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Effect of Tomato Waste Meal on Lay Performance, Egg Quality, Lipid Profile and Carotene Content of Eggs in Laying Hens

Research Article

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ABSTRACT

An eight week study was conducted to investigate the effect of inclusion of tomato waste meal in layer diets on laying performance, egg quality and lipid profile as a means to reduce feed cost and pollution. Four laying diets containing tomato waste meal (TWM) at four levels of 0, 3, 6 or 9% were assigned randomly to 4 groups of 40 birds divided among four replicates of 10 birds in each dietary treatment in a completely randomized experimental design. Collected on egg production, egg quality, yolk lipid profile and its carotenoid content which were analyzed by analysis of variance using the general linear model procedure of SAS. Statistical results showed no differences in hen-day production at either 0, 3 or 6% inclusion level (68.30%, 67.80% and 68.10% respectively) but at the 9% (63.45% hen-day production) of inclusion level a significant (P<0.05) decrease was observed. Feed conversion ratio was significantly higher at the 9% inclusion level. Egg weight, Haugh unit and yolk index were not affected by dietary treatments. Yolk colour increased significantly with increasing levels of TWM in the diets. Yolk lipids (including cholesterol) were at the lowest amounts at 6% and 9% inclusion level. Yolk carotenoid content (including lycopene) of the birds that were fed diets containing TWM was significantly increased with increasing dietary content of TWM. It was concluded that up to 6% TWM can be included in layer diets without any adverse effect on egg quality and compromising egg production rate. This inclusion level also showed to be beneficial via enhancing yolk colour score and lycopene concentration and reducing egg yolk cholesterol content.

KEY WORDS egg weight, fen-day production, haugh unit, yolk cholesterol, yolk lycopene.

INTRODUCTION

The greatest problem preventing the development of the livestock industry in Rwanda is inadequate feed resources. This is due to a high man:land ratio (0.4 sq hectare per family) which limits local production of food and feed resources. Rwanda produced more than 102501 tons of fresh tomato (FAOSTAT, 2011) from an area of 264.9 ha with opportunity for increased production and emergence of a larger tomato processing industry. Tomato waste (peel and seeds) is one of the by-products of tomato processing industries and hotels. The advent of a local food processing industry in Rwanda is currently creating a pollution problem in urban centers and is likely to create more with further industrialization of the country. Tomato waste consists of tomato skin, pulp and seeds that remain after processing tomato fruits into juice, paste and ketchup. It constitutes about 20-50% of the initial weight of tomato (Monika *et al.* 2005). Tomato waste contains on a dry basis 175.6g crude protein, 95.9 g lipid, 495.3 g crude fibre, 36.4 g ash, 405.4 g insoluble fibre and 590.7 g total carbohydrates per kilogram of residue (Alvarado *et al.* 2001). It has been proposed that the use of tomato waste as feed for poultry may be a way of reducing the cost of feeding poultry and help to alleviate the problem of solid waste management in Rwanda. The lycopene in tomato waste can also help to control prostate cancer in man (Giovannucci *et al.* 2002) and can be recycled into human consumers via various poultry products. This present study was conducted to evaluate the effects of inclusion of tomato waste in laying hen diets on egg production, egg quality, yolk lipid and the lycopene contents of the egg yolk.

MATERIALS AND METHODS

The study was conducted at the Poultry Unit of Ecole Agronomique et Veterinaire de Kabutare (EAVK) situated in Butare, Huye district, South Province of Rwanda. The district is characterized by a sub-equatorial temperate climate with an average temperature fluctuating around 20 ˚C and an annual rainfall of 1160 to 1400 mm.

Tomato waste (peel and seeds) used in this study was collected from the restaurant of the National University of Rwanda. The procedures for peeling was that of pouring hot water of about 70 ˚C on the tomatoes for five minutes and then spraying them with cold water to split the peels before removing them. The waste was dried in an oven at 65 ˚C for 48 hours until moisture content was reduced to 10%. The dried tomato waste was milled using hammer mill with sieve of about 2mm to obtain tomato waste meal (TWM).

The control diet was formulated to contain 15% crude protein and 2460 kcal ME/kg. The TWM was included in three experimental diets at levels of 3%, 6%, or 9% at the expense of white maize. Other ingredients apart from TWM were supplied from the feed store of Ecole Agronomique et Veterinaire de Kabutare (EAVK). The feeds were Iso-nitrogenous and adjusted for energy as much as possible. The composition of the diets is shown in Table 1. One hundred and sixty (160) Rhode Island Red laying hens (36 weeks of age) were used for the study. The birds were divided randomly into four groups of 40 birds each, and each group was given one of the four experimental diets in a completely randomized experimental design. Each experimental group was divided into four replicate groups of 10 birds per replicate Birds were housed in 3 m × 1 m deep litter pens equipped with a bank of 45 cm × 45 cm × 30 cm laying nests.

Feed and water were provided for *ad libitum* consumption using a feeding trough and a water trough. Diets were presented in mash form. Eggs were collected two times a day (9-10 a.m. and 3-4 p.m.). The laying facility was cleaned each morning before the daily feed was provided manually. The study was conducted over a period of 8 weeks. Data were collected on feed intake, egg production and egg weight.

The efficiency of feed utilization and hen-day production were determined.

Table 1 Ingredients and chemical composition of the experimental diets

Ingredient (%)	Inclusion level of tomato waste meal (TWM %)			
	0 (control)	3.0	6.0	9.0
Maize (white variety)	58.29	55.79	54.29	51.79
TWM	0.0	3.0	6.0	9.0
[1] Cotton seed cake meal	10.45	10.45	10.45	10.45
[2] Soya bean meal	7.0	7.0	7.0	7.0
[3] Blood meal	2.5	2.5	2.5	2.5
Rice bran	13.81	13.31	11.81	11.31
Dicalcium phosphate	7.0	7.0	7.0	7.0
NaCl	0.25	0.25	0.25	0.25
DL-methionine	0.20	0.20	0.20	0.20
L-lysine.Hcl	0.20	0.20	0.20	0.20
Vitamin and mineral premix[4]	0.30	0.30	0.30	0.30
Total	100	100	100	100
Determined analysis				
Crude protein (%)	15.50	15.52	15.53	15.56
Crude fibre (%)	3.5	4.2	6.6	7.7
ME (kcal/g)	2.46	2.46	2.41	2.30

TWM: tomato waste meal and ME: metabolizable energy.

[1] Contains 25% crude protein.

[2] Contains 42% crude protein.

[3] Contains 80% crude protein.

[4] Premix composition: vitamin A: 20000000 IU; vitamin D_3: 4000000 IU; vitamin E: 460 mg; vitamin K_3: 40 mg; vitamin B_1: 60 mg; vitamin B_2: 120 mg; vitamin B_6: 100 mg; vitamin B_{12}: 5 mg; Niacin: 1000 mg; Calcium pantothenate: 200 mg; Folic acid: 20 mg; Biotin: 1 mg; Chlorine chloride: 8000 mg; Manganese: 2400 mg; Iron: 2000 mg; Zinc: 1600 mg; Copper: 170 mg; Iodine: 30 mg; Cobalt: 6 mg; Selenium: 24 mg and Anti-oxidant: 2400 mg.

Feed intake was calculated as the difference in the feed offered in a day and the residual the following morning. Eggs collected in the last 3 days of the week were pooled and 20 eggs were selected randomly and weighed individually using Ohaus electronic top loading weighing balance. Egg length and breadth were measured using a centimeter ruler. Feed conversion efficiency was calculated as kg feed consumed/kg egg laid. Hen-day egg production was calculated as:

(number of eggs-produced×100) / (number of hens×number of hens in production)

Egg quality evaluations were conducted at the 4th and 8th weeks of the study. Eggs collected in the last two days of 4th and 8th weeks were pooled and 16 eggs were selected randomly from the pool for egg quality evaluation. The eggs were weighed individually and broken carefully into a clean, smooth, flat surface to measure internal characteristics. Yolk height and albumen height were measured using a tripod micrometer, and results were recorded to the nearest 0.1 cm. Measurement for albumen height was taken between yolk edge and the external edge of the thick albumen. Yolk diameter was measured using a pair of vernier calipers. Yolk colour was determined using the Roche col-

our fan. Egg shell membrane was removed carefully and manually from the broken egg shell and the thickness of the shell measured using a micro-meter screw gauge.
Yolk Index was calculated as follows:

Yolk index= height of the yolk (cm) / diameter of yolk (cm)

The Haugh unit was calculated using the formula of Haugh (1937).

HU= 100 log $(H+7.5-1.7W^{0.37})$
HU= condition of thick albumen in Haugh units.
H= height of thick albumen in mm.
W= weight of egg in gram.

Chemical analysis

Proximate analysis of TWM and the feeds was determined by the methods of AOAC (1990). Gross energy of the TWM and the feed was determined using ballistic bomb calorimeter (AOAC, 1990).

Phosphorus was determined using the spectrophotometric phosphoammonium vanadate reaction. Calcium was determined using atomic absorption spectrophotometry (AOAC, 1990).

Methionine and lysine contents were determined using a liquid chromatography technique as described by Ijarotimi and Olopade (2009). Total yolk cholesterol and egg yolk phospholipids were determined using a gas chromatography method as described by Pasin *et al.* (1998) and Kivini *et al.* (2004), respectively.

Yolk total lipid was determined using the gas chromatography methods as described by Agah *et al.* (2010). Free fatty acids and triacylglycerol were determined by gas chromatographic analysis (Liu *et al.* 2005). Lycopene, lutein, zeaxanthin, α-carotene, β-carotene and cisβ-carotene content of the yolk was determined using an HPLC method described by Hart and Scott (1995).

Data analysis

Data were analyzed by one-way analysis of variance (ANOVA) using the General Linear Model Procedure of SAS, (1996). Where significance was indicated, means were grouped using the Least Significant Difference Option of the same software. Significance was determined at $P \leq 0.05$.

RESULTS AND DISCUSSION

The chemical analysis of the TWM used in this study is shown in Table 2. It is rich in protein (21.22%), minerals (especially phosphorus and calcium) and essential amino acids (methionine and lysine).

It also contains high fibre content (43.15%) and a substantial amount of energy (4248 kcal/kg gross energy).

Table 2 Chemical composition of tomato waste meal (TWM)

Fraction	TWM
Dry matter (%)	96.82
Crude protein (%)	21.22
Ether extract (%)	14.42
Crude fibre (%)	43.15
Ash (%)	6.81
Nitrogen free extract (%)	14.40
Gross energy (kcal/kg)	4248
Calcium (mg/g)	0.51
Phosphorus (mg/g)	0.61
Lysine (%)	0.3
Methionine (%)	0.4
Lycopene (ug/g⁻)	350
Lutein (ug/g)	8.30
Zeaxanthin (ug/g)	2.1
∞-carotene (ug/g)	0.13
β-carotene (ug/g)	19.2
Cis β-carotene (ug/g)	7.5

The TWM also contains carotenoid compounds: lycopene (350 ugg^{-1}), lutein (8.30 ugg^{-1}), zeaxanthin (2.1 ugg^{-1}), α-carotene (0.13 ugg^{-1}), β-carotene (19.2 ugg^{-1}) and cis β-carotene (7.5 ugg^{-1}). The performance and egg quality characteristics of the hens fed TWM are shown in Table 3.

Table 3 Performance and egg quality of laying hens fed different levels of tomato waste meal (TWM)

Parameter	0 (control)	3	6.0	9.0	SEM
Feed intake (g/bird/day)	123.3	125.5	124.7	127.6	6.0
Hen-day (%)	68.30^a	67.80^a	68.10^a	63.45^b	1.5
Feed conversion ratio	2.73^b	2.74^b	2.76^b	3.32^a	0.20
Mortality (%)	0.00	0.00	0.00	0.00	0.0
Egg weight (g)	58.20	58.40	58.30	58.10	2.0
Yolk weight (g)	9.2	9.3	9.4	9.1	1.0
Yolk index	0.55	0.55	0.54	0.53	0.1
Egg shell weight (g)	6.4	6.3	6.2	6.3	1.3
Albumen weight (g)	30.2	30.3	30.1	30.4	1.0
Egg shell thickness (mm)	0.38	0.37	0.38	0.39	0.40
Haugh unit	91.41	91.91	91.96	91.68	3.0
Yolk colour score	4.66^c	6.33^b	9.15^a	9.60^a	0.8

The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Feed intake was not significantly affected by inclusion of TWM in the diet, but egg production and feed conversion ratio were significantly (P≤0.05) affected. The percent hen-day production of the groups fed 3% and 6% TWM was not different from that of the control group, but a significant (P≤0.05) depression was observed at the 9% inclusion level. Feed conversion ratios of the birds that were fed 3%

and 6% TWM were similar to that of the control group. Those that were fed 9% TWM however had higher (P<0.05) feed conversion ratio which is an indication of poor feed utilization.

No mortality was recorded throughout the duration of the study. Yolk colour score increased progressively with increased levels of TWM in the diet. No significant (P>0.05) effect of diet was observed for egg weight, egg shell weight, albumen weight, yolk weight, yolk index, egg shell thickness and Haugh unit. The lipid profile and carotene content of egg yolk from hens fed TWM are shown in Table 4.

Table 4 Lipid profile and carotenoid content of egg yolk from hens fed different levels of tomato waste meal (TWM)

Parameter	Level of tomato waste meal in the diets				
	0 (control)	3.0	6.0	9.0	SEM
Total cholesterol (mg/mL)	2.32[a]	2.31[a]	1.82[b]	1.61[b]	0.29
Total lipids (mg/mL)	8.38[a]	8.25[a]	6.94[b]	6.38[b]	0.80
Free fatty acids (mg/mL)	0.59[a]	0.57[a]	0.31[b]	0.28[b]	0.10
Phospholipids (mg/mL)	0.34[a]	0.33[a]	0.29[b]	0.28[b]	0.03
Triglyceride (mg/mL)	9.23[a]	9.11[a]	8.98[ab]	7.11[b]	1.10
Lycopene (ug/g)	0.00[c]	0.50[b]	0.83[a]	0.95[a]	0.2
Lutein (ug/g)	10.1[b]	13.2[a]	13.6[a]	13.9[a]	1.3
Zeaxanthin (ug/g)	9.40[b]	12.40[a]	12.80[a]	12.92[a]	1.2
∞-cryptoxanthin (ug/g)	0.82[b]	1.28[a]	1.23[a]	1.25[a]	0.1
β-cryptoxanthin (ug/g)	0.26[b]	0.48[a]	0.43[a]	0.49[a]	0.1

SEM: standard error of the means.

No significant difference was observed in the total cholesterol, total lipids, free fatty acids, phospholipids and triglycerides contents of the yolk at 0 and 3% TWM inclusion levels, but the concentration of these compounds was significantly reduced at the 6% and 9% inclusion level. Inclusion of TWM in the diets resulted in deposition of lycopene in the egg yolk. The concentration of lycopene increased with increasing levels of TWM in the diet. The concentration of other carotenoid compounds was significantly lower (P≤0.05) in the eggs from hens given the control diet.

The high nutrient content of TWM makes it a potential feed resource for livestock animals. The crude protein content of tomato waste meal used in this study (21.22%) is higher than the value reported by Alvarado *et al.* (2001) but lower than that reported for seed byproduct by Knoblich *et al.* (2005). The presence of carotenoid compounds in TWM will be an advantage for the development of egg yolk colour. However, the high content of fibre in TWM will definitely limit its use as poultry feed as it interferes with nutrient digestion and absorption. Its inclusion at a lower level may however be an advantage in that it may help to reduce production cost and cholesterol level of the egg yolk.

This study revealed a depression in the egg production rate of the hen at 9% TWM inclusion level. This could be due to the slightly low energy content of this diet. Li *et al.* (2013) reported a poor egg production on Lohmann brown pullet fed low energy diet. Rezaei and Hafezian (2007) also attributed the depression that was observed in egg production of the hen fed 15% high fibre sunflower diet to the dilution effect of of fibre on the energy content of the feed. The depression that was observed on feed conversion of the birds at 9% inclusion level can be attributed to the high fibre content of TWM.

The limitation impose on digestion and feed conversion by high dietary fibre is well documented (Oladunjoye *et al.* 2010). This limitation occurs as a result of interference with digestion and absorption of nutrient in the digestive system. The result obtained in this study agree with that of Lira *et a.* (2010) who also observed a poor feed conversion in broilers fed TWM.

In this study feed intake of the birds were not affected by dietary treatment. This disagree with the reports of Lira *et al.* (2010) who observed an increase in the feed intake of the broilers at 10% inclusion level and that of Alvarado *et al.* (2001) who also reported increased feed intake of rats fed tomato byproducts.

High yolk colour that was observed in birds that were fed TWM can be attributed to higher concentration of lycopene and other carotenoid compounds in TWM. Knoblich *et al.* (2005) also reported that feeding the tomato byproducts affected the visual appraisal of egg yolk pigmentation and altered the carotenoid content.

In this study, a reduction was observed in the total cholesterol, total lipids, free fatty acids, phospholipids and triglycerides of the egg yolk from the birds fed 6% and 9% TWM. This could be due to high level of dietary fibre in TWM (McNaughton, 1978).

High intake of food rich in soluble fibre has also been reported to lower blood cholesterol level in man (Jenkins *et al.* 1993). The result reported here however contradict the findings of Safamehr *et al.* (2011) who reported that tomato pomace inclusion in the layers hen had no significant effect on the yolk cholesterol. The difference could be due to the difference in the strain of birds used for the two studies. This study revealed that lycopene was transferred from the feed into the egg yolk.

This is in line with Knoblich *et al.* (2005) who also reported increase in the lycopene content of egg yolk from laying chicken fed tomato seed and peels. Tomato has been identified as the major source of lycopene (Agarwal *et al.* 2001), therefore feeding of TWM to laying hen can be a way of increasing the lycopene content of poultry eggs.

This will be of health importance since lycopene has been linked with low incidence of prostate cancer on people that eat more serving of tomato products (Rehman *et al.* 1999; Barber and Berber, 2002).

CONCLUSION

This study revealed that laying hens can tolerate up to 6% TWM in their diet without any adverse effect on egg production and quality. Within this level TWM improved egg yolk colour score, reduced yolk cholesterol and increased yolk lycopene concentration. However, egg production can be depressed when TWM is increased beyond the 6% inclusion level, but this can also be related to lower feed energy.

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