208-20.

Ojewola GS, Eburuaja AS, Okoye FC, Lawal AS, Akinmutimi AH. Effect of inclusion of grasshopper meal on performance, nutrient utilization and organ of broiler chicken. Journal of Sustainable Agriculture and the Environment 2002;5:19-25.

Popova T, Petkov E, Ignatova M. Effect of black soldier fly (*Hermetia illucens*) meals on the meat quality in broilers. Agricultural and Food Science 2020;29:177-88.

Qiao M, Fletcher DL, Smith DP, Northcutt JK. The effect of broiler breast meat color on pH, moisture, water-holding capacity, and emulsification capacity. Poultry Science 2001;80:676-80.

SAS Institute. SAS/STAT user's guide: Version 8.2. Cary: SAS Institute; 2002.

Schiavone A, Dabbou S, Petracci M, Zampiga M, Sirri F, Biasato I, *et al.* Black soldier fly defatted meal as a dietary protein source for broiler chickens:effects on carcass traits, breast meat quality and safety. Animal 2019;13:2397-405.

Secci G, Moniello G, Gasco L, Bovera F, Parisi G. Barbary partridge meat quality as affected by *Hermetia illucens* and *Tenebrio molitor* larva meals in feeds. Food Research International 2018;112:291-8.

Seidemann J. Chokeberries a fruit little-known till now. Deutsche Lebensmittel-Rundschau 1993;89:14951.

Sinnhuber RO, Yu TC. The 2-thiobarbituric acid reaction, an objective measure of the oxidative deterioration occurring in fats and oil. Journal of Japan Oil Chemists' Society 1977;26:259-67.

Thirumalaisamy G, Muralidharan J, Senthilkumar S, Hema Sayee R, Priyadharsini M. Cost-effective feeding of poultry. International Journal of Science, Environment and Technology 2016;5:3997-4005.

Yosef T, Demise N, Tadesse T, Daneil T. Study on the animal feed ingredients and livestock product supply, price and market-related constraints in Ethiopia. International Journal of Agricultural Research 2022;17:102-15.