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RESEARCH ARTICLE

Effects of an emulsifier on the performances of Khaki Campbell ducks added with different sources of fats

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Abstract **An experiment was conducted to assess the effects of different sources of fats added with an external emulsifier (lecithin) on the performances of Khaki Campbell Ducks in an eight-week trial. Ducks were grouped into five dietary groups with three replicates ($n = 10$) in each group. The ducks were fed with a basal diet supplemented with 3% soybean oil and without emulsifier (C1), 3% palm oil without emulsifier (C2), 3% soybean oil with emulsifier (T1), 3% palm oil with emulsifier (T2) and 3% lard with emulsifier (T3). The growth performance of ducks did not vary ($P > 0.1$) among the dietary treatments. Feed intakes by ducks were also similar ($P > 0.1$) among treatments within the periods. Similarly, feed intake to gain ratios were not affected by any dietary treatments. The metabolizability of dry matter, crude protein and nitrogen free extract also did not change ($P > 0.1$) due to various dietary treatments. However, the metabolizability of fats in all the emulsifier added groups (T1, T2 and T3) was greater ($P < 0.05$) than the dietary groups without emulsifier (C1 and C2). Various carcass traits such as percentages of hot carcass, breast, legs, lungs, hearts, gizzard, giblets weights relative to bodyweights did not vary ($P > 0.1$) among the groups. The carcass yield tended ($P = 0.06$) to be greater in the T1 than in the C1 group. The moisture, fats, protein and ash composition of meat (percent on fresh basis) was similar ($P > 0.1$) among treatments. In conclusion, supplementation of lecithin as an emulsifier to the diets containing different sources of fats (3%) appears to have no major impact on the overall performances of Khaki Campbell ducks in their grower phase.**

Keywords Khaki Campbell ducks, fats, emulsifier, performance

Introduction

Diets are usually required to supply with high nutrient and energy concentrations in order to meet the nutrient requirements of modern intensively reared birds. To achieve this high energy density, fats and oils are often included in the diets to increase the amount of energy provided to the birds. Besides contributing energy to the birds, adding fats into the poultry diets reduces dustiness, which may otherwise have adverse effects on bird health. Furthermore, lipids supply essential fatty acids and help to the absorption of fat-soluble vitamins. The energy yielding potential of lipids is determined by degree of saturation and chain length. A beneficial growth response to supplemental oils is noted in animals, particularly when compared with animal fat sources (Cera et al., 1989).

Fats insoluble in a water medium of the gastrointestinal tract, should first be emulsified before they can be digested by lipolytic enzymes (Gu and Li, 2003). The process of this emulsification depends on the nature of fats mainly determined by the chain length, the position of the fatty acids on the triglycerides and the fat saturation (Gu and Li, 2003). A low ratio of unsaturated to saturated fats has been reported to limit fat digestibility especially in young pigs and chickens (Wiseman et al., 1998). To improve fat digestibility, emulsifiers can be used as they increase the solubilization and hence the absorption of the fatty acids from the gut. External emulsifiers sometimes enhance the absorption of other nutrients such as proteins (Polin, 1980; Jones et al., 1992). Addition of lecithin as an emulsifier has also been shown to increase the apparent metabolizability of dietary fats fed to chicks (Polin, 1980; Roy et al., 2010) and pigs (Jones et al., 1992). It may also improve feed conversion ratio, feed intake and performance of animals depending upon fat sources and

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age of the animals (Cera et al., 1988b; Li et al., 1990; Kim et al., 2008; Roy et al., 2010). However, influences of an emulsifier in diets with different sources of fats on the performances of ducks appear to be unknown. Therefore, this experiment was undertaken to study the effects of lecithin as an emulsifier on the performances of Khaki Campbell ducks.

Materials and methods

Experimental ducks and treatments

Khaki Campbell ducklings were fed with a starter diet without any fat supplementation up to 21 days. Then the ducks were offered the experimental grower diets (Table 1 and Table 2) with addition of different sources of fats for eight weeks. One hundred and 50 ducks were grouped into five dietary groups with three replicates ($n = 10$) in each group. In the five dietary groups, the ducks were fed with a basal diet containing 3% soybean oil and without emulsifier (C1), 3% palm oil without emulsifier (C2), 3% soybean oil with emulsifier (T1), 3% palm oil with emulsifier (T2) and 3% lard with emulsifier (T3). The emulsifier was added at the rate of 0.5 g/kg basal diet (T1, T2 and T3). The feeders and water troughs were properly cleaned and placed inside the pens. Feeds in wet mash form were placed in feeders everyday at 8:00 am and 4:30 pm. Drinking water was offered ad libitum all the time.

Table 1 Ingredient composition of diet fed to Khaki Campbell ducks

Ingredients	Composition
Maize (g/kg)	400
Soybean (g/kg)	150
Rice bran (g/kg)	350
Fish meal (g/kg)	40
Fats (g/kg)*	30
Di-calcium phosphate (g/kg)	15
L-lysine (g/kg)	7.5
DL-methionine (g/kg)	3.0
Common salt (g/kg)	2.5
Premix**	1.2
Trace minerals***	0.9
Calculated chemical composition	
Crude protein (g/kg)	182
Metabolizable energy (Mcal/kg)	2.88
Lysine (g/kg)	17.2
Methionine (g/kg)	6.21
Calcium (g/kg)	7.52
Phosphorous (g/kg)	5.14

* C1, supplemented with soybean oil; C2, supplemented with palm oil; T1, supplemented with soybean oil and an emulsifier; T2, supplemented with palm oil and an emulsifier; T3, supplemented with lard and an emulsifier. Emulsifier was added at 500 g per tonne of feed. ** Supplied per kg diet: Vitamin A 8000 IU, Vitamin D_3 1200 IU, Vitamin E 24 IU, Vitamin K 1.5 IU, Thiamin 1 mg, Riboflavin 6 mg, Niacin 60 mg, Pantothenic acid 10 mg, Pyridoxine 2.5 mg, Cobalamin 20 µg, Biotin 0.15 mg, Folic acid 100 mg, Choline chloride 800 mg, Selenium 150 µg. *** For 100 kg feed: Ferrous sulphate 45 g, Zinc sulphate 22.50 g, Manganese sulphate 23.61 g, Copper sulphate 3.60 g, Potassium iodide 0.15 g and Sodium selenite 0.20 g.

Measurements

Bodyweights of each of the ducks were recorded on day 0 and subsequently at one week intervals up to 56 days of experimental period. Measured quantity of feeds was offered to the ducks every day in wet mash form. The residues left were quantified everyday and total feed intake was calculated by estimating the dry matter (DM) content of feeds offered and the residues left. Feed intake to bodyweight gain ratio was calculated as the measure of feed utilization efficiency.

Metabolism trial

A metabolism trial was conducted after the feeding trial ended. Two ducks from each replicate were transferred to metabolism cages and placed there for 7 days including a collection period of 5 days. During the metabolism trial, the amount of feed offered and that of the residue left were measured in replicate wise. The total amount of excreta obtained in a 24 h period was weighed and put in zipped polyethylene sachets. The excreta were manually mixed and a sub sample measuring 1/5 of the total excreta volume was kept daily in a hot air oven at 80°C for 16 h to determine the DM, and dried excreta was stored in replicate wise for analysis of nutrients. Another sub sample measuring 1/10 of the total excreta was collected in plastic containers for 5 days, pooled in replicate wise and frozen at −20°C until analysis of crude proteins (CP).

Carcass traits

The birds were slaughtered on day 56 of experimental period by randomly picking three ducks from each replicates of all treatment groups. The birds were killed after an overnight fast by decapitation, and processed for carcass characteristics, which included hot carcass (with the head, blood, neck, and hocks removed), eviscerated carcass weight, carcass yield (weight of de-feathered eviscerated carcass relative to live weight) and yields of breast and legs. Breast weight includes the breast fillet and the tenders (pectoralis major and minor). The giblet include liver, lungs, heart and gizzard. The carcass components were stored at −20°C for analyses. For analysis of moisture, ash, protein and ether extract (EE) contents in meat, the eviscerated frozen carcass cuts were thawed and the muscles were manually separated from bones, minced mechanically and homogenized in a tissue homogenizer (Remi Motors, Mumbai, India). The homogenized sub samples were finally mixed in a mechanical mixer to analyze the meat composition.

Blood and intestinal samples

Blood samples were collected from three ducks of each replicate into test tubes after decapitation of ducks (during

Table 2 Analyzed chemical composition of diets dry matter basis fed to Khaki Campbell ducks

Chemical composition	C1	C2	T1	T2	T3
Crude protein (g/kg)	183	180	186	186	180
Crude fiber (g/kg)	68.8	76.5	77.5	69.8	76.5
Nitrogen free (g/kg)	621	610	602	608	606
Ether extract (g/kg)	51.1	50.8	51.3	54.8	52.0
Ash (g/kg)	76.2	82.6	82.9	80.9	85.4
GE (Mcal/kg)	3.945	3.927	3.993	3.923	3.983

C1, supplemented with soybean oil; C2, supplemented with palm oil; T1, supplemented with soybean oil and an emulsifier; T2, supplemented with palm oil and an emulsifier; T3, supplemented with lard and an emulsifier.

slaughter). The serum was separated by centrifuging blood at 2500 rpm for 10 min (Remi Research Centrifuge, Model R-8C, Remi Research Laboratories Mumbai, India) and harvested into polystyrene tubes and stored at −20°C until analysis.

The duodenum, jejunum and ileum were separated at the time of slaughter, and a small portion of each part was collected in a bottle containing 20% formalin. The samples were then sent for preparation of tissue blocks in paraffin by standard procedure. Thin sections (5 μm) were cut and stained with routine Haematoxylin and Eosin. After staining, the segments were processed (Yu and Chiou, 1997; Iji et al., 2001; Incharoen et al., 2009) for light microscopy. All the measurements were taken using micro-measurement and image analysis software (Biowizard 4.2, Dewinter Optical Inc., New Delhi, India). The villus length was measured from the tip to the bottom excluding the crypt.

Chemical analyses

The proximate analysis of feeds and excreta was analyzed as per the methods of AOAC (1995) to determine DM by the oven drying method (934.01), organic matter (OM) by muffle furnace incineration (967.05), CP by Kjeldahl method (984.13) (N × 6.25) in an automated Kjeldahl distillation apparatus (Kel Plus Calssic DX, Pelican Equipments, Chennai, India), ether extract (920.39) in an automated ether extract assembly (Socs Plus SCS 4, Pelican Equipments, Chennai) and ash (942.05). The composition of CP, EE and ash was also determined by AOAC (1995) methods. Serum cholesterol was estimated by using commercial kits (RFCL Ltd., Haridwar, India) with the help of an Automatic Blood Analyzer (Microlab 200, E-Merck India Ltd., India).

Statistical analyses

The data were analyzed as a completely randomized design with replicate as the experimental unit and the treatment as the main effect. All data were analyzed by multivariate analysis of variance in the general linear model (GLM) of the Statistical Package for Social Sciences (SPSS, 1997). Data involving measurement at different time intervals (day) were analyzed by the repeated measures procedure of GLM. A probability value of $P < 0.05$ was described as statistically significant and that of $P < 0.1$ was described as a trend.

Results

Bodyweight

The bodyweights of ducks did not differ ($P > 0.1$) among the dietary treatments within period (Table 3). It was observed that bodyweights of ducks in the T1 group (soybean oil with emulsifier) were numerically better at days 14 to 28 compared with C1 (soybean oil supplemented without emulsifier). However, in the subsequent periods, bodyweights were similar to other treatments. The final bodyweights were not affected due to dietary treatments.

Intake and feed efficiency

Intakes by ducks did not differ ($P > 0.1$) among treatments within any period (Table 3). Similarly, feed to gain ratio was not affected by any treatments. Although, feed to gain ratio was found to be better in T1 than in C1 (9.7%) for days 15–28, but was not statistically significant. The overall feed efficiency was similar ($P > 0.1$) among the treatments.

Nutrients intakes and metabolizability

The intake of different nutrients such as CP, EE, nitrogen free extract was similar ($P > 0.1$) among treatments during the metabolic trial (Table 4). The metabolizability of DM, CP and nitrogen free extract also did not change due to various dietary treatments. However, the metabolizability of fats in the emulsified treated groups was greater ($P < 0.01$) compared with the treatments without the emulsifier.

Carcass traits and meat composition

Various carcass traits such as percentages of hot carcass, breast, legs, lungs, hearts, gizzard, giblets relative to bodyweights did not vary ($P > 0.1$) among treatments (Table 5). However, there was a trend ($P = 0.08$) for liver weight (% of bodyweight) to decrease in the T1 group compared with C1 and C2. The carcass yield also tended ($P = 0.06$) to be greater

Table 3 Effects of different sources of fat supplementation with an emulsifier on bodyweight (g per duck), intake (g per day) and feed to gain ratio (g/g) of Khaki Campbell ducks

Items	Treatments					SEM	*P* value
	C1	C2	T1	T2	T3		
Bodyweight (g)							
Day 0	174.4	167.1	170.5	174.4	169.4	2.15	0.45
Day 7	275.0	258.6	266.7	283.3	312.2		
Day 14	435.0	440.0	471.8	445.0	464.4		
Day 21	568.8	614.3	645.0	594.4	594.4		
Day 28	711.2	752.9	782.5	729.4	722.2		
Day 42	966.2	924.3	980.0	934.0	927.2		
Day 56	1102	1085	1136	1126	1106		
Intake (g/day)							
Day 0–14	51.0	50.9	52.9	51.7	51.1	2.58	0.80
Day 15–28	81.4	81.3	81.9	82.1	81.7		
Day 29–56	113.7	114.3	114.7	115.9	115.3		
Overall	86.5	86.9	87.6	87.9	87.3		
Feed to gain ratio (g/g)							
Days 0–14	2.80	2.80	2.73	2.71	2.42	0.045	0.21
Days 15–28	4.12	3.72	3.78	4.07	4.44		
Days 29–56	8.32	9.59	8.98	8.14	8.33		
Overall	5.22	5.30	5.08	5.17	5.22		

C1, supplemented with soybean oil; C2, supplemented with palm oil; T1, supplemented with soybean oil and an emulsifier; T2, supplemented with palm oil and an emulsifier; T3, supplemented with lard and an emulsifier.

Table 4 Effects of different sources of fat supplementation with an emulsifier on intake and metabolizability of nutrients in Khaki Campbell ducks

Items	Treatments					SEM	*P* value
	C1	C2	T1	T2	T3		
Daily intake							
Dry matter (g)	105.5	103.5	105.5	105.8	105.1	1.466	0.65
Ether extract (g)	5.39	5.27	5.41	5.91	5.46	0.157	0.15
Crude protein (g)	19.3	18.7	19.7	19.6	18.9	0.314	0.29
Nitrogen free extract (g)	64.5	63.1	63.5	64.3	62.6	0.875	0.46
Gross energy (kcal)	416	407	421	415	417	2.87	0.21
AME (kcal)	388	328	349	345	346	20.7	0.16
Metabolizability							
Dry matter (g/kg)	798	790	816	822	815	8.84	0.19
Fat (g/kg)	912a	916a	937b	939b	942b	3.46	0.01
Crude protein (g/kg)	748	769	785	779	785	25.8	0.35
Nitrogen free extract (g/kg)	948	935	950	949	947	5.55	0.37
Energy (g/kg)	813	806	829	831	829	7.21	0.18
AME (Mcal/kg)	3.206	3.165	3.310	3.260	3.301	0.072	0.15
Villi length (μm)							
Duodenum	835	671	925	998	773	92.3	0.09
Jejunum	950	640	701	775	686	86.5	0.23
Ilium	790	723	743	823	678	45.8	0.32
Cholesterol (mg/dL)	166	176	147	132	135	9.29	0.08

C1, supplemented with soybean oil; C2, supplemented with palm oil; T1, supplemented with soybean oil and an emulsifier; T2, supplemented with palm oil and an emulsifier; T3, supplemented with lard and an emulsifier.AME, apparent metabolizable energy; SEM, standard error of mean.

in T1 than in C1 group. The meat composition such as moisture, fats, proteins and ash (percent on fresh basis) was similar ($P > 0.1$) among treatments.

Serum cholesterol and intestinal morphology

The villi length of duodenum, jejunum and ilium was not

Table 5 Effects of different sources of fats supplementation with an emulsifier on carcass traits and meat composition of Khaki Campbell ducks

Items	Treatments					SEM	*P* value
	C1	C2	T1	T2	T3		
Carcass traits (g/kg of BW)							
Hot carcass	616	620	647	633	623	10.0	0.32
Breast	120	154	167	142	149	11.4	0.29
Legs	102.6	96.8	102.8	99.1	96.8	2.97	0.40
Liver	21.7	21.3	18.1	19.8	20.2	0.68	0.08
Lungs	11.1	10.0	13.0	10.6	10.0	1.09	0.41
Gizzard	51.3	43.8	44.5	51.8	46.3	2.55	0.21
Heart	11.1	11.9	11.4	11.8	13.0	1.14	0.81
Giblets	92.0	82.4	83.0	89.6	84.6	3.05	0.24
Carcass yield	448	484	511	482	480	10.2	0.06
Meat composition (g/kg, fresh basis)							
Dry matter	281	278	281	265	260	8.86	0.40
Protein	199	202	210	205	199	3.66	0.22
Fat	22.5	22.1	22.6	21.1	22.1	0.79	0.71
Ash	14.2	14.7	14.3	13.0	14.0	0.89	0.73

C1, supplemented with soybean oil; C2, supplemented with palm oil; T1, supplemented with soybean oil and an emulsifier; T2, supplemented with palm oil and an emulsifier; T3, supplemented with lard and an emulsifier.

impacted ($P > 0.1$) by various dietary treatments except for palm oil group (Table 4). The villi length was relatively shorter ($P = 0.09$) in the palm oil supplemented group than the group supplemented with palm oil and emulsifier. Serum cholesterol tended ($P = 0.08$) to decrease in the emulsified added groups compared with the groups without emulsifier.

Discussion

Bodyweight gain

Bodyweight of ducks was not affected by supplementation of soybean oil and palm oil with the emulsifier, although the metabolizability of fats increased in this study due to the addition of emulsifier. There is probably no reported study in ducks fed with rations containing emulsifiers. It appears that the addition of different sources of fats with emulsifiers may not induce growth performance traits in ducks with low growth rates such as Khaki Campbell ducks. Recently, it has been reported that the addition of different sources of fats i.e. soybean oil and fish oil (2%) to a basal diet did not affect the growth of mucovy ducks (Schiavone et al., 2010). However, Roy et al. (2010) observed that the addition of glyceryl polyethylene glycol ricinoleate as an emulsifier in the diets containing 1% added palm oil improved the growth performances of broiler chickens. There are contrasting reports on the effects of fats and emulsifiers on the performance of non-ruminants. Jones et al. (1992) reported that different fat sources such as soybean oil, coconut oil, tallow and lard did not improve growth performance for the first 7 to 14 d post-weaning compared with a control diet with no added fat in piglets. Similarly, Van Wormer and Pollman (1985) and Overland et al. (1993) reported that growth performance was not increased by addition of lecithin to diets for weanling pigs. However, Xing et al. (2004) reported a linear improvement of bodyweight gain due to supplementation of lard with lysolecithin in pig from days 15 to 35.

Emulsifiers had no effect on feed intake. Similarly, Roy et al. (2010) did not observe any effect of the emulsifier on the intake of DM in broiler chickens. In general, addition of fat with emulsifiers does not exert profound effect on intake of pigs (Overland et al., 1993; Kim et al., 2008).

Metabolizability

There was no significant difference in the metabolizability of fats from different sources fed to ducks in this experiment. However, Cera et al. (1988b, 1989) and Li et al. (1990) demonstrated that vegetable fats were more digestible than animal fats. Unsaturated fats (e.g., soybean oil) have increased the ability to be partitioned into the micellar phase (Freeman et al., 1968), and could be expected to have higher digestibility than long-chain saturated fats (e.g., tallow and lard). Jones et al. (1992) also studied the interaction between fat source and type of emulsifier. Tallow was more digestible when lecithin was added compared with lysolecithin, but lard was less digestible when the emulsifiers were added. Additionally, there was a greater improvement in digestibility of tallow but a greater decrease in digestibility of lard when lecithin was the emulsifier versus and lysolecithin was the emulsifier. In this study, it was observed that addition of emulsifier with lecithin improved the metabolizability of fats, which might be due to increased absorption of fats from digestive tract. In some other studies, lecithin also increased the apparent digestibility of dietary fat in diets fed to chicks (Polin, 1980; Roy et al., 2010) and pigs (Overland et al., 1993; Dierick and Decuypere, 2004). In contrast, soy-lecithin as an external emulsifier did not improve the apparent digestibility of rendered fat in cereal-soybean meal-based diets (Overland et al., 1994) as well as of lard and soybean oil (Soares and Lopez-Bote, 2002) fed to growing pigs. It has been also reported that soybean oil and coconut oil were superior to fat sources such as tallow and lard, but addition of lecithin to tallow improved nutrient digestibilities to levels more comparable to those for diets with soybean oil and coconut oil without emulsifiers (Jones et al., 1992). Blanch et al. (1996) noted that supplementation of tallow with soybean lecithin did not improve the utilization of this animal fat in adult roosters.

Serum cholesterol and carcass characteristics

Lecithin has hypocholesterolemic properties (Wilson et al., 1998; Huang et al. 2008). The addition of lecithin tended to lower serum cholesterol levels in this experiment, which was also observed in the study of Jones et al. (1992), Kim et al. (2008) and Huang et al. (2008). Although the mechanism is not clear, it has been suggested that lecithin may inhibit the absorption of cholesterol in the small intestine (Spilburg et al., 2003; Huang et al. 2008). Besides, lecithin is essential in reverse cholesterol transport as a component of the high density lipoprotein (HDL) fraction. The enzyme lecithin cholesterol acyl transferase removes a fatty acid from lecithin and esterifies the fatty acid to free cholesterol, allowing cholesterol to be solubilized into the HDL particle (Rinninger and Pittman, 1987), thus reducing free cholesterol in the serum. An interaction occurred between emulsifiers and tallow and lard (Jones et al., 1992). There are also reports that serum cholesterol was lower for pigs fed lard plus lecithin than for pigs fed tallow plus lecithin, but pigs fed lard plus lysolecithin had higher cholesterol than did pigs fed tallow plus lysolecithin. Similarly, in this study, lecithin reduced serum cholesterol. The addition of glyceryl polyethylene glycol ricinoleate as an emulsifier also decreased serum total cholesterol in broiler chickens (Roy et al., 2010). The proximate composition of meat was within the reported values for ducks (Cobos et al., 2000), which indicates that emulsifier has no influence of these parameters.

Intestinal morphology

Optimal intestinal morphology is important for maximum digestive and absorptive capacity. The age of the animal and diet influence the enterocyte function (Smith and Jarvis, 1978; Cera et al., 1988a). Therefore, addition of different sources of fats may also affect the intestinal absorptive surface area and functionality. Cera et al. (1988a) reported that pigs fed corn-oil-supplemented diets (6% corn oil) had shorter villi than pigs fed diets without added corn oil. This reduced villus height, resulting in a significant dietary corn-oil effect at days 14, 21 and 28 pos-weaning. Similarly, Li et al. (1990) using scanning electron microscopy showed that pigs fed a combination of 50% soybean oil and 50% coconut oil had long and round villi, whereas pigs fed diets containing soybean oil or coconut oil alone had shorter villi. The villi length in the duodenum tended to decrease in palm oil supplemented group compared with palm oil with emulsifier (lecithin) supplemented group. The exact reason for this change is unclear. The study of Li et al. (1990) and Cera et al. (1988a) included fats at higher levels (5% to 10%), but fats were included at 3% in this study. Therefore, it seems at higher inclusion levels of some fats in ducks might also influence intestinal morphology. Increased small intestine weights and lengths were noted when rats were fed the diets containing low fat content (Younoszai et al., 1978). Thomson and Keelan (1986) suggested that dietary fat may influence enterocyte membrane lipid composition. Marenus and Sjöstrand (1982) also reported that feeding supplemental fat to mice resulted in structural changes in the small intestinal columnar enterocyte population. The proportion of fatty acids in different fats may also influence the intestinal morphology (Li et al., 1990). Because palm oil along with lecithin as emulsifier increased villi length compared with palm oil alone, it is likely that more micellar formation than free fats in the intestine and transport of fats from enterocytes might have affected villi morphology in this study.

Conclusions

The metabolizability of fats could be improved with the addition of lecithin as an emulsifier, but metabolizability of other nutrients may not be affected by different sources of fats and the emulsifier. Lecithin as an emulsifier also appeared to have no major effect on the growth performance, nutrient metabolizability, carcass traits and meat composition in Khaki Campbell ducks in their grower phase in this experiment. The addition of high doses of fats with emulsifiers in the diet of meat type ducks with greater growth rates may be studied for their growth and feed efficiency as these types of ducks would require higher concentrations of energy in their diets.

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