

## **Influence of natural pigment sources on growth performance, live and post-slaughter skin pigmentation, serum carotenoids and lipid profile of broiler chickens**

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### **Abstract**

Carotenoids are bioactive molecules synthesized in plants and are important in the development of hues in the skin and muscles of chickens, which influence consumer perception and consumption. The extent of absorption and assimilation of carotenoids from different plant-based pigment sources was explored in this study. One hundred and twenty-eight day old broiler chicks were allotted to four treatments, four replicates of eight chicks each. Chicks were fed a starter diet for 21 days and thereafter grower-finisher diets containing one of moringa (*Moringa oleifera*), baobab (*Adansonia digitata*) leaves, roselle (*Hibiscus sabdariffa*) calyces and orange (*Citrus x sinensis*) rind- at 4% of their diet for 35 days. Skin pigmentation was scored in the apterylum region and shank of live broiler chicken weekly and in the breast, back, vent, shank and abdominal fat of 56 day old broiler chicken post-slaughter using a DSM broiler colour fan. Serum carotenoids measured as red and yellow pigments and serum lipid profile were determined by a spectrophotometric method. Pigmentation was higher in the shank, with visual score ranging from 101.0 – 103.78 and least in the skin of the back ranging from 101.0 – 102.0 ( $P < 0.05$ ), while pigmentation in the vent and breast were similar for chickens on the different dietary treatments. Higher live and post-slaughter skin pigmentation was observed in chickens on moringa diet with visual score ranging from 103.1 – 103.75 and 102.0 – 103.78 respectively, and lower pigmentation in those on roselle diet, ranging from 101.13 – 101.32 and 101.0 – 101.34 respectively. Shank pigmentation score peaked at 21d for chickens on baobab (102.32) and roselle (101.32) diets, and 35d for chickens on the moringa and orange rind (103.75 and 102.06, respectively) diets. Apterylum pigmentation peaked at 21d for chickens on baobab (101.54) and orange (101.40) diets and 28d for chickens on the moringa (102.40) diet. Dietary sources of carotenoids did not significantly influence yellow pigment deposition in the serum between 21-28d of exposure while red pigment deposition in the serum was unaffected by the dietary treatments after 28d of exposure. Yellow pigment composition of serum was significantly ( $P < 0.05$ ) lowest in chickens on moringa diet at 14 and 21d (19.84 and 18.54 ppm). A similar trend was observed for red pigment composition of serum of chickens on moringa diet at 28 and 35d (19.60 and 18.36 ppm). However the serum lipid profile of chickens in the study was not affected by the different pigment sources in their diets. Absorption and assimilation of carotenoids varied for the different carotenoid sources assessed, with *Moringa oleifera* leaves significantly improving live and post-slaughter pigmentation of broilers.

**Keywords:** antihyperlipidemic properties; antioxidants; grower-finisher diets; growth performance; serum yellow and red pigments

### **Introduction**

Physical appearance of colour is a basic determinant of food choice for humans (Anon 1990) and plays a major role in acceptability of food products. Yellow

pigmentation in the skin of poultry species is associated with good health of the animal and perceived palatability, safety and overall quality by consumers (Bunnell and Bauernfiend 1962, Fletcher 1999,

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Castenada *et al.*, 2005). Carotenoids - lipid-soluble, yellow-orange-red pigments found in photosynthetic tissues as well as non-photosynthetic tissues of higher plants (Breithaupt, 2007) are the most widespread group of pigments in nature (Sirri *et al.*, 2007), and have been identified as responsible for colour function in animals particularly in birds (Negro *et al.*, 1998, 2000). Animals are unable to synthesize carotenoids, hence are dependent on their diets for carotenoid supply which are digested, transported in the blood and stored in their liver, eggs, subcutaneous fat, skin, feathers, beaks and shanks (Tunio *et al.*, 2013). Pigments derived from carotenoids include but are not limited to carotene (  $\alpha$ - and  $\beta$ - carotene), lycopene, zeaxanthin, lutein, capsanthin, capsorubin and violaxanthin (Breithaupt *et al.*, 2002). Carotenoids also play significant roles in growth metabolism, immunomodulation, vitamin A precursors, antioxidation and fertility in poultry species (Scheldt, 1998).

While bright coloured poultry are more likely to sell at a premium, egg yolks with intense colouring are preferred for production of food products such as noodles, mayonnaise and other egg containing products. To achieve the desired colour, feed producers gravitate towards incorporating commercially available synthetic pigments/dyes into diets. Although synthetic pigments are more stable in nature, lower priced compared to natural pigments and are able to optimally enhance the scale of pigmentation in poultry products, they are not suited to organic production systems and may pose health threats to the consumers (Breithaupt, 2007, Liu *et al.*, 2008; EFSA, 2014).

Natural pigments widely used by the poultry industry for colouring egg yolk and skin of broiler chickens include carotenoids originating from petals of marigold (*Tagetes erecta*) and paprika

(*Capsicum annum* L) as they represent rich sources of lutein and capsanthin esters respectively (Breithaupt *et al.*, 2003; Castenada *et al.*, 2005; Sirri *et al.*, 2007). Other less researched natural pigment sources include orange rind (Hasin *et al.*, 2006) and green leafy vegetables such as *Talinium triangulare* and *Adansonia digitata* (Abiodun *et al.*, 2014). Carotenoids are found in large quantities in green leaves, about 10-20% consisting mainly of lutein and  $\beta$ -carotene (Mortensen, 2006). Although they are visually masked by chlorophyll, their ability to impart colour in birds is evidenced in the intense yellow colour of yolk and skin of chickens raised on free range (Marusich and Bauernfeind, 1981; Hasin *et al.*, 2006).

The ability of carotenoids to influence skin pigmentation differ to varying degrees, and differences in their profiles in various tissues are directly influenced by the quantities of carotenoid consumed, absorption and transfer efficacy, chemical composition of the carotenoid source as well as metabolic capacity to modify carotenoids (Hamilton, 1992; Hamelin and Altemueller, 2012). Plant sources of carotenoids are also sources of a variety of volatile acids and phenolic compounds, to which antioxidant and antihyperlipidemic activities have been ascribed. Leaves of *Moringa oleifera* have been reported to possess high quantities of polyphenols (Sreelatha and Padma, 2009; Verma *et al.*, 2009) which serve as antioxidants, efficiently diminishing lipid peroxidation and its negative effects on consumer desired meat variables (Qwele *et al.*, 2013). Antioxidant and antihyperlipidemic activities of orange peels *Adansonia digitata* leaves and extracts of *Hibiscus sabdariffa* calyces have also been confirmed *in vitro*, in rats and chickens (Malterud and Rydland, 2000; Ochani and

D'Mello, 2009; da Silva *et al.*, 2001; Vertuani *et al.*, 2002).

The objective of this study was to comparatively evaluate variations in absorption and assimilation of carotenoids from orange (*Citrus x sinensis*) rind, roselle (*Hibiscus sabdariffa*) calyces, *Moringa oleifera* and baobab (*Adansonia digitata*) leaves as pigment sources in grower-finisher diets and their effects on the serum lipid profile of broiler chickens.

### **Materials and methods**

#### ***Processing of pigment sources***

Leaves of *Moringa oleifera* and *Adansonia digitata* were harvested while orange rind collected from orange fruit hawkers within the University of Ibadan campus. Leaves and orange rind were air dried for 5 days while desiccated roselle (*Hibiscus sabdariffa*) calyx was purchased from a reputable retailer. The different pigment sources were milled and stored in air tight bags in a cool, dry place.

#### ***Animals, housing and management***

The study was conducted using day old (n=128) unsexed broiler (Arbor-acre) chicks. The chicks were neck tagged, weighed and randomly allotted to four treatments, four replicates of eight chicks per replicate in a completely randomized design and raised in floor pens. Natural lighting was used in the day time (0700 - 1800hrs) and artificial lighting between 1800-0600hrs. Temperature was controlled within the pens at 32-35°C for the first week and 30-32°C for the second week, thereafter temperature ranged between 24-30°C for the rest of the study period.

#### ***Diets and feeding program***

Chicks were raised on a starter diet (3183.74 kcal/kg ME, 23.21% CP, 1.07% Ca and 0.59 nPP) without natural or synthetic pigments for 21 days. Grower-finisher diets were formulated to contain 4% of either moringa (*Moringa oleifera*)

leaves, baobab (*Adansonia digitata*) leaves, roselle (*Hibiscus sabdariffa*) calyces or orange (*Citrus x sinensis*) rind as pigment sources and fed for 35 days (Table 1). Both starter and grower-finisher diets were presented as a mash. Analyzed pigment composition of the test ingredients are also presented in Table 1.

#### ***Performance and colour evaluation***

The chickens were weighed at the beginning of the grower-finisher phase of the experiment. Body weight gain, feed intake and feed conversion ratio monitored until day 56, and averaged per pen. Skin pigmentation scores of live chickens was measured in the lateral apterylum region and shank of each chicken at days 35, 42, 49 and 56 of the study by visual observation using the DSM broiler colour fan, a colour graduated visual aid.

At day 56, two chickens per replicate were slaughtered by a unilateral neck cut through the jugular vein, exsanguination (300s) and cold defeathering. Carcasses were chilled in ice slush for 45 mins and skin pigmentation scored in skin of the shank, breast, vent, back and abdominal fat. Carotenoid deposition in serum was assessed by a spectrophotometric method (Fletcher 1977, Castenada *et al.*, 2005). In brief, 5 mL blood samples were collected from the web-veins of two chickens per replicate on days 35, 42, 49 and 56 of the study. Blood was collected in plain tubes, serum was subsequently decanted and stored at -20°C. 0.2 mL serum was transferred into a 2 mL microcentrifuge tube and deproteinized by adding 1.8 mL acetone. Thereafter tubes were vortexed and centrifuged at 3000 rpm for three minutes, decanted and absorbance read on a spectrophotometer at 423nm for red pigments and 473 nm for yellow pigments. Samples were analyzed in duplicates, results averaged and absorbance converted to concentration using a  $\alpha$ -carotene

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**Table 1: Composition of experimental grower-finisher diets (g/100g), calculated nutrient content and carotenoid composition of pigment sources ( -carotene equivalents, ppm)**

Ingredients	Baobab diet	Moringa diet	Orange rind diet	Roselle diet
Maize	54.8	54.8	54.8	54.8
SBM	35.0	35.0	35.0	35.0
Baobab	4.0	-	-	-
Moringa	-	4.0	-	-
Orange rind	-	-	4.0	-
Roselle	-	-	-	4.0
Soybean oil	3.0	3.0	3.0	3.0
Dicalcium phosphate (DCP)	0.8	0.8	0.8	0.8
Limestone	1.7	1.7	1.7	1.7
Vit-mineral premix §	0.2	0.2	0.2	0.2
Lysine-HCl	0.1	0.1	0.1	0.1
DL- methionine	0.2	0.2	0.2	0.2
NaCl	0.2	0.2	0.2	0.2
Total	100	100	100	100
Calculated nutrients of experimental diets †				
Metabolizable energy				
(ME kcal/kg)				3031
Crude Protein, %				20.9
Calcium, %				0.91
Phosphorus, %				0.56
Methionine, %				0.52
Lysine, %				1.19
Carotenoid composition of pigment sources ( -carotene equivalents, ppm)‡				
	Yellow pigment	Red pigment	Xanthophylls	
Baobab	38.95	67.75	63.50	
Moringa	103.79	127.39	158.91	
Orange rind	87.96	97.76	94.48	
Roselle	59.41	101.90	102.54	

§ Optimix poultry chick nourisher, Animal Care, Nigeria. Provided the following per kg/diet: vitamin A, 20,000 IU; vitamin D<sub>3</sub>, 4,000 IU; vitamin E, 20 mg; vitamin K<sub>3</sub>, 4 mg; vitamin B<sub>1</sub>, 3 mg; vitamin B<sub>2</sub>, 10 mg; niacin 16 mg; calpan 16 mg; vitamin B<sub>6</sub>, 6 mg; vitamin B<sub>12</sub>, 0.03 mg; choline chloride, 200 mg; folic acid, 2 mg; biotin, 0.1 mg; manganese, 120 mg; iron, 40 mg; zinc, 100 mg; copper, 10 mg; iodine, 2 mg; cobalt, 0.4 mg; selenium, 0.4 mg; antioxidant, 250 mg.

† Calculated analysis based on values for feed ingredients (NRC, 1994) on dry matter basis, and not inclusive of pigment sources.

‡ Carotenoid composition of pigment sources determined on dry matter-basis.

standard curve.

***Serum lipid profile***

Sera obtained was used for spectrophotometric determinations of serum triacylglycerol, total cholesterol, and high density lipoprotein (HDL) using specific diagnostic kits (Quimica Clinica Aplicada, S.A, Amposta, Spain) while low density lipoprotein (LDL) and very low density lipoprotein (VLDL) were estimated

(Moslehi *et al.*, 2015).

***Statistical analysis***

Data obtained for growth performance: body weight gain, feed consumption and feed conversion ratio, pigmentation and lipid profile were analyzed for treatment effect over the period of exposure to the pigment source in their diets with data for skin pigmentation also compared among carcass sections using ANOVA (SPSS,

2011) as a completely randomized design, and means separated using LSD with a 5% level of probability.

**Results and discussion**

**Growth performance**

Effect of the different pigment sources on growth performance of broiler chickens during grower-finisher phase is shown in Table 2. Live weight of chickens at the beginning and end of the study period i.e. at 21d and 56d were not statistically different between treatment groups (P = 0.25 and P = 0.06, respectively). However, feed consumption, body weight gain and feed conversion ratio were influenced by the pigment sources. Feed consumption was higher in chickens on the orange rind diet (142 g/day) and least in chickens on the moringa diet (127 g/day). Body weight gain was highest in chickens on the roselle and moringa diets (55.1 and 54.1 g/day respectively) and least in chickens on the baobab diet (48.3 g/day). Chickens on the moringa and roselle diets also had more efficient feed conversion (2.38 and 2.40, respectively) compared to chickens on the baobab diet (2.85) and orange rind diet (2.89). The differences observed in growth performance variables across dietary treatments could be attributed to variations in the chemical and nutrient composition of the pigment sources used in this study. For example, high tannin content in baobab leaves and high fibre and antinutrients in

moringa leaves have been cited as responsible for impaired performance of laying, broiler and pullet birds at levels higher than 2% in various studies (Butswat *et al.*, 1997, Oludoyi and Toye, 2012).

**Skin pigmentation measurements**

Table 3 shows the effect of the pigment sources on skin pigmentation in the apterylum region and shank of live broiler chickens during grower-finisher phase using a visual colour score (DSM broiler colour fan). Pigment sources were seen to influence skin pigmentation differently with more intense pigmentation observed in the shanks compared to the apterylum region in chickens on the baobab, moringa and orange rind diets (P = 0.00) at all ages.

Similar trend was observed in chickens fed the roselle diet at week 6 (P = 0.00) and week 7 (P = 0.019), however, pigmentation in the skin of the apterylum region and shank did not differ significantly in chickens on the roselle diet at weeks five and eight. Skin pigmentation also differed significantly between treatment groups (P = 0.00) when measured in the skin of the apterylum region and shank. Chickens on the moringa diet showed more intense skin pigmentation while chickens on the roselle diet showed less intense skin pigmentation throughout the study period compared to the other treatment groups. Apterylum pigmentation peaked at 35d for chickens on the roselle diet (101.10), at 42d for chickens on the baobab (101.54) and orange (101.40)

**Table 2: Relative effect of pigment sources on growth performance of broiler chickens grower-finisher phase (21-56 days)**

Growth performance criteria	Dietary treatments				SEM	P
	Baobab diet	Moringa diet	Orange rind diet	Roselle diet		
Live weight , g						
At 21 d	394.25	382.30	408.83	379.13	5.57	0.25
At 56 d	2077.50	2287.63	2147.31	2322.63	70.8	0.06
Feed consumption, g/day	135.00 <sup>b</sup>	126.76 <sup>a</sup>	141.66 <sup>c</sup>	130.35 <sup>ab</sup>	2.22	0.00
Body weight gain, g/day	48.29 <sup>b</sup>	54.09 <sup>a</sup>	49.89 <sup>ab</sup>	55.09 <sup>a</sup>	1.90	0.04
Feed conversion	2.85 <sup>b</sup>	2.38 <sup>a</sup>	2.89 <sup>b</sup>	2.40 <sup>a</sup>	0.11	0.00

<sup>abc</sup> Means in the same row with common letters are different at P<0.05

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**Table 3: Effect of pigment sources on skin pigmentation of live broiler chickens during grower finisher phase (21-56 days)<sup>1</sup>**

	Age of broiler chickens (days)			
	35	42	49	56
<b>Apterylum region</b>				
Baobab diet	101.25 <sup>b</sup>	101.54 <sup>b</sup>	101.50 <sup>b</sup>	101.40 <sup>b</sup>
Moringa diet	101.84 <sup>a</sup>	102.23 <sup>a</sup>	102.40 <sup>a</sup>	102.31 <sup>a</sup>
Orange rind diet	101.07 <sup>b</sup>	101.40 <sup>b</sup>	101.17 <sup>c</sup>	101.25 <sup>b</sup>
Roselle diet	101.10 <sup>b</sup>	101.00 <sup>c</sup>	101.00 <sup>d</sup>	101.00 <sup>c</sup>
SEM <sup>2</sup>	0.10	0.11	0.12	0.16
<i>P</i>	0.00	0.00	0.00	0.00
<b>Shank</b>				
Baobab diet	102.11 <sup>b</sup>	102.32 <sup>b</sup>	102.21 <sup>b</sup>	102.13 <sup>b</sup>
Moringa diet	103.10 <sup>a</sup>	103.37 <sup>a</sup>	103.70 <sup>a</sup>	103.75 <sup>a</sup>
Orange rind diet	101.67 <sup>c</sup>	101.40 <sup>c</sup>	101.90 <sup>c</sup>	102.06 <sup>b</sup>
Roselle diet	101.13 <sup>d</sup>	101.00 <sup>d</sup>	101.16 <sup>d</sup>	101.13 <sup>c</sup>
SEM <sup>2</sup>	0.16	0.16	0.19	0.26
<i>P</i>	0.00	0.00	0.00	0.00

<sup>1</sup> Visual colour score was obtained using the DSM broiler colour fan

<sup>2</sup> Standard error of mean

<sup>abc</sup> Means in the same column with common letters are different at  $P < 0.05$

diets and at 49d for chickens on the moringa diet (102.4), while shank pigmentation peaked at 49d for chickens on the roselle (101.16) and baobab (102.21) diets and at 56d for chickens on the moringa (103.75) and orange ring (102.06) diets. The effect of pigment sources on post-slaughter pigmentation of broiler chickens at 56 days measured in the skin of the shank, breast, vent, back and abdominal fat is also shown in Table 4.

Post-slaughter pigmentation in all carcass

sections; shank, breast, vent, bank and abdominal fat was significantly more intense in chickens on the moringa diet and similar in chickens on the baobab, orange rind and roselle diets. When pigmentation in the carcass sections was compared within each treatment, significant differences were observed. The trend of pigmentation observed in this study agrees with trends reported by Liu *et al.* (2008) where it was observed that the skin of the shank developed relatively quicker, more intense

**Table 4: Effect of pigment sources on post-slaughter skin pigmentation of meat-type chicken at 56 days<sup>1</sup>**

	Carcass sections					SEM	<i>P</i>
	Shank	Breast	Vent	Back	Abdominal fat		
Baobab diet	102.0 <sup>b</sup> <sub>x</sub>	101.8 <sup>b</sup> <sub>x</sub>	102.0 <sup>b</sup> <sub>x</sub>	101.1 <sup>b</sup> <sub>y</sub>	101.1 <sup>b</sup> <sub>y</sub>	0.088	0.00
Moringa diet	103.8 <sup>a</sup> <sub>x</sub>	102.8 <sup>a</sup> <sub>yz</sub>	103.2 <sup>a</sup> <sub>xy</sub>	102.0 <sup>a</sup> <sub>z</sub>	102.6 <sup>a</sup> <sub>yz</sub>	0.115	0.003
Orange rind diet	101.4 <sup>bc</sup> <sub>x</sub>	101.0 <sup>c</sup> <sub>y</sub>	101.1 <sup>c</sup> <sub>xy</sub>	101.0 <sup>b</sup> <sub>y</sub>	101.0 <sup>b</sup> <sub>y</sub>	0.072	0.02
Roselle diet	101.0 <sup>c</sup> <sub>y</sub>	101.0 <sup>c</sup> <sub>y</sub>	101.2 <sup>c</sup> <sub>x</sub>	101.0 <sup>b</sup> <sub>y</sub>	101.0 <sup>b</sup> <sub>y</sub>	0.069	0.02
SEM 2	0.44	0.30	0.35	0.18	0.29		
<i>P</i>	0.01	0.00	0.01	0.21	0.00		

<sup>1</sup> Visual colour score was obtained using the DSM broiler colour fan

<sup>2</sup> Standard error of mean

<sup>abc</sup> Means in the same column with common superscript letters are not significantly different

<sup>xyz</sup> Means in the same row with common subscript letters are not significantly different

pigmentation followed by the skin of the vent and breast, with the back skin being least pigmented. The effect of pigment sources on red and yellow pigment concentration in serum of broiler chickens during grower-finisher phase is shown in

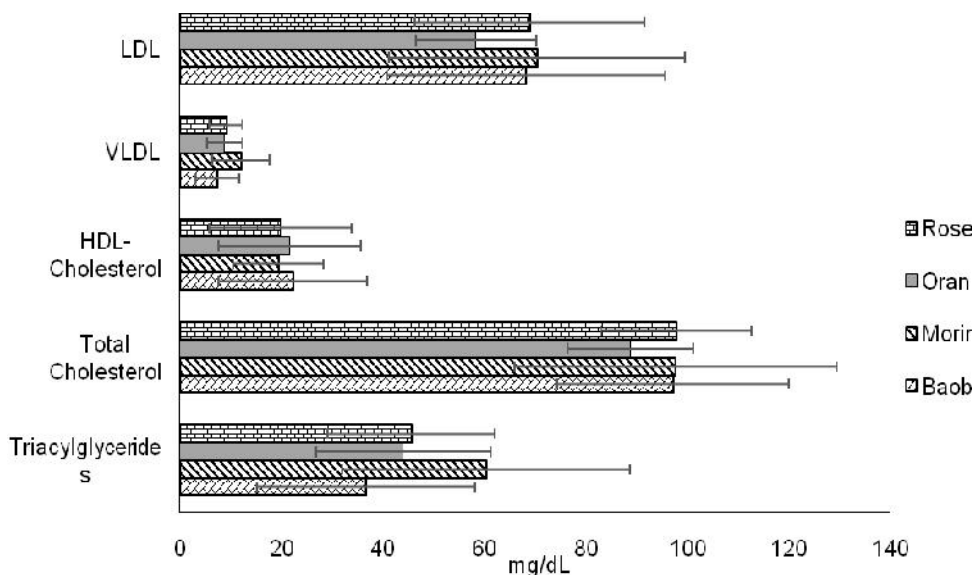
Table 5. Chickens fed the baobab, orange rind and roselle diets had similar concentration of red pigments at 35d and 42d and yellow pigments 35d, while lower concentration of red and yellow pigments was observed in chickens fed the moringa diet.

**Table 5: Effect of pigment sources on red and yellow pigments (  $\beta$ -carotene equivalents, ppm) in serum of broiler chickens during grower finisher phase (21-56 days)**

	Age of broiler chickens (days)			
	35	42	49	56
<b>Red pigment ( <math>\beta</math>-carotene equivalents, ppm)</b>				
Baobab diet	20.46 <sup>a</sup>	18.88 <sup>a</sup>	19.78	18.74
Moringa diet	19.84 <sup>b</sup>	18.54 <sup>b</sup>	19.6	18.36
Orange rind diet	20.46 <sup>a</sup>	18.92 <sup>a</sup>	19.86	18.14
Roselle diet	20.53 <sup>a</sup>	19.01 <sup>a</sup>	20.1	18.37
SEM <sup>1</sup>	0.15	0.13	0.23	0.23
P	0.00	0.05	0.43	0.33
<b>Yellow pigment ( <math>\beta</math>-carotene equivalents, ppm)</b>				
Baobab diet	20.46 <sup>a</sup>	19.52	20.36	19.08 <sup>a</sup>
Moringa diet	19.97 <sup>b</sup>	18.97	20.02	18.02 <sup>b</sup>
Orange rind diet	20.44 <sup>a</sup>	19.28	20.04	18.14 <sup>b</sup>
Roselle diet	20.58 <sup>a</sup>	19.44	20.2	18.83 <sup>a</sup>
SEM <sup>1</sup>	0.13	0.22	0.17	0.33
P	0.02	0.30	0.44	0.049

<sup>1</sup> Standard error of mean

<sup>abc</sup> Means in the same column with common letters are different at P<0.05



**Figure 1: Relative effect of pigment sources on serum lipid profile of broiler chickens at 56 days.**

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At 35d (after exposure to the pigment sources in the diets for 14 days) both red and yellow pigment concentration approached plateau in the serum. Yellow pigment concentration was significantly higher in serum of chickens on the baobab and roselle diets (19.08 and 18.83 ppm respectively) compared to birds on the moringa (18.02 ppm) and orange rind (18.14 ppm) diets at 56d.

#### ***Serum lipid profile***

The effect of pigment sources on serum lipid profile - serum triacylglycerol, total cholesterol, high density lipoprotein (HDL) low density lipoprotein (LDL) and very low density lipoprotein (VLDL) of broiler chickens during grower-finisher phase is shown in Figure 1. The ability of orange peels at 5% of the diet of hypercholesterolemic rats to significantly lower serum lipid indices, total cholesterol, triacylglycerides, LDL and VLDL has been documented (Adbelbaky *et al.*, 2009). Similar antihyperlipidemic properties have also been reported for *Moringa oleifera* (Pankaj *et al.*, 2010), *Hibiscus sabdariffa* leaves and calyces extracts (Ochani and D'Mello, 2009; Yang *et al.*, 2010; Gosain *et al.*, 2010). Hence a comparison of antihyperlipidemic activity on the different pigment sources showed that inclusion of the pigment sources at 4% inclusion level in the diets of grower-finisher broiler chickens did not influence serum lipid profile variables. It could thus be inferred that the pigment sources tested in the present study possessed similar abilities to influence serum lipid indices levels, hence no significant differences in serum lipid indices were observed.

#### **Conclusion**

The study showed that inclusion of the pigment sources, orange (*Citrus x sinensis*) rind, roselle (*Hibiscus sabdariffa*) calyces, *Moringa oleifera* and baobab (*Adansonia*

*digitata*) leaves at 4% of the diet of grower-finisher broiler chickens resulted in differences in growth performance. Variations in absorption and assimilation of carotenoids from the pigment sources influenced skin pigmentation and serum pigment concentrations differently. However, serum lipid indices were not affected differently by the pigment sources.

#### **References**

- Abiodun, B. S., Aderibigbe, S. A. and Elegbeleye, A. 2014.** Lesser known indigenous vegetables as potential natural egg colourant in laying chickens. *Journal of Animal Science and Technology* 56 (18): 1-5.
- Adbelbaky, M. S., Elmehiry, H. F. and Ali, N. K. M. 2009.** Effect of some citrus peels on hypercholesterolemic rats. The 1<sup>st</sup> International and 4<sup>th</sup> Arab Annual Scientific Conference on Academic Accreditation for Higher Specific Education Institutions and Programs in Egypt and Arab World "Reality and Expectation".
- Anon. 1990.** Factors influencing food choice in human. *Nutritional Reviews* 48(12): 442-444.
- Breithaupt, D. E., Wirt, U. and Bamedi, A. 2002.** Differentiation between lutein monoester regioisomers and detection of lutein diesters from marigold flowers (*Tagetes erecta* L.) and several fruits by liquid chromatography-mass spectrometry. *Journal of Agriculture and Food Chemistry* 50:66-70.
- Breithaupt, D. E., Weller, P. and Grashorn, M. A. 2003.** Quantification of carotenoids in chicken plasma after feeding free

- or esterified lutein and capsanthin using high-performance liquid chromatography and liquid chromatography-mass spectrometry analysis. *Poultry Science* 82: 395-401.
- Breithaupt, D. E. 2007.** Modern application of xanthophylls in animal feeding-A review. *Trends in Food Science and Technology* 18: 501-506.
- Bunnell, R. H. and Bauernfeind, J. C. 1962.** Chemistry, uses and properties of carotenoids in foods. *Food Technology* 16: 42-43.
- Butswat, I. S., Nelson, F. N., Oyawoye, E. O. and Akande, F. O. 1997.** Utilization of baobab (*Adansonia digitate* L.) leaf meal for egg yolk pigmentation in layers. *Indian Journal of Animal Science* 67(1): 82-83.
- Casteneda, M. P., Hirschler, E. M. and Sams, A. R. 2015.** Skin pigmentation evaluation in broilers fed natural and synthetic pigments. *Poultry Science* 84: 143-147.
- EFSA, 2014.** Scientific opinion on the safety and efficacy of canthaxanthin as a feed additive for poultry and for ornamental birds and ornamental fish. *European Food Safety Authority Journal* 12 (1): 3527-3551.
- Fletcher, D. L. 1977.** Factors affecting the measurement and utilization of xanthophylls in the egg yolk and broiler skin. Dissertation. University of Florida, Gainesville, FL.
- Fletcher, D. L. 1999.** Broiler breast meat colour variation, pH and texture. *Poultry Science* 78: 1323-1327.
- Gosain, S., Ircchiaya, R., Sharma, P. C., Thareja, S., Kalra, T., Deep, A. and Bhardwaj, T. R. 2010.** Hypolipidemic effect of ethanolic-extract from the leaves of *Hibiscus sabdariffa* L. in hyperlipidemic rats. *Acta Poloniae Pharmaceutica – Drug Research* 67(2): 179-184.
- Hamelin, C. and Altemueller, U. 2012.** The effect of carotenoids on yolk and skin pigmentation. *World Poultry* 8: August 13.
- Hamilton, P. B. 1992.** The use of high-performance liquid chromatography for studying pigmentation. *British Poultry Science* 71: 718-724.
- Hasin, B. M., Ferdaus, A. J. M., Islam, M. A., Uddin, M. J. and Islam, M. S. 2006.** Marigold and orange skin as egg yolk color promoting agents. *International Journal of Poultry Science* 5(10): 979-987.
- Liu, G. D., Hou, G. Y., Wang, D. J., Lv, S. J., Zhang, X. Y., Sun, W. P. and Yang, Y. 2008.** Skin pigmentation evaluation in broilers fed different levels of natural okra and synthetic pigments. *Journal of Applied Poultry Research* 17: 498-504.
- Malterud, K. E. and Rydland, K. M. 2000.** Inhibitors of 15-lipoxygenase from orange peel. *Journal of Agriculture and Food Chemistry* 48: 5576-5580.
- Marusich, W. L. and Bauernfeind, J. C. 1981.** Oxycarotenoids in poultry feeds. In Carotenoids as colorants and vitamin A precursors: technological and nutritional applications. Bauernfeind J. C (Ed.) Pp 319-441. Academic Press, Inc, New York.
- Mortensen, A. 2006.** Carotenoids and other pigments as natural colorants. *Pure and Applied Chemistry* 78(8): 1477-1491.
- Moslehi, A., Sadeghi, A. A., Shawrang, P. and Aminafshar, M. 2015.** Blood

- lipid components in broiler chickens fed on diets containing lipids from different sources. *Indian Journal of Fundamental and Applied Life Sciences*, 5(1): 142-148.
- Negro, J. J., Bortolotti, G. R., Tella, J. L., Fernie, K. J. and Bird, D. M. 1998.** Regulation of integumentary colour and plasma carotenoids in American kestrels consistent with sexual selection theory. *Functional Ecology* 12:307–312.
- Negro, J. J., Tella, J. L., Blanco, G., Forero, M. G. and Garrido-Fernandez, J. 2000.** Diet explains interpopulation variation of plasma carotenoids and skin pigmentation in Nestling White Storks. *Physiological and Biochemical Zoology: Ecological and Evolutionary Approaches* 73(1): 97-101.
- Ochani, P. C. and D'Mello, P. 2009.** Antioxidant and antihyperlipidemic activity of *Hibiscus sabdariffa* Linn. Leaves and calyces extracts in rats. *Indian Journal of Experimental Biology* 7: 276-282.
- Oludoyi, I. A. and Toye, A. A. 2012.** The effects of early feeding of *Moringa oleifera* leaf meal on performance of broiler and pullet chicken. *Agrosearch* 12(2): 160-172.
- Pankaj, G. J., Savita, D. P., Nitin, G. H., Manaj, V. G. and Sanjay, J. S. 2010.** Hypolipidemic activity of *Moringa oleifera* Lam. Moringaceae on high fat diet induced hyperlipidemia in albino rats. *Brazilian Journal of Pharmacognosy* 20(6): 969-973.
- Qwele, K., Muchenje, V., Oyedemi, S. O., Moyo, B. and Masika, P. J. 2013.** Effect of dietary mixtures of moringa (*Moringa oleifera*) leaves, broiler finisher and crushed maize on antioxidant potential and physicochemical characteristics of breast meat for broilers. *African Journal of Biotechnology* 12(3): 290-298.
- Scheldt, K. 1998.** Absorption and metabolism of carotenoids in birds, fish and crustaceans. In: Biosynthesis and metabolism (Eds. Britton G, Jensen S L and Pfander H), Volume 2, Birkhauser, Verlag, Switzerland pp 285-358.
- da Silva, R. R., de Oliveira, T. T., Nagem, T.J., da Silva, P. A., Teixeira, L.F., de Alreida, M. R., Kling de Moraes, G.H. and Pinto, J.G. 2001.** Efeito hypocholesterolemico dos flavonoids naringinases e rutina. *Archivos Latinoamericanos de Nutricion* 51: 258-264.
- Sirri, F., Iaffaldano, N., Minelli, G., Meluzzi, A., Rosato, M. P. and Franchini, A. 2007.** Comparative pigmentation efficiency of high dietary levels of apoester and marigold extract on quality traits of whole liquid egg of two strains of laying hens. *Journal of Applied Poultry Research* 16: 429-437.
- Sreelatha, S. and Padma, P. R. 2009.** Antioxidant activity and total phenolic content of *Moringa oleifera* leaves in two stages of maturity. *Plant Foods for Human Nutrition* 64: 303-311.
- SPSS, 2011.** IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp. USA
- Tunio, M. T., Yang, S., Chen, Z., Zubair, M., Qui, J., Zhao, Y., Chen, G., Chow, Y. and Chen, A. 2013.** Effect of pigments with different origins on pigmentation and performance of broilers. *Pakistan*

- Journal of Zoology* 45(6): 1715-1725.
- Verma, A. R., Vijjayakumar, M., Mathela, C. S., and Chandana, V. R. 2009.** *In vitro* and *in vivo* antioxidant properties of different fractions of *Moringa oleifera* leaves. *Food and Chemical Toxicology* 47(9): 2196-2201.
- Vertuani, S., Braccioli, E., Buzzoni, V. and Manfredini, S. 2002.** Antioxidant capacity of *Adansonia digitate* fruit pulp and leaves. *Acta Phytotherapeutica* 2(2): 2-7.
- Yang, M. H., Peng, C. H., Chan, K. C., Yang, Y. S., Huang, C. N. and Wang, C. J. 2010.** The hypolipidemic effect of *Hibiscus sabdariffa* polyphenols via inhibiting lipogenesis and promoting hepatic lipid clearance. *Journal of Agriculture, Food and Chemistry* 58: 850-859.

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