Available online at www.ijrp.org

International Journal of Research Publications

Dietary replacement of fishmeal by sprat-head meal and its effect on the growth performances of broiler chicken

M.S.M. Nafees*, Y. Mohanthas and M. Pagthinathan

Department of Animal Science, Faculty of Agriculture, Eastern University, Sri Lanka

Abstract

High cost of fishmeal used in broiler diets often challenges profit margin of boiler production. Hence, researchers are more focused on evaluating alternative animal protein sources to cut down the feed cost which accounts for 60 to 75% of the total production cost. In this context, sprat-head meal (SHM) was studied to partially replace fishmeal in broiler finisher diet. Sixty-four Lohmann Indian River broiler chicks were divided into four groups with two replicates for each. For the first 21 days, chicks were fed with Prima broiler starter ration. Finisher basal diet was formulated using 5% fishmeal (SHM_0) to have 18.9% crude protein (CP) and 2 990.8 kcal/kg of metabolizable energy. Experimental diets were prepared by replacing 25% (SHM_{25}), 50% (SHM_{50}) and 75% (SHM_{75}) of fishmeal in the basal diet. All the birds were fed with the finisher diet from 22 to 42 d. At the end of the study, live weight (LW), average weight gain (AWG), average daily gain (ADG), dressing percentage (DP), feed intake, FCR, viability, European Production Efficiency Factors (EPEF) and European Broiler Index (EBI) were estimated. Results showed that there was not any difference (P>0.05) in LW, AWG, ADG, DP, FCR, EPEF and EBI of the birds among the treatments. Mean LW when birds entered finisher phase at 21 d was 806±3.2 g. AWG at the finisher phase (22 to 42 d) were: SHM_0, 1 107 g; SHM_{25}, 1 097 g; SHM_{50}, 1 055 g and SHM_{75}, 1 048 g. Overall ADG of the birds were: SHM_0, 52.7 g/bird; SHM_{25}, 52.2 g/bird; SHM_{50}, 50.3 g/bird and SHM_{75}, 49.9 g/bird. DP ranged from 60.7% to 71.8%. Average FCR during the finisher phase were: SHM_0, 2.8; SHM_{25}, 2.8; SHM_{50}, 2.9 and SHM_{75}, 2.9. Overall mean EPEF and EBI of the groups were 416 and 201 respectively. As the dietary replacement of fishmeal did not cause any differences in the productive performances of broiler chicken, SHM can be used to replace 75% of fishmeal (w/w) without challenging the production performances of broiler chicks.

Keywords: Sprat-head meal; Fishmeal; Broiler chicken; Growth performance

1. Introduction

Broiler chicken is preferably consumed as a protein food by the people across almost all the religions and cultures in the world. One of the reasons for high preference of chicken than other meats is its low lipid composition with relatively high content of polyunsaturated fatty acids (PUFA) (Nkukwana et al., 2014). Commercial broiler chicken strains are targeted to yield 2.5 to 3.0 kg of body weight by 5 to 6 weeks with maximum feed conversion efficiency (Nakhon, et al., 2019). Accordingly, they are considered as most efficient terrestrial animals in converting feed nutrients into muscle (Rodrigues and Choct, 2019). Genetic potential of modern broiler chicken strains for faster growth demand high quality feed including appropriate protein and amino acid compositions to support the deposition of muscle fibres. Traditionally, fishmeal and soybean meal play a vital role in supplying dietary protein in broiler diets. However, use of fishmeal has become critical due to its short supply and subsequent high price in the recent past. Around 60 to 75% of the total cost in poultry industry is incurred by feed cost, in which protein accounts 15% (Awoniyi et al., 2004; Khan et al., 2010; Khan et al., 2016). Escalated feed price due to increasing cost of ingredients has significantly declined its profit margin of poultry industry and constantly challenging the researchers for limiting the expenses for feed (Biswas, 2019). In this context, continuous efforts have been made with supplementation of different alternative ingredients with the objectives of reducing production cost and improving the performance and quality of meat. Use of alternative supplement ingredients varies country to country based on their availabilities. Accordingly, past studies have used broiler offal (Hossain et al., 2003), whole wheat (Husvéth et al., 2015), red earthworm meal (Ljiljana et al., 2015), maggot meal (Khan et al., 2016), palm kernel cake fermented with *Sclerotium roflsii* (Mirnawati et al., 2018a), palm oil sludge fermented with *Neurospora crassa* (Mirnawati *et al.*, 2018b), yeast cell wall (Liu et al., 2018), *Ginkgo biloba* leaves (Ren et al., 2018), insect meal (Khan et al., 2018), grasshopper meal (Brah et al., 2018), sugar beet pulp and rice hull (Sabour et al., 2019), rice hull silicon (Nakhon et al., 2019), *etc.* Results of these studies have been concluded at different angles. For example, dietary replacement of soya bean meal by 30% of maggot meal in broiler ration significantly reduced the feed intake while increasing body weight, feed conversion ratio and dressing percentage over the last 28 days of growth (Khan et al., 2016). In contrast, Mirnawati *et al.* (2018a) reported that inclusion of up to 32% of palm kernel cake fermented with *Sclerotium roflsii* did not yield any change in body growth and feed efficiency of broilers. In another study they also concluded palm oil sludge fermented with *Neurospora crassa* could be incorporated into broiler diet up to 22% without affecting the feed efficiency and body weight gain of birds (Mirnawati *et al.*, 2018b).

Fishmeal used in feed manufactures is prepared from fish and fish wastes of different fish species and these species vary from country to country, for example Turkey uses sprat and anchovy (Kocatepe and Çetiner, 2013). In Sri Lanka, dried sprats (*Stolephorus* sp.) are highly preferred for food (Bostock et al., 1992; Ginigaddarage et al., 2018) and they one of the main dishes for rice-based food. According to Ministry of Fisheries and Aquatic Resources Development & Rural Economy (2018), out of 33 012 tonnes of dried fish imported in Sri Lanka in 2017, 69% was sprats. It has been observed that the head portions of sprat are discarded when preparing them for food. In this context, a preliminary experiment was conducted to analyse the feasibility of utilizing the discarded dried sprat-head to partially replace the fishmeal in broiler chicken diet by studying their growth performances.

2. Materials and Methods

2.1 Preparation of sprat-head meal (SHM)

Sprat-heads were collected from the local market in the Eastern region of Sri Lanka and cleaned to remove the inert materials. Then it was dried in the sunlight for 3 days. The dried sprat-heads were ground into powder.

2.2 Experimental diets and management of experimental birds

A total of 64 unsexed, Lohmann Indian River day-old broiler chicks with the mean weight of 43±0.7 g were randomly divided into four groups (16 birds per group). Each group was subdivided into two replicates with 8 birds each. The birds were given 900 cm^2/bird floor space with paddy husk as litter material. Routine vaccinations were done for the birds and the rearing environment was maintained with optimum hygienic conditions. Commercial broiler starter ration (Prima) was used to feed the birds for the first 21 days of rearing. Finisher basal diet (SHM_0) was formulated with 5% fishmeal (w/w) to have 18.9% crude protein (CP) and 2 990.8 kcal/kg of metabolizable energy (Table 1). Experimental diets were prepared by replacing 25% (SHM_{25}), 50% (SHM_{50}) and 75% (SHM_{75}) of fishmeal with SHM (w/w) by keeping the total fishmeal-SHM combination to 5% (Table 1). The birds were randomly assigned to any of the four diets in a completely randomized design (CRD). The experimental diets were provided from 22 to 42 days of growth. Both feed and water were given *ad libitum*. At the end of the study, all the birds were slaughtered and eviscerated to determine carcass weight as a percentage of live weight (Dressing Percentage). Carcass weight was measured after defeathering and removal of feet, head and viscera. Average weight gain (AWG), feed intake, feed conversion ratio (FCR), and viability were estimated as described by Kryeziu *et al.* (2018) at 1^{st}, 21^{st} and 42^{nd} days of growth. European Production Efficiency Factors (EPEF) and European Broiler Index (EBI) were calculated as described by Marcu *et al.* (2013). Production number which depends on the body mass, feed conversion, duration of fattening process and mortality rate was calculated as per Ljiljana *et al.* (2015).

Table 1. Diet composition and predicted nutrient specification of the experimental diets

Ingredients	SHM_0	SHM_{25}	SHM_{50}	SHM_{75}
Maize	48.0	48.0	48.0	48.0
Soybean	20.4	22.0	24.0	26.0
Broken rice	9.5	9.7	10.7	8.7
Rice bran	11.0	8.0	6.0	6.0
Imported fishmeal	5.0	3.8	2.5	1.3
Sprat-head meal	0.0	1.3	2.5	3.8
Wheat	3.8	5.0	4.0	4.0
Premix	0.3	0.3	0.3	0.3
DCP	2.0	2.0	2.0	2.0
Total	100.0	100.0	100.0	100.0

3. Results

There was not any difference (P>0.05) in average live weight (LW), average weight gain (AWG), average daily gain (ADG) and dressing percentage (DP) of the birds among the treatment groups (Table 2). The overall mean live weight of 21-old chicks was 806±3.2 g when they enter the finisher phase. AWG of the birds during the finisher phase (22 to 42 d) for the respective diet groups were: SHM_0, 1 107 g; SHM_{25}, 1 097 g; SHM_{50}, 1 055 g and SHM_{75}, 1 048 g. The daily weight gains of the birds for the respective treatment groups in the finisher stage were: SHM_0, 52.7 g/bird; SHM_{25}, 52.2 g/bird; SHM_{50}, 50.3 g/bird and SHM_{75}, 49.9 g/bird. Dressing percentage of the birds ranged from 60.7% to 71.8% with an overall mean value of 64.6±2.2%.

Table 2. Effect of partial replacement of dietary fishmeal with SHM on body weight of broiler chicks at 42 days of age.

Estimates	Groups	Mean	95% Confidence Limit for Mean	
			Lower	Upper
LW (g/bird)	SHM_0	1 918.4 ± 190.7	1 816.8	2 020.1
	SHM_{25}	1 899.1 ± 230.2	1 776.4	2 021.7
	SHM_{50}	1 861.6 ± 173.3	1 769.2	1 953.9
	SHM_{75}	1 852.8 ± 211.5	1 740.1	1 965.5
AWG (g/bird)	SHM_0	1 856.5 ± 190.7	1 754.9	1 958.2
	SHM_{25}	1 837.0 ± 230.2	1 714.3	1 959.6
	SHM_{50}	1 801.2 ± 173.3	1 708.8	1 893.5
	SHM_{75}	1 790.9 ± 211.5	1 678.2	1 903.6
ADG (g/bird/d)	SHM_0	44.2 ± 4.5	41.8	46.6
	SHM_{25}	43.7 ± 5.5	40.8	46.7
	SHM_{50}	42.9 ± 4.1	40.7	45.1
	SHM_{75}	42.6 ± 5.0	39.9	45.3
DP (%)	SHM_0	65.0 ± 2.2	63.8	66.2
	SHM_{25}	64.3 ± 1.9	63.3	65.3
	SHM_{50}	64.3 ± 1.2	63.6	64.9
	SHM_{75}	64.7 ± 3.2	63.0	66.4

The average cumulative feed and water intake of the birds after 42 days of growth was 3 971.3 g/bird and 9 473.0 mL/bird respectively. The mean values of the feed and water intake of the birds were not different (P>0.05) among the treatments (Table 3). Accordingly, the respective FCR also did not differ significantly (Table 3). Average FCR during the starter phase (0-21 d) was 1.3. During 22 to 42 days, FCR of the respective groups were: SHM_0, 2.8; SHM_{25}, 2.8; SHM_{50}, 2.9 and SHM_{75}, 2.9.

Survival rate of the birds was 100% in all experimental groups. Accordingly, calculated EPEF and EBI of the birds did not differ (P>0.05) among the treatments (Table 3). Overall mean EPEF and EBI of the trial were 416 and 201 respectively. The birds' yield per unit area (YUA) for the respective treatment were: SHM_0, 21.3 kg/m^2; SHM_{25}, 21.1 kg/m^2; SHM_{50}, 20.7 kg/m^2 and SHM_{75}, 20.6 kg/m^2.

Table 3. Effect of partial replacement of dietary fishmeal with SHM on feed efficiency and performance of broiler chicks at 42 days of age.

Treatments	Water intake (mL/bird)	Average feed intake (g/bird)			FCR	EPEF	EBI
		Starter	Finisher	Total			
SHM_0	9 465.5	1 007.5	3 045.0	4 052.5	2.20	422.5	204.5
SHM_{25}	9 473.0	965.0	2 982.5	3 947.5	2.18	426.8	206.5
SHM_{50}	9 477.5	975.0	2 955.0	3 930.0	2.20	409.7	198.3
SHM_{75}	9 476.0	972.5	2 982.5	3 955.0	2.23	404.6	195.6

4. Discussion

Replacement of fishmeal by alternative animal protein sources are widely experimented as a mean to reduce the broiler production cost. Current study revealed that up to 75% of replacement of fishmeal in the broiler finisher feed did not affect the birds' growth and productive performances significantly. According to initial mean weight of day-old chicks (43±0.7 g) and weight at 21 days of growth (806±3.2 g), the birds reached an overall average weight of 1 883 g at 42 days. However, the average live weights of the birds were in the acceptable range of the breed when compared with past studies. Chen *et al.* (1987) reported that mixed sex of Indian River crosses fed with starter (0-21 d with 21.2% CP) and finisher (22-42 d with 19.3% CP) diets yielded 1 624 g of LW with a DP of 76% after 42 days of growth. Aviagen (2019) reported that the standard performance objectives of Indian River broiler birds with an initial weight of 42.6 g is 978 g at 21 days of growth and 2 915 g at 42 days of growth. Deviation in final body weight of the current study is due to difference in body weight when the birds are recruited into the experimental trials. Moreover, it can be attributed to the variation in proximate compositions of sprat head meal. Kocatepe and Çetiner (2013) found that temperature and duration of storage of sprat fishmeal affect their nutritional quality, especially crude protein content. Waldroup *et al.* (1965) found that dietary substitution of 25 to 50% of soybean protein with fishmeal prepared from anchovy (*Engraulis rigens*) collected in the open market did not have any significant effect on body weight or feed utilization of broilers. They also reported that replacement of 75% of soybean protein by menhaden (*Brevoortia tyrannus*) fishmeal significantly reduced the body weight of broilers. These findings show the influence of the quality of fishmeal on broiler productive performances and supports the current results. Use of fish silage more than 20% to replace soybean meal in broiler diet did not yield any significant improvement in broiler growth parameters (Al-Marzooqi et al., 2010). Dietary manipulation with poultry by-product meal to replace 25 to 100% of fishmeal did not affect the feed efficiency and weight gain of Arian broiler chicken after 42 days of growth (Khosravinia et al., 2015). Ljiljana et al., (2015) concluded that dehydrated earthworm meal can be used to replace 100% of fishmeal in *Hybro G* broiler diets as they did not significantly influence the productive performance of the birds after 42 days of growth. In contrast, substitution of 30% of soybean meal with maggot meal in the diet of Ross 308 broiler chicks significantly reduced the feed intake and increased the weight gain with a dressing percentage of 60.8% after 28 days of growth (Khan *et al*., 2016). Furthermore, they concluded that maggot meal can be used as a cheaper protein source in the broiler diet without affecting the carcass quality of Ross 308 broiler chicken. Starbro broiler chicks grown on a feed with a maximum of 8% dietary broiler offal meal instead of fishmeal positively improved the feed consumption and feed efficiency of the birds at 42 days of age (Hossain et al., 2003).

Body weight gain and feed efficiency of broilers are highly influenced by feed intake (Ferket and Gernat, 2006). Current study revealed that the dietary replacement of fishmeal with SHM resulted an overall DP of 60.7 to 71.8% and 1.7 to 2.7 FCR. Because of comparatively low cumulative feed intake of the birds than the recommended cumulative value (4 748 g) of Indian River birds (Aviagen, 2019), the weight gain was lower (Table 2) than the expected weight (2 915 g) as per the Aviagen (2019). It could be attributed to the imbalance in two protein sources and poor palatability of formulated feed. Frempong et al., (2019) observed reduced cumulative feed intake and body weight of male Cobb 500 broiler chicks fed for 42 days with fishmeal-based diet compared to the birds fed with either soybean meal or poultry by-products meal which gave better feed efficiency and weight gain. Javeed and Mahendrakar (1996) reported that when the fishmeal is replaced with up to 50% of fish viscera silage (21% CP) in the broiler diets, productive performance of the birds was not significantly influenced by the diets and their DP and FCR ranged from 68.2 to 68.4% and 2.2 to 2.29 respectively.

EPEF and EBI were evaluated by incorporating survival rate and daily weight gain of the birds to observe their performance. A higher value of EPEF is an indicator for good flock management as it incorporates survival and feed efficiency of the birds. Likewise, high EBI is an indicator for uniform body weight and good health of the flocks (Bhamare et al., 2016). Though the results obtained from the current study were not significantly different among the treatments, they are comparable with previous studies. Around 410 of EPEF was derived from the SHM_{50} with a YUA of 20.7 kg/m^2. This estimate is quite high compared with Kryeziu et al., (2018) who reported a mean EPEF value of 273 with a YUA of 29 kg/m^2 in Ross 308 broiler chickens at the end of 6 weeks. A feed trial to evaluate the nutritive value of cashew apple wastes on the performance of Vencobb 400 broiler chicks resulted a significantly higher EBI of 365 on control group while significantly a lower value of 231.8 on 20% dietary inclusion of cashew apple wastes (Bhamare et al., 2016).

5. Conclusion

Dietary replacement of fishmeal by sprat-head meal could be an alternative to cut down the feed cost in broiler production. As per the current study, up to 75% of fishmeal in the finisher diet could be replaced by sprat-head meal without challenging the production performances such as body weight gain, FCR, DP etc. of broiler chicks. However, there is a need for research on proper balancing of ingredients in the finisher diet to improve the performances further up to the species-specific standards.

References

Al-Marzooqi, W., Al-Farsi, M. A., Kadim, I. T., Mahgoub, O and Goddard, J. S. (2010). The Effect of Feeding Different Levels of Sardine Fish Silage on Broiler Performance, Meat Quality and Sensory Characteristics under Closed and Open-sided Housing Systems. *Asian-Aust. J. Anim. Sci. 23(12):*1614-1625.

Aviagen, (2019). Indian River/Indian River FF: Broiler performance objectives. https://thepoultrysite.com/news/2019/05/new-2019-broiler-performance-objectives-and-nutrition-specifications-aviagen

Awoniyi, T. A. M., Adebayo, I. A and Aletor, V. A. (2004). A study of some erythrocyte indices and bacteriological analysis of broiler chickens raised on maggot-meal based diets. *International Journal of Poultry Science*, *2*, 386–390.

Bhamare, K.S., Dildeep, V., Senthil, M.S. and Chavan, S.J. (2016). Nutritive evaluation of cashew apple waste in broilers. *Intern. J. Sci. Nat.* 7, 629-632.

Biswas, A., Mohan, N., Raza, M., Mir, N.A and Mandal, A. (2019). Production performance, immune response and blood biochemical parameters in broiler chickens fed diet incorporated with prebiotics. *Journal of Animal Physiology and Animal Nutrition, 103,* 493–500. DOI: 10.1111/jpn.13042

Bostock, T.W., Kalavathy. M.H and Vijaynidhi, R. (1992). The processing and marketing of Anchovy in the Kanniyakumari District of South India Scope for development. Bay of Bengal Programme (BOBP/WP/85), Madras, India.

Brah, N., Houndonougbo, F.M and Issa, S. (2018). Grasshopper Meal (*Ornithacris cavroisi*) in Broiler Diets in Niger: Bioeconomic Performance. *International Journal of Poultry Science, 17(3),* 126-133. DOI: 10.3923/ijps.2018.126.133

Chen, T.C., Omar, S., Schultz, D., Dilworth, B.C and Day, E.J. (1987). Processing, Parts, and Deboning Yields of Four Ages of Broilers. *Poultry Science, 66*, 1334-1340.

Ferket, P.R and Gernat, A.G. (2006). Factors that affect feed intake of meat birds: A Review. *International Journal of Poultry Science 5(10)*, 905-911.

Frempong, N.S., Nortey, T.N.N., Paulk, C and Stark, C.R. (2019). Evaluating the Effect of replacing fish meal in broiler diets with either Soybean meal or poultry by-product Meal on Broiler Performance and total feed cost per kilogram of gain. *J. Appl. Poult. Res*. 0:1–7. http://dx.doi.org/10.3382/japr/pfz049

Ginigaddarage, P.H., Surendra, I.H.W., Weththewa, W.K.S.R., Ariyawansa, K.W.S., Arachchi, G.J.G., Jinadasa, B.K.K.K., Hettiarachchi, K.S and Edirisinghe, E.M.R.K.B. (2018). Microbial and chemical quality of selected dried fish varieties available in Sri Lankan market. *Sri Lanka J. Aquat. Sci., 23(1),* 119-126. http://doi.org/10.4038/sljas.v23i1.7552

Hossain, M.H., Ahammad, M.U and Howlider, M.A.R. (2003). Replacement of fish meal by broiler offal in broiler diet. *International Journal of Poultry Science, 2(2),* 159-163.

Husvéth, F., Pál, L., Galamb, E., Ács, K.C., Bustyaházai, L., Wágner, L., Dublecz, F and Dublecz, K. (2015) Effects of whole wheat incorporated into pelleted diets on the growth performance and intestinal function of broiler chickens. *Animal Feed Science and Technology, 210*, 144–151. http://dx.doi.org/10.1016/j.anifeedsci.2015.09.021

Javeed, A and Mahendrakar, N. S. (1996). Growth and meat quality of broiler chicks fed with fermented fish viscera silage. *International Journal of Animal Sciences*, 11 (1): 1-5.

Khan, R. U., Durrani, F. R., Chand, N and Anwar, H. (2010). Influence of feed supplementation with Cannabis sativa on quality of broilers carcass. *Pakistan Veterinary Journal*, *30*(1), 34–38.

Khan, S., Khan, R. U., Alam, W and Sultan, A. (2018). Evaluating the nutritive profile of three insect meals and their effects to replace soya bean in broiler diet. *Journal of Animal Physiology and Animal Nutrition*, *102*, e662–e668. DOI: 10.1111/jpn.12809

Khan, S., Khan, R. U., Sultan, A., Khan, M., Hayat, S. U and Shahid, M. S. (2016). Evaluating the suitability of maggot meal as a partial substitute of soya bean on the productive traits, digestibility indices and organoleptic properties of broiler meat. *Journal of Animal Physiology and Animal Nutrition*, *100*, 649–656. DOI: 10.1111/jpn.12419

Khosravinia, H., Azarfar, A and Sokhtehzary, A. (2015). Effects of substituting fish meal with poultry by-product meal in broiler diets on blood urea and uric acid concentrations and nitrogen content of litter. *Journal of Applied Animal Research*, 43:2, 191-195. DOI: 10.1080/09712119.2014.963085

Kocatepe, D and Çetiner, B. (2013). Changes in proximate composition of sprat (*Sprattus sprattusphalericus*, Risso 1826) fishmeal stored at different temperatures. *Indian J. Anim. Res.,* 47(6), 551-554.

Kryeziu, A.J., Mestani, N., Berisha, Sh and Kamberi, M.A. (2018). The European performance indicators of broiler chickens as influenced by stocking density and sex. *Agronomy Research* 16(2), 483 491. https://doi.org/10.15159/AR.18.040

Liu, N., Wang, J.Q., Jia, S.C., Chen, Y.K and Wang, J.P. (2018).Effect of yeast cell wall on the growth performance and gut health of broilers challenged with aflatoxin B1 and necrotic enteritis. *Poultry Science, 97,* 477–484. http://dx.doi.org/10.3382/ps/pex342

Ljiljana, J., Brana, R., Marijana, V., Dragan, S., Radislava, T., Milutin, Đ and Katarina, R. (2015). Effects of fish meal replacement by red earthworm (*Lumbricus rubellus*) meal on broilers' performance and health. *Acta Veterinaria-Beograd, 65*(2), 271-286. DOI: 10.1515/acve-2015-0023

Marcu, A., Vacaru- I., Gabi, D., Liliana, P.C., Marcu, A., Marioara, N., Ioan, P., Dorel, D., Bartolomeu, K. & Cosmin, M. (2013). The Influence of Genetics on Economic Efficiency of Broiler Chickens Growth. *Anim. Sci. Biotech*. 46, 339-346.

Ministry of Fisheries and Aquatic Resources Development & Rural Economy. (2018). *Fisheries Statistics 2018*. Maligawatta, Colombo, Sri Lanka.

Mirnawati., Ciptaan, G and Djulardi, A. (2018a). The effect of palm kernel cake fermentation with *Sclerotium rolfsii* by adding humic acid in broiler diets. *Indian J. Anim. Res., 52* (6), 882-886.

Mirnawati., Djulardi, A. and Ciptaan, G. (2018b). Effect of Fermented Palm Oil Sludge with *Neurospora crassa* Added to Rations on Broiler Production Performance. *Pakistan Journal of Nutrition, 17* (10), 487-491. DOI: 10.3923/pjn.2018.487.491

Nakhon, S., Numthuam, S., Charoensook, R., Tartrakoon, W., Incharoen, P and Incharoen, T. (2019). Growth performance, meat quality, and bone-breaking strength in broilers fed dietary rice hull silicon. *Animal Nutrition, 5*, 152-155. https://doi.org/10.1016/j.aninu.2018.11.003

Nkukwana, T., Muchenje, V., Masika, P., Hoffman, L., Dzama, K and Descalzo, A. (2014). Fatty acid composition and oxidative stability of breast meat from broiler chickens supplemented with Moringa oleifera leaf meal over a period of refrigeration. *Food Chemistry*, *142*, 255–261. https://doi.org/10.1016/j.foodchem.2013.07.059

Ren, X. J., Yang, Z. B., Ding, X and Yang, C.W. (2018). Effects of *Ginkgo biloba* leaves (*Ginkgo biloba*) and *Ginkgo biloba* extract on nutrient and energy utilization of broilers. *Poultry Science, 97,* 1342–1351. http://dx.doi.org/10.3382/ps/pex445

Rodrigues, I and Choct, M. (2019). Feed intake pattern of broiler chickens under intermittent lighting: Do birds eat in the dark? *Animal Nutrition, 5*, 174-178. https://doi.org/10.1016/j.aninu.2018.12.002

Sabour, S., Tabeidian, S.A and Sadeghi, G. (2019). Dietary organic acid and fiber sources affect performance, intestinal morphology, immune responses and gut microflora in broilers. *Animal Nutrition, 5*, 156-162. https://doi.org/10.1016/j.aninu.2018.07.004

Waldroup, P. W., van Walleghem, P., Fry, J. L., Chicco, C and Harms, R.H. (1965). Fish Meal Studies: 1. Effects of Levels and Sources on Broiler Growth Rate and Feed Efficiency. *Poultry Science*, 44 (4), 1012–1016. https://doi.org/10.3382/ps.0441012