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Effects of Dietary Tomato Processing Byproducts on Pork Nutrient Composition and Loin Quality of Pigs

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ABSTRACT

The objective of the present study was to evaluate effects of tomato processing byproducts supplementation to the finishing pig diet on pork quality. A total of 135 crossbred pigs (Landrace×Yorkshire×Duroc) with an average initial body weight of 75.7 kg were allotted to 3 dietary treatments. A basal diet was prepared primarily based on corn, wheat, palm kernel meal and distillers dried grains with solubles. Two additional diets were prepared by adding 3 or 5% of tomato processing byproducts. After feeding the experimental diets for 7 weeks, 3 pigs from each group were randomly selected pork quality assessment. The contents of moisture, crude protein, ether extract and ash were not affected by the inclusion rate of tomato processing byproduct. Proline concentration in loin decreased linearly ($p = 0.001$) with increasing inclusion rate of tomato processing byproduct. The total ω6:ω3 ratio tended to increase with increasing concentration of tomato processing byproducts ($p = 0.085$). Shear force of loin was affected by dietary tomato processing byproduct (quadratic, $p = 0.032$). The scores of tenderness were increased linearly ($p = 0.006$) with increasing levels of the tomato processing byproducts. Taken together, dietary tomato processing byproducts may affect the pork tenderness in finishing pigs. Further research to elucidate the mode of action of tomato by products on pork quality is warranted.

Key words: Feed supplement, pork quality, swine production

INTRODUCTION

The tomato (*Lycopersicon esculentum*) is rich in red-color pigment, lycopene. Lycopene is one of carotenoid family antioxidants and has relatively high antioxidative activity (Di Mascio *et al*., 1989). The antioxidants in natural food are related with prevention of cancer, inhibition of oxidative damage and reduction of low density lipoprotein formation (Kaur and Kapoor, 2001).

The tomato coproducts produced from manufacturing process of tomatoes contain lycopene, lutein and zeaxanthin (Sies and Stahl, 2003; Viuda-Martos *et al*., 2014). Tomato byproducts have been investigated in poultry diets as feed antioxidants (Botsoglou *et al*., 2004; Selim *et al*., 2013). In addition, tomato coproducts were used as a source of antioxidants in meat product processing (Kim and Chin, 2013; Joseph *et al*., 2014).

To our knowledge, however, data on the effects of lycopene supplementation to swine diets on pork quality are very limited. Therefore, this study was conducted to evaluate effects of tomato processing byproducts supplementation to the finishing pig diet on pork quality.

MATERIALS AND METHODS

Animals and experimental diets: A total of 135 crossbred pigs (Landrace×Yorkshire×Duroc) with an average body weight of 75.7 kg (standard deviation = 6.2) were allotted to 3 dietary treatments in a completely randomized design. A basal diet was prepared primarily based on corn, wheat, palm kernel meal and distillers dried grains with solubles (Table 1). Vitamins and minerals were supplemented to meet or exceed the requirement estimates (NRC., 2012). Two additional diets were prepared by adding 3 or 5% of tomato processing byproducts. Pigs had free access to feed and water.

Sample collection: After feeding the experimental diets for 7 weeks, 3 pigs were randomly selected from each treatment group for pork quality assessment. After slaughtering the pigs, a steak was removed from *Longissimus dorsi* (loin) muscle and analyzed for free amino acids and fatty acid concentrations and meat quality.

Chemical analysis: The amino acids in the loin muscles from each group were frozen and lyophilized to be analyzed. The amino acid concentrations of loin samples were analyzed using an ion-exchange chromatography with a postcolumn derivatization with ninhydrin. Methionine and cysteine in the samples were oxidized with performic acid. The samples were then neutralized by sodium metabisulfite (Llames and Fontaine, 1994; EC., 1998). Amino acids were isolated from the protein hydrolyzed with 6 N HCl for 24 h at 110°C and the liberated amino acids were quantified with the internal standard by measuring the absorption rate of reaction products with ninhydrin at 570 nm.

The samples were also analyzed for dry matter (AOAC., 2005, method 930.15), crude protein (AOAC., 2005, method 990.03), ether extract (AOAC., 2005, method 920.39) and ash (AOAC., 2005, method 942.05).

Table 1: Ingredient and nutrient composition of the basal diet, as-fed basis

Ingredients	Percentage	Calculated composition of nutrients	Values
Ground corn	39.34	Digestible energy (kcal kg^{-1})	3.45
Ground wheat	20.00	Crude protein (%)	15.00
Palm kernel meal	10.00	Ether extract (%)	5.60
Distillers dried grains with solubles	7.00	Ash (%)	4.10
Soybean meal, 48% crude protein	5.12	Crude fiber (%)	5.30
Rapeseed meal	4.00	Calcium (%)	0.65
Lys cell mass	1.00	Phosphorus (%)	0.40
Soybean milk residue	1.00	Lys (%)	0.86
Blood meal	0.50	Met (%)	0.26
Wheat bran	4.00	Thr (%)	0.63
Molasses	3.00		
Choice white grease	2.16		
L-Lys·HCl, 78%	0.23		
L-Thr, 98%	0.09		
Limestone	0.95		
Dicalcium phosphate	0.16		
Salt	0.30		
Choline chloride, 50%	0.10		
Vitamin-mineral premix	1.05		

Intramuscular fat was extracted in 50 mL chloroform-methanol from the 10 g of loin muscle samples (Jayasena *et al*., 2013) and analyzed for the fatty acid concentrations by gas chromatography (AOAC., 2005, method 996.06).

Pork quality assessment: A sample of 5 g was mixed with 20 mL of distilled water and homogenized for 1 min at 8,000 rpm. The pH of the mixer was then measured using a por pH meter equipped with a glass electrode. A colorimeter (Chroma meter, CR 210; Minolta, Tokyo, Japan) was used to measure the lightness (L*), redness (a*) and yellowness (b*) of the loin muscle samples. The steaks were cooked in a water bath at 75°C for 30 min then cooled for the cooking loss analysis (Hur *et al*., 2013). The cooking loss was calculated by subtracting the weight of the loin sample after cooking from the initial weight.

The water holding capacity was determined with a filer paper press method. The sample of 0.3 g was put on Whatman No. 2 filter paper (Whatman, Ltd., Maidstone, UK), placed between two plexiglass plates and then press for 3 min. The wet area was measured with a planimeter and calculated with the initial moisture content. The shear force was measured with a texture analyzer. The cross head speed for the analysis was 2 mm sec^{-1}.

The loin samples were cooked before the sensory panel analysis. In a tasting room, 5 sessions of sensory tests including overall score were evaluated by sensory panelists. Nine steak cubes were served randomly to 12 sensory panelists. The judgments of the sensory analysis were based on: Tenderness (1 = extremely tough to 5 = extremely tender); flavor (1 = extremely weak to 5 = extremely strong); chewiness (1 = not chewy to 5 = extremely chewy); juiciness (1 = extremely dry to 5 = extremely juicy); overall (1 = extremely tasteless to 5 = extremely tasty).

Statistical analysis: Data were analyzed as a completely randomized design using the GLM procedures of SAS (SAS Institute Inc., Cary, NC, USA). The model included diets. Orthogonal polynomial contrasts were performed to determine linear and quadratic effects. Appropriate contrast coefficients for the unequally spaced lycopene concentrations were obtained using the interactive matrix language procedure. Each pig served as the experimental unit. An alpha level of less than 0.05 was considered significant and of less than 0.10 was considered tendency.

RESULTS

Chemical compositions: The contents of moisture, crude protein, ether extract and ash were not affected by the levels of the tomato byproduct (Table 2). The AA contents also were not changed with the supplementation of the tomato byproduct except for proline whose concentration was decreased linearly ($p = 0.001$) with increasing the level of tomato byproduct. The pigs tended to have the increased concentration of valine ($p = 0.099$) and reduced arginine ($p = 0.053$) in the loin muscles.

Fatty acid compositions: The fatty acid compositions of the loin muscle from the pigs fed the experimental diets were presented (Table 3). There was no significant difference among the loin muscle samples but total ω6 to ω3 ratio had a trend of increasing ($p = 0.085$) when the level of tomato byproducts increased.

Color characteristics and meat quality: The results showed that the significant quadratic response of shear force on tomato byproduct levels was observed ($p = 0.032$; Table 4). Other response criteria, however, were not affected by the tomato byproducts supplementation.

Table 2: Chemical compositions of loin muscle from pigs fed diets with different inclusion rates of tomato byproduct

	Tomato byproduct (%)				p-value	
Item (%)	0	3	5	SEM	Linear	Quadratic
Water	2.37	2.21	2.37	0.12	0.880	0.340
Crude protein	69.00	71.70	72.40	2.80	0.399	0.843
Ether extract	25.40	24.50	23.20	2.60	0.581	0.890
Crude ash	4.42	4.15	4.76	0.29	0.527	0.236
Indispensable amino acids						
Arginine	0.09	0.06	0.07	0.010	0.053	0.094
Histidine	7.11	7.26	7.68	0.390	0.366	0.699
Isoleucine	0.03	0.03	0.04	0.003	0.536	0.644
Leucine	0.13	0.13	0.13	0.010	0.970	0.745
Lysine	0.09	0.08	0.08	0.010	0.550	0.583
Methionine	0.05	0.05	0.06	0.003	0.517	0.163
Phenylalanine	0.06	0.06	0.07	0.010	0.214	0.342
Threonine	1.22	0.93	1.02	0.130	0.278	0.332
Valine	0.05	0.06	0.06	0.003	0.099	0.124
Dispensable amino acids						
Alanine	0.40	0.46	0.42	0.05	0.655	0.410
Cystein	0.07	0.09	0.09	0.01	0.158	0.796
Glutamic acid	0.16	0.16	0.17	0.01	0.532	0.640
Glycine	0.22	0.21	0.23	0.02	0.801	0.465
Proline	0.14	0.11	0.10	0.00	0.001	0.363
Tyrosine	0.17	0.18	0.18	0.02	0.737	0.798

Each least squares mean for all treatments represents 3 observations, SEM: Standard error of the means

Table 3: Fatty acid compositions of loin muscle from pigs fed diets with different inclusion rates of tomato byproduct

	Tomato byproduct (%)				p-value	
Item (%)	0	3	5	SEM	Linear	Quadratic
C14:0	0.45	0.40	0.40	0.04	0.429	0.809
C16:0	6.49	6.30	5.84	0.63	0.504	0.808
C18:0	3.90	3.81	3.54	0.41	0.579	0.805
C20:0	0.06	0.06	0.05	0.01	0.510	0.614
Total SFA	10.90	10.60	9.84	1.03	0.511	0.804
C16:1 n-7	0.62	0.68	0.60	0.10	0.925	0.609
C18:1 n-9	10.30	10.20	9.61	1.14	0.698	0.854
C20:1 n-9	0.28	0.23	0.24	0.03	0.338	0.620
Total MUFA	11.30	11.20	10.50	1.20	0.676	0.811
C18:2 n-6	2.48	2.17	2.29	0.38	0.691	0.683
C20:2 n-6	0.13	0.11	0.12	0.02	0.513	0.504
C20:3 n-6	0.04	0.02	0.03	0.01	0.276	0.493
C20:4 n-6	0.08	0.06	0.07	0.02	0.814	0.601
Total ω6	2.73	2.36	2.49	0.42	0.660	0.668
C18:3 n-3	0.15	0.13	0.13	0.03	0.609	0.641
C20:3 n-3	0.03	0.03	0.03	0.01	0.763	0.815
Total ω3	0.20	0.17	0.16	0.03	0.366	0.826
Total ω6:ω3 ratio	13.80	14.10	15.80	0.60	0.085	0.301
Total PUFA	2.93	2.52	2.65	0.44	0.638	0.677
Total PUFA:SFA ratio	0.27	0.23	0.27	0.03	0.998	0.317
Unidentified	0.29	0.24	0.21	0.04	0.184	0.945
Total	25.40	24.50	23.20	2.60	0.580	0.891

Each least squares mean for all treatments represents 3 observations, SEM: Standard error of the means, SFA: Saturated fatty acids, MUFA: Mono-unsaturated fatty acids, PUFA: Poly-unsaturated fatty acids

Table 4: Color characteristics (Hunter L, a, b values) and meat quality of loin muscle from pigs fed diets with different inclusion rates of tomato byproduct

	Tomato byproduct (%)				p-value	
Item	0	3	5	SEM	Linear	Quadratic
pH	5.52	5.61	5.56	0.04	0.464	0.273
L*	55.20	53.80	53.40	1.70	0.463	0.903
a*	15.10	15.40	16.20	1.00	0.498	0.752
b*	2.68	2.47	2.65	0.50	0.944	0.778
Cooking loss (%)	27.10	28.60	26.80	0.90	0.935	0.162
WHC (%)	43.00	46.60	41.20	3.90	0.838	0.370
Shear force (N)	5.35	5.79	4.77	0.23	0.190	0.032

Each least squares mean for all treatments represents 3 observations, SEM: Standard error of the means, *L: Lightness, a*: Redness, b*: Yellowness, WHC: Water holding capacity

Table 5: Sensory panel scores of cooked loin muscle from pigs fed diets with different inclusion rates of tomato byproduct

	Tomato byproduct (%)				p-value	
Item	0	3	5	SEM	Linear	Quadratic
Tenderness	3.36	3.53	3.97	0.15	0.006	0.280
Flavor	2.92	3.22	3.17	0.16	0.244	0.444
Chewiness	3.44	3.39	3.71	0.16	0.309	0.293
Juiciness	3.25	3.56	3.47	0.17	0.297	0.403
Overall	3.53	3.44	3.58	0.11	0.864	0.386

Each least squares mean for all treatments represents 3 observations, respectively. SEM: Standard error of the means, Tenderness (1: Extremely tough to 5: Extremely tender), Flavor (1: Extremely weak to 5: Extremely strong), Chewiness (1: Not chewy to 5: Extremely chewy), Juiciness (1: Extremely dry to 5: Extremely juicy), Overall (1: Extremely tasteless to 5: Extremely tasty)

Sensory panel scores: The taste panel did not detect any difference in the flavor, chewiness and juiciness of the cooked loin muscles except tenderness (Table 5). The scores of tenderness were increased linearly ($p = 0.006$) with increasing levels of the tomato byproducts.

DISCUSSION

There is very limited information available in the literature on the effects of dietary lycopene or dietary tomato byproducts on pork quality. To our knowledge, only a very recent publication addresses the effects of tomato silage on performance and pork quality (Aguilera-Soto *et al*., 2014). We first report the effects of tomato processing byproducts on amino acid and fatty acid concentrations of pork.

In the present study, proximate composition of pork was not affected by dietary tomato coproducts (Table 2). In agreement, dry matter and crude protein of chicken meat was not affected by dietary lycopene (Sevcikova *et al*., 2008; Pozzo *et al*., 2013). In our study, most amino acid and fatty acid composition of pork was not affected by dietary tomato coproducts. Botsoglou *et al*. (2004) also reported that dietary tomato pulp up to 10% did not alter fatty acid composition in breast meat of quail. This indicates that bioactive components in tomato byproducts including lycopene, lutein and zeaxanthin (Sies and Stahl, 2003) do not directly influence nutrient composition of pork. Although antioxidative effects of direct application of tomato powder on pork sausages have been reported (Kim and Chin, 2013), anti-oxidative effects of dietary tomato products on pork quality have not been documented.

Recently, Aguilera-Soto *et al.* (2014) reported that pork pH was not affected by dietary tomato coproducts. We also failed to find the effects of tomato byproducts on the loin pH as well as pork color and water holding capacity. These indicates that antioxidants or carotenoids do not always affect the acidity, or color of loin muscle. In accordance, cooked loin quality evaluated by panelists was not influenced by dietary tomato byproducts in the present study. Exceptionally, tenderness of cooked loin was improved by dietary tomato processing byproducts. The authors do not know why only tenderness was affected by the dietary treatments.

One of the limitations in the present study was that we did not use pure lycopene, lutein, or zeaxantin but used tomato processing byproducts. However, as the purpose of the present study was to test the values of dietary tomato processing byproducts in swine diets, the pure bioactive compounds were not tested. In the future research, the absorbability of bioactive compounds in tomato products in the gastrointestinal tract of pigs needs to be measured. The retention of the bioactive compounds in pork also needs to be quantified. To elucidate more detailed mechanisms of lycopene, lutein and zeaxantin, the pure compounds should be dose-dependently tested in swine diets.

Taken together, dietary tomato processing byproducts may affect the pork tenderness in finishing pigs. Further research to elucidate the mode of action of tomato by products on pork quality is warranted.

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