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Influence of dried tomato pomace as an alternative to wheat bran in maize or wheat based diets, on the performance of laying hens and traits of produced eggs

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Summary

In a $2 \times 3 \times 2$ factorial arrangement, 144, fifty-four-week-old laying hens, in 12 treatments with 12 replicates for each treatment, received one of 12 diets based on maize or wheat containing three levels of dried tomato pomace (DTP: 0, 50 and 100 g/kg) as a substitute for wheat bran, and two levels of pigment (0 and 900 mg/kg), for 9 weeks. Weight gain (WG), egg production (EP), egg weight (EW), egg mass output (EM) and feed intake (FI) were determined. Shell weight (ShW), shell thickness (ShT), Haugh unit (HU) and yolk colour score (YCS) were also measured. Maize decreased body weight of the birds and increased HU, ShW/EW ratio, ShT, and YCS of the eggs when compared with wheat diets. DTP had no effect on these parameters, but increased YCS. Pigment reduced ShW/EW ratio and ShT, but increased YCS of the eggs. There were significant interactions between the source of energy (ES) and DTP on ShT and YCS of the eggs. There were also interactions significant between ES and pigment on ShT and YCS. As an alternative for wheat bran, 100 g/kg of DTP produced comparable egg quality and laying performance, and it contributed to a deeper yolk colour.

Key words: Dried tomato pomace, Laying performance, Egg quality, Yolk colour

Introduction

Researchers have done tremendous efforts on increasing the table egg yolk colour as this brings significant premiums in most markets and food processing industries that prefer natural darker coloured yolks rather than adding artificial yolk colouring agents. Different dietary ingredients can contribute to the colouration of egg yolk to varying extents. Since yellow maize has various carotenoids such as *zeaxanthin*, it has been the primary pigmentation source for poultry industry. However, the substitution of wheat, barley and rice into the feeds further dilutes out these pigmentation sources.

Iran produces up to 4,200,000 tones of fresh tomatoes annually (FAO, 2006), which most of them are used for processing in tomato cannery factories, producing a considerable amount of wet tomato pomace

as a byproduct. Tomato pomace is a good source of protein, vitamins and minerals but may be limited in energy due to the high fiber content. Although notable variations has been reported in chemical composition of tomato pomace, it is shown that crude protein, crude fiber, diethyl ether extract, nitrogen free extract, and total ash contents of DTP might be up to 215, 398, 160, 433, and 40 g/kg, respectively (Harb, 1986; Persia *et al.*, 2003; King and Zeidler, 2004; Jafari *et al.*, 2006). Substitution of tomato pomace instead of other dietary ingredients shows comparable performance parameters in table egg-laying hen (Yannakopoulos *et al.*, 1992; Dotas *et al.*, 1999; Persia *et al.*, 2003; Jafari *et al.*, 2006). Besides, tomato pomace contains notable amounts of natural pigments such as β -carotene and lycopene, which in combination with commercially available pigments, could contribute to a darker yolk colour that is desirable for the

consumers (Mlodkowski and Kuchta, 1998).

The objective of this study was to evaluate the feasibility of using dried tomato pomace (DTP), as a substitute for wheat bran in maize or wheat-based diets, on the performance of table egg-laying hens and the quality of produced eggs. In this study, DTP in combination with commercially available natural pigments, Bio-Caps and Bio-Gold, were used to assess the contribution of each colourant in producing darker egg yolks, using Roche egg yolk colour fan (Hoffman- La Roche Ltd., Basel, Switzerland).

Materials and Methods

Preparation of experimental diets

Wet tomato pomace was air-dried to final moisture content in order to obtain DTP (9% moisture), and ground through a 2

mm mesh. The nutrient analysis of DTP was carried out according to the standard methods of analysis (AOAC, 1996) in order to determine dry matter (code 934.01), crude protein (code 976.05, Kjeldahl titration unit, Tecator Kjeltec 1030 Auto Analyzer, Hoganas, Sweden), crude fiber (code 978.10, Tecator Fibertec System I, Hoganas, Sweden), crude fat (code 920.39) and ash (code 942.05). The gross energy of DTP was measured by a bomb calorimeter (Model C5001, IKA, Germany). The natural saponified pigments of paprika (*Capsicum annum*, Bio-Caps) and marigold flowers (*Tagetes erecta*, Bio-Gold) were used by the courtesy of Biochem Company (Biochem Nantes Sarl, 48, Bd du Batonnier Cholet – 44100 Nantes, France)

Ingredients and calculated chemical compositions of basal diet fed to laying hens are shown in Table 1. Diets were formulated

Table 1: Diet formulation and estimated chemical composition of experimental rations

Diet composition (g/kg)	Diet 1 [#]	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
Maize	496	510	523	0	0	0
Wheat	0	0	0	546	560	573
Soybean meal (CP 44%)	235	229	223	172	165	158
Wheat bran	100	50	0	100	50	0
Dried tomato pomace	0	50	100	0	50	100
Vegetable oil	54	45.6	37.8	66	58.1	51.0
Di-Calcium phosphate	19.5	19.6	19.8	19.5	19.6	19.8
Calcium carbonate	45	45	45	45	45	45
Oyster shell	40	40	40	40	40	40
D-L methionine	1.80	2.10	2.40	2.20	2.40	2.60
L-Lysine	0	0	0.30	0.90	1.50	2.10
Salt	3.7	3.7	3.7	3.40	3.40	3.40
Vitamin premix [*]	2.50	2.50	2.50	2.50	2.50	2.5
Mineral pemix ^{**}	2.50	2.50	2.50	2.50	2.50	2.5
Chemical composition (calculated)						
Methabolisable energy (kcal/kg)	2760	2760	2760	2760	2760	2760
Crude protein	164	164	164	164	164	164
Crude fiber	38.3	47.0	55.7	39.5	48.2	56.9
Ether extract	69.6	64.3	59.4	74.1	69.0	64.5
Methionine	4.3	4.5	4.7	4.3	4.5	4.7
Methionine + cystine	6.7	6.9	7.1	6.7	6.9	7.1
Lysine	7.9	7.8	7.7	7.6	7.7	7.7
Threonine	6.0	5.7	5.4	5.2	4.9	4.6
Sodium	1.8	1.8	1.8	1.8	1.8	1.8
Calcium	36	36	36	36	36	36
Available phosphorus	4.7	4.7	4.7	4.7	4.7	4.7

^{*} Vitamin premix supplied per kg of diet; Vit A 8800IU, Vit D3 2500IU, Vit E 11IU, Vit B1 1.5 mg, Vit B2 4.0 mg, Vit B3 (Calcium panthotenate) 8 mg, Vit B5 (Niacin) 35 mg, Vit B6 2.5 mg, Vit B12 0.01 mg, Biotin 0.15 mg, Folic Acid 0.48 mg, Cholin Chloride 400 mg, Vit K3 2.2 mg. ^{**} Mineral premix supplied per kg of diet; Manganese 75 mg, Iron 75 mg, Zinc 64.8 mg, Copper 6.0 mg, Iodine 0.87 mg, Selenium 0.2 mg. [#] Diets 7-12 were the same as diets 1-6 but containing 700 mg/kg Bio-Caps and 200 mg/kg Bio-Gold

Table 2: The overall influence of maize or wheat as dietary sources of energy (ES), dried tomato pomace (DTP) and pigment (Pig) on the performance of table laying hens and the quality of produced eggs

	ES			DTP (g/kg)			Pig (mg/kg)			Statistical significance							
	Maize	Wheat	SEM	0	50	100	SEM	0	900	SEM	ES	DTP	Pig	ES×DTP	ES×Pig	DTP×Pig	ES×DTP×Pig
WG (%)	-2.16 ^a	0.89 ^b	0.544	0.39	-0.95	-1.35	0.697	-1.23	-0.05	0.569	***	NS	NS	NS	NS	NS	NS
EP (%)	86.6	85.5	0.73	86.3	86.9	84.9	0.89	85.4	86.7	0.73	NS	NS	NS	NS	NS	NS	NS
EW (g)	63.9	63.8	0.29	63.9	63.3	64.4	0.35	63.8	63.9	0.29	NS	NS	NS	NS	NS	NS	NS
EM (g)	55.2	54.3	0.46	54.7	55.0	54.6	0.56	54.4	55.2	0.46	NS	NS	NS	NS	NS	NS	NS
FI (g)	90.0	91.4	0.70	90.2	90.1	91.6	0.86	91.0	90.3	0.71	NS	NS	NS	NS	NS	NS	NS
HU	97.8 ^a	95.7 ^b	0.33	96.8	96.5	97.0	0.42	97.1	96.5	0.34	***	NS	NS	NS	NS	NS	NS
ShW/EW (%)	8.96 ^a	8.68 ^b	0.041	8.81	8.82	8.82	0.052	8.89 ^a	8.76 ^b	0.042	***	NS	NS	NS	NS	NS	NS
ShT (µm)	366 ^a	355 ^b	2.0	361	358	362	2.5	365 ^a	355 ^b	2.1	***	NS	NS	NS	NS	NS	NS
YCS	9.9 ^a	7.9 ^b	0.25	6.7 ^c	9.7 ^b	10.3 ^b	0.28	6.5 ^a	11.1 ^b	0.19	***	***	***	*	***	*	NS

a, b, c Means with different superscripts for each parameter in each row are significantly different ($P < 0.05$); * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$; NS, Not significant ($P > 0.05$); SEM; Standard Error of the Mean; ES, Source of Energy; DTP, Dried Tomato Pomace; Pig, Pigment; WG, Weight Gain; EP, Egg Production/Day; EW, Egg Weight; EM, Egg Mass ($EG \times EP$); FI, Feed Intake/Day; HU, Haugh Unit; ShW/EW, Shell Weight/ Egg Weight; ShT, Shell Thickness; YCS, Yolk Colour Score

using UFFDA feed formulation package according to the nutrient requirements of white laying hens (NRC, 1994) and balanced to be iso-nitrogenous and iso-caloric, and meet all other nutrient requirements of the birds. Two diets based on maize or wheat as sources of energy (ES) contained three levels of DTP (0, 50 and 100 g/kg) as substitutes for wheat bran, with two levels of pigment (700 mg/kg Bio-Caps and 200 mg/kg Bio-Gold) based on the manufacturer's recommendation.

Rearing conditions

The experiment was carried out at the poultry research station, Amin-Abad Veterinary Research Institute, Faculty of Veterinary Medicine, University of Tehran. In a $2 \times 3 \times 2$ factorial design, 144 apparently healthy laying hens (Single Comb White Leghorn, Hy-Line W36, 54-week-old), in 12 treatments with 12 replicates for each treatment, were kept individually in laying cages ($30 \times 40 \times 40$ cm in dimension), in an environmentally-controlled, closed-sided poultry house (18°C , 50% relative humidity and 16 h of light daily) for 10 weeks (one-week adaptation period and 9-week experimental period). Prior to the experiment, all birds were fed wheat based commercial diet for 7 days to deplete carotenoids. During the experimental period hens had free access to water and one of 12 experimental diets. All birds survived and remained healthy during the experimental period. At the first and last days of experiment, all birds were weighed individually. Daily egg production, egg

weight and weekly feed intake were recorded on the first, fifth and ninth week of the experiment. Weight gain of the birds (WG) and overall hen-day egg production (EP), egg weight (EW), egg mass output (EM) and feed intake (FI) were determined from the recorded data. The internal egg quality characteristics measured were albumen height, Haugh unit (HU) and yolk colour score (YCS). The Haugh unit was calculated using the following formula:

$$\text{Haugh unit} = 100 \log H_A + 7.57 - 1.7W_E^{0.37}$$

where H_A is albumen height and W_E is egg weight (Doyon *et al.*, 1986). Egg yolks collected from each treatment were scored using the Roche egg yolk colour fan by three different individuals.

Eggshells were dried at room temperature and weighed. Shell thickness (ShT) and albumen height were measured by a vernier calliper and tripod micrometer, respectively. Shell weight (ShW), ShT, HU and YCS were measured on the last week of the experiment.

Statistical analysis

The experiment had a complete random design with a $2 \times 3 \times 2$ factorial arrangement (analysis of variance (ANOVA), Minitab 13.2 statistical package, Minitab Inc. State College, PA, USA). Fisher's LSD method was used to find the confidence intervals for all pair-wise differences between means. The general linear model (GLM) was used to determine the main effects of factors and any possible interaction between factors, using the

following equation:

$$y_{ijkl} = \mu + a_i + b_j + c_k + a_i b_j + a_i c_k + b_j c_k + a_i b_j c_k + e_{ijkl}$$

where

y_{ijkl} = l th observation for a hen fed diet type i , DTP supplementation j , pigment supplementation k

a_i = Diet type (maize or wheat)

b_j = DTP supplementation

c_k = Pigment supplementation

$a_i b_j, a_i c_k, b_j c_k, a_i b_j c_k$ = Interaction terms

e_{ijkl} = error term

Results

The proximate analysis showed that DTP used in this study contained 910 g/kg dry matter, 30.2 g/kg total nitrogen, 189 g/kg crude protein ($N \times 6.25$), 286 g/kg crude fiber, 56 g/kg diethyl ether extract, 63 g/kg total ash, 316 g/kg total nitrogen free extract, 3930 kcal/kg gross energy. Metabolisable energy value of DTP was assumed to be equal to wheat bran.

Results showed that ES had significant influences on WG, HU, ShW/EW ratio, ShT and YCS of the experimental birds (Table 2). Dietary maize decreased body weight of the birds and increased HU, ShW/EW, ShT, and YCS of the produced eggs when compared with wheat ($P < 0.001$). Inclusion of 100 g/kg of DTP to the diet had no effect on the measured parameters. However, DTP raised YCS of the produced eggs ($P < 0.001$). Although, dietary pigment reduced ShW/EW ($P < 0.05$) and ShT ($P < 0.001$) of the produced eggs, it profoundly elevated YCS of the eggs ($P < 0.001$). Significant interactions were noted between ES and DTP on ShT ($P < 0.05$) and YCS of the produced eggs ($P < 0.05$). There were also significant interactions between ES and pigment on ShT ($P < 0.05$) and YCS ($P < 0.001$). DTP and pigment showed a significant interaction on YCS ($P < 0.05$).

Discussion

Different variations were seen in chemical composition of DTP which could be due to several factors including origin of the farm (area, state), soil conditions and use of fertilizers, means of irrigation, variety of tomato, ripeness, tomato processing

conditions and cannery plants, relative percentage of seed, skin, pulp and leaves in wet pomace, and many more factors related to drying process (Persia *et al.*, 2003; King and Zeidler, 2004; Jafari *et al.*, 2006). However, the proximate analysis of DTP in this experiment and the previous reports show that the appreciable amounts of nutrients are found in tomato pomace (Brodowski and Giesman, 1980; Giesman, 1981). Since reported data are scarce on the metabolisable energy value of DTP for broilers (Mansoori *et al.*, 2008), metabolisable energy value of DTP was assumed to be equal to wheat bran in this experiment.

The lower quality of egg (HU, ShW/EW and ShT) in hens provided with diets containing wheat as the source of energy, might be due to the higher concentration of antinutrients such as phytates and non-starch polysaccharides in such diets. These antinutrients are known to disturb the optimum absorption and/or utilization of dietary nutrients by the bird that resulting lower quality of the laid egg (Zyla *et al.*, 2000; Lazaro *et al.*, 2003; Silversides *et al.*, 2006).

As expected, those diets containing maize resulted in darker egg yolk colours (YCS = 5.8 to 9.6) than the diets containing wheat (YCS = 2.3 to 7.0). Yellow maize is among the conventional sources of carotenoids and rich in *zeaxanthin*. Saxena *et al.* (1982) reported that feeding hens diets containing 400 g/kg of yellow maize increased markedly the YCS of produced eggs from 2 to 8 in 3-7 days.

Inclusion of DTP into the diet up to 100 g/kg in the current experiment gave similar results with that of the previous works on tomato pomace (Dotas *et al.*, 1999; Ferrante *et al.*, 2003; Kang *et al.*, 2003; Persia *et al.*, 2003; Jafari *et al.*, 2006; Sahin *et al.*, 2006). It has been reported that feeding laying hens diets containing DTP at inclusion rates up to 120 g/kg did not affect egg production, food consumption and efficiency of the hen as well as egg weight and shell thickness (Dotas *et al.*, 1999; Jafari *et al.*, 2006).

Tomato by-products contain considerable amounts of lutein, β -carotene, *cis*- β -carotene, and lycopene. A notable increase in YCS of eggs, as a result of dietary

inclusion of DTP in this experiment, was most likely due to the presence of appreciable amounts of carotenoid pigments, particularly lycopene. Lycopene is responsible for the red colour of tomato and DTP.

Diets containing 8 or 15% tomato meal (undefined contents) or 12% tomato pulp increased the yolk colour score (Yannakopoulos *et al.*, 1992; Mlodkowski and Kuchta, 1998; Dotas *et al.*, 1999). Similar results were also shown in quails fed diets containing 20 g/kg of tomato powder (Karadas *et al.*, 2006). In fact, feeding laying hens diets containing tomato by-products may transfer up to 5.8% of the dietary lycopene to the egg yolk (Knoblich *et al.*, 2005; Karadas *et al.*, 2006).

It is found that the combination of DTP and natural pigments used in this study had no adverse effect on the egg quality and benefited the birds to lay eggs with deeper yolk colours (YCS = 11.9 to 12.4). However, further works should be carried out to find out the proper ratio of DTP and commercially available pigments in feed in order to produce table eggs with yolk colours that are desirable for consumers and/or food industries.

In conclusion, DTP up to 100 g/kg showed to be a well substitute for wheat bran in table egg-laying hen rations, producing comparable or even superior influences on the performance of the hen and the quality of the egg. Although DTP could not compete with natural pigments in producing deeper egg yolk colour, it showed promising results on the colouration of egg yolk. Tomato pomace is a good source of protein and vitamins, rich in carotenoid pigments, readily available as well as low-cost in tomato producing countries. However, further studies are needed to measure an apparent and true digestibility of DTP nutrients in laying hen. The influence of DTP on the digestion and utilization of other dietary ingredients, function of the immune system and resistance to diseases, and finally, on the fertility and hatchability of breeder hens should also be elucidated.

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