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Effects of tomato pomace supplementation on carcass characteristics and meat quality of fattening rabbits

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Abstract

The aim of this study was to determine how a feeding plan characterized by different levels of tomato pomace (TP) supplementation influences the carcass characteristics, the chemical, physical and sensorial characteristics of rabbit meat. 144 weaned crossbred rabbits were divided into three groups of 48 each. The first group was fed a basal diet without TP, while the other two groups were fed the basal diet after replacing part of the diet with TP at 3% and 6%, respectively. There was a significant difference between the experimental groups in terms of live and carcass weights. The meat of rabbits fed on a 6% TP diet exhibited higher yellowness (b*) and Chroma values when compared to others. The saturated fatty acid content in the longissimus dorsi muscle and perirenal fat decreased significantly with increasing TP inclusion, while polyunsaturated fatty acids increased. Furthermore, our results indicate that a diet integrated with 6% TP could influence positively the overall preference of cooked meat.

Introduction

Tomato production is a major industry in Italy. It is primarily focused on processing tomatoes, which accounts for 88% of the total 6.6 million tons reported in 2004, while a considerable quantity of by-products are generated every year. After the juice has been extracted, a mixture of tomato peels, cores, culls, pulp, crushed seeds and unprocessed green tomatoes is generated. Tomato pomace (TP) is a by-product from this processing and its utilization as an alternative feedstuff could provide extra income for the tomato industry and, at the same time, reduce the problem of waste disposal (Vasta, Nudda, Cannas, Lanza, & Priolo, 2008). The composition of TP is linked to the morphology of the original feedstock and to the extraction technique used; it varies according to the agricultural and processing practices, the degree of drying, moisture removal and separation of cellulose (King & Zeidler, 2004). TP could be used as a source of fiber, protein or fat and is rich in nutrients and antioxidants, such as carotenes (lycopene and β-carotene) and phenolic compounds (Del Valle, Cámara, & Torija, 2006). The dietary supplementation of lycopene positively affected the lipid profile of blood plasma in broiler chickens (Ševčikova, Skřivan, & Dlouha, 2008). According to Dotas, Zamanidis, and Balios (1999) incorporation of dried tomato pulp in the diet of laying hens up to levels of 12 and 15% did not affect laying but significantly improved yolk color. Improved yolk color was also reported in hens fed a diet with tomato peel and seed by-products included at a level of 75 g/kg diet (Knoblich, Anderson, & Latshaw, 2005). Tomato powder supplemented in quail diets increased the total carotenoid concentration in the egg yolk of female quails, and its inclusion resulted in the transfer of lycopene to the egg (Karadas, Grammenidis, Surai, Acamovic, &

Sparks, 2006). The aim of the present study was to evaluate the effects of TP supplementation on the carcass characteristics, on perirenal fat (fatty acid profile), and on the chemical (pH, proximate composition, fatty acid profile, TBARS), physical (color and cooking losses) and sensorial (affective test) characteristics of rabbit meat.

Materials and methods

Animals and diets

The study was carried out at the experimental rabbitry of the Department of Agriculture, Forestry, and Food Sciences in Carmagnola (NW Italy). One-hundred and forty four weaned crossbred (Hycole × Grimaud) rabbits, 38 days old, with a mean weight of 1166 ± 13 g, were randomly assigned to three groups of 48 (50% male and 50% female rabbits each) with equal initial weight variability. The animals were single housed in wire cages at a height of 90 cm from the concrete floor at a temperature of 22 ± 2 °C and had free access to clean drinking water. Three isoproteic and isoenergetic diets were formulated with increasing levels of tomato (Solanum lycopersicum Mill.) pomace (TP) (0% TP, 3% TP, and 6% TP), which were obtained from a private tomato processing company (TOMATOFARM Srl) at Pozzolo Formigaro, Italy in July 2010. TP was ensiled for 2 months without any additive in a trench silo on a concrete floor and then dried in an oven at 60 °C until constant weight. All the diets were pelleted, stored in darkness to avoid auto-oxidation of the lipid sources and offered ad libitum. Individual body weights and feed intakes were recorded on a fortnightly basis during the experimental period, except for the last period, which lasted 8 days. The average feed consumption of each rabbit was used to calculate the individual feed/gain ratio. The performance and apparent digestibility have been previously reported (Peiretti, Gai, Rotolo, & Gasco, 2012). TP and diet samples were analyzed in duplicate for crude fiber according to the Weende method, crude protein (AOAC 955.04) and ether extract (AOAC 963.15) according to the methods of the Association of Official Analytical Chemists (1990), neutral detergent fiber (NDF) without sodium sulfite and α-amylase, and acid detergent fiber (ADF), as described by Van Soest, Robertson, and Lewis (1991) expressed exclusive of residual ash. Starch content was determined using the Ewer's polarimetric method (EEC, 1972). The total carotenoid (TC) content was determined as reported by Bono et al. (2012) with slight modifications. Briefly, 1 g of the dried material was homogenized for 30 s at full speed with 20 ml of acetone using a vortex (Heidolph REAX 2000, Germany). 10 ml of petroleum ether (BP 40–60 °C) was added to the acetone extract and then vortexed for 30 s. Ten milliliters of 0.1% NaCl was added to the acetone/petroleum ether mixture and then vortexed for 30 s. After centrifugation of the homogenate (6000 rpm for 10 min), the supernatant was removed and then evaporated under vacuum at room temperature using a Speedvac (SC210A, Savant Instruments, Farmingdale, NY). The resulting TC concentrate was taken up in chloroform and the absorbance of the appropriately diluted extract was measured at 450 nm using a Helios spectrophotometer (Unicam Limited, Cambridge, UK) against a reagent blank. The concentration of TC in the extract was quantified using a standard calibration curve at four concentration levels (1, 2, 4, 8 mg/l) utilizing a pure synthetic β-carotene standard (Sigma Aldrich srl, Milan, Italy) and then expressed as mg of β-carotene per g as fed basis. The gross energy (GE) was determined using an adiabatic bomb calorimeter (IKA C7000, Staufen, Germany).

Slaughter procedures and sample collection

At the end of the experimental period, which lasted 50 days, 10 rabbits per group were weighed and then slaughtered in an experimental slaughterhouse. The carcasses were prepared by removing the skin, genital organs, urinary bladder, digestive tract and the distal part of the legs, as recommended by Blasco, Ouhayoun, and Masoero (1993). The weights of the skin and paws and full gastrointestinal tract were recorded and expressed as a percentage of slaughter weight (SW). Carcasses (with head, thoracic cage organs, liver, kidneys) were chilled at +4 °C for 24 h in a refrigerated room. The chilled carcass weight (CCW), dressing out percentage (CCW as percentage of SW) and the ratio of liver, kidneys and thymus, trachea, heart and lungs (TTHL) were expressed as a percentage of CCW.

Meat quality analysis

Sample preparation

After chilling the carcasses were halved and the two longissimus dorsi (LD) muscles were excised. The left LD muscle was divided into two parts. The fore part was used to measure pH, color and cooking losses. The hind part of the left LD was vacuum-packed, frozen at− 20 °C and then freeze dried. Proximate composition, fatty acid profile and thiobarbituric-acid reactive substances (TBARS) values were determined on freeze-dried samples. The whole right LD was vacuum packed, frozen at −20 °C and stored until sensory analysis. The perirenal fat was vacuum-packed, frozen and stored at −20 °C for a week until gas chromatographic analysis.

pH measurement

Ultimate pH measurements (24 h) were taken in duplicate using a Crison portable pH meter (Crison Instruments, S.A., Alella, Spain) fitted with a spear-type electrode and an automatic temperature compensation probe. pH was determined at the level of the 7th lumbar vertebra. 2.3.3.

Color measurements

The color was measured on the surface of the LD muscle (10 mm thickness), at the level of the 7th lumbar vertebra, at 24 h post mortem, using a Minolta CR331C Colorimeter (Minolta Camera Co., Japan). The light source was D65 and a 2° standard observer was used. Color data were expressed in terms of Lightness (L*), redness (a*) yellowness (b*) in accordance with CIELAB color space (CIE, 1976). Chroma (C*), which is a measure of the color intensity, and hue angle (H*), which describes the fundamental color of a substance, were calculated as: (a*2 + b*2)0.5 and tan−1(b*/a*), respectively. The hue angle was converted from radians to degrees for data analysis. In order to define the extent of the total difference in meat color, the total color differences (ΔE*0-n) between the 0% TP and each other experimental groups were calculated as follows:

$$\Delta E^*_{0-n} = \left[(L^*_0 - L^*_n)^2 + (a^*_0 - a^*_n)^2 + (b^*_0 - b^*_n)^2 \right]^{0.5},$$

where L*0, a*0, and b*0 represents the meat color of 0%TP group and L*n, a*n, and b*n represent the meat color of 3% or 6% TP groups (AMSA, 1991).

Cooking losses

The raw samples were individually weighed, vacuum packaged in a plastic bag and cooked in a water bath at 80 °C for 1 h (Ramírez et al., 2004). The samples were then removed from the water bath, cooled under tap water, blotted and reweighed. Cooking losses were determined by calculating the weight difference in samples before and after cooking, expressed as percentage of initial weight.

Proximate analyses and gross energy

Proximate analyses were carried out according to the Association of Official Analytical Chemists (AOAC, 1990) methods. Tissue samples were weighed, dried at 125 °C for 5 h and reweighed to determine the water content. The samples remaining from the water analysis were placed into a furnace oven at 525 °C for 10.5 h for ash determination. The meat was further lyophilized and ground in a blender for analyses of protein and intramuscular fat. Nitrogen was determined by the Kjeldahl method using a Buchi System apparatus (Buchi Labortechnik, Flawil, Switzerland). The crude protein was then calculated by multiplying N × 6.25. Lipid extraction of intramuscular fat was determined by the Soxhlet method using a Buchi Extraction System (Buchi Labortechnik, Flawil, Switzerland).

TBARS assay

Lipid oxidation was determined on the LD muscle after 3 months of storage at −20 °C. The TBARS assay was modified from that of Witte, Krause, and Bailey (1970) and was performed for each meat sample in triplicate; 3 g of freeze-dried meat was homogenized for 30 s at high speedwith 20 mLof 10% trichloroacetic acid (TCA) using a Polytron tissue homogenizer (Type PT 10–35; Kinematica GmbH, Luzern, Switzerland). The supernatant was filtered through Whatman #1 filter paper. One millilitre of filtrate was combined with 1 mL of a 0.02 M aqueous 2-thiobarbituric acid solution (TBA), heated in a boiling water bath for 20 min together with a blank containing 1 mL of a TCA/water mix (1/1) and 1 mL of a TBA reagent and subsequently cooled under running tap water. The samples were analyzed in duplicate and the results were expressed as mg malonyldialdehyde (MDA) per kilogram of freeze dried meat, using a standard curve that covered the concentration range of 1 to 10 mM 1,1,3,3-tetramethoxypropane (Sigma-Aldrich, Steinheim, Germany). The absorbance was measured at 532 nm with a Helios spectrophotometer (Unicam Limited, Cambridge, UK) against a blank that contained all the reagents, but no meat.

Fatty acid determination

Lipid extraction was performed on the TP, the diets and the perirenal fat and LD muscle samples according to Peiretti and Meineri (2008). The FA content in the TP was the average of three replicates, while in the experimental diets it was the average of two replicates. The FA were analyzed as the methyl esters. The analysis was carried out by gas chromatography, using a Dani GC 1000 DPC (Dani Instruments S.P.A., Cologno Monzese, Italy), equipped with a fused silica capillary column — Supelcowax-10 (60 m × 0.32 mm (i.d.), 0.25 μm). The PTV injection and flame ionization detector (FID) ports were set at 245 °C and 270 °C, respectively. The oven temperature programme was set at 50 °C for the first min, increased at a rate of 5 °C/min to 230 °C, where it remained for 24 min. The carrier gas was hydrogen. One microlitre was injected using a Dani ALS 1000 auto sampler with a 1:50 split ratio. The peak area was measured using a Dani Data Station DDS 1000, and each peak was identified and quantified according to pure methyl ester standards (Restek Corporation, Bellefonte, PA, USA).

Consumer tests

The consumer evaluation consisted of 48 panellists, 33 males and 15 females, ranging in age from 21 to 60 years. Although the AMSA (1995) recommends a consumer panel size of at least 50 individuals, limitations in product sample size did not allow for this. Panellists were untrained students and staff members recruited from the campus of the University of Torino, and of the Italian National Research Council of Torino. All were already involved in surveys on rabbit preference/acceptability tests and were regular consumers of rabbit meat. The entire LD muscles from rabbits of the three groups were simultaneously cooked without salt or spice on a double plate grill, preheated at 250 °C, to a final internal temperature of 70 °C. Cooking temperature was monitored by an iron/constantan thermocouple placed in the geometric center of each loin. After grilling, the loins were immediately cut into equal sizes and coded with a three-digit random number. Meat samples arising from the three rabbit groups fed with 0%, 3%, and 6% TP, respectively, were given to the panellists in a predetermined balanced order and were evaluated in a preference ranking test. Panellists were asked to rank the samples in order of preference with 1 being the most preferred and 3 being the least preferred; ties were not allowed. Evaluation took place in individual booths in a sensory testing laboratory under controlled conditions. Between each sample, panellists were instructed to rinse their mouths with water served at room temperature.

Statistical analysis

The statistical analyses were performed using the SPSS software package (version 11.5.1 for Windows, SPSS Inc., USA). Analysis of variance was used to evaluate the effects of different concentrations of TP on the performance, carcass characteristics, meat composition and FA profile of the meat and fat of the rabbits. The differences were tested using Duncan's New Multiple Range Test. Significance was accepted for P b 0.05. The results of sensory analysis were analyzed by Friedman's test and R-index test. The Friedman rank sum was performed to determine whether the panellists were able to discriminate

between samples. Then, the least significant ranked difference values were calculated to ascertain which samples were significantly preferred to the others (Meilgaard, Civille, & Carr, 1999). The R-index measure the degree of difference between a standard or control sample, designed as the “noise” sample, and a comparison sample, designed as a “signal” or treatment sample, in terms of the probability of distinguishing between the two, if bothwere presented in a paired comparison (Bi & O'Mahony, 1995; O'Mahony, 1992). An R-index of 100% indicates that the samples are perfectly distinguishable, while an R-index of 50% indicates the samples cannot be distinguished. Significant differences between R-index values were determined using critical values published by Bi and O'Mahony (2007). The critical values for significance at P b 0.05 were 59.82% and 61.58% for one-tailed and two-tailed tests, respectively. This means that the R-index can deviate from a non detection value (50%) in 9.82% by chance. The R-indices were computed in two ways. Firstly, R-indices were calculated with reference to the 0% TP group. R-index expressed consumer preferences as a probability of preferring a experimental meat over the control meat. Secondly, R-indices were computed in a pairwise fashion, with R-index giving a measure of spacing between individual ranks in terms of choice probabilities.

Results and discussion

Composition and fatty acid profile of the TP and the diets

The ingredients and chemical composition of the TP and of the three diets are shown in Table 1 (data previously reported by Peiretti et al. (2012)).

Table 1
Ingredients and chemical composition of tomato pomace (TP) and experimental diets. (From Peiretti et al. (2012)).

	TP	Compound diets		
		0% TP	3% TP	6% TP
Ingredients (g/kg as fed basis)				
Alfalfa meal (17%CP)		290	270	250
Barley		190	190	190
Wheat bran		200	200	200
Dried beet pulp		140	140	130
Soybean meal (45%CP)		60	60	60
Sunflower meal (30%CP)		60	60	50
Tomato pomace		0	30	60
Molasse		15	15	15
Soybean oil		10	10	10
Corn gluten		10	10	10
Wheat straw		10	0	0
Corn meal		0	0	10
Vitamin–mineral premix[a]		10	10	10
Bicalcium phosphate		5	5	5
Chemical composition (g/kg as fed basis)				
Dry matter,	235	908	914	913
Crude ash,	12.9	61.8	60.3	58.4
Crude fiber	100.8	171.6	171.8	175.3
Ether extract	22.1	26.3	32.0	32.0
Crude protein	43.9	165.3	165.4	166.2
Neutral detergent fiber	13.1	366.3	354.3	348.7
Acid detergent fiber	12.4	208.7	195.7	193.3
Starch	1.9	153.0	221.3	229.3
Total carotenoids, mg/g	0.169	0.103	0.086	0.092
Gross energy, MJ/kg	5.6	17.2	17.0	17.4

[a] Per kg of diet: vitamin A 200 U, α-tocopheryl acetate 16 mg, niacine 72 mg, vitamin B_6 16 mg, choline 0.48 mg, DL-methionine 600 mg, Ca 500 mg, P 920 mg, K 500 mg, Na 1 g, Mg 60 mg, Mn 1.7 mg, Cu 0.6 mg.

The FA pattern of the TP and the three experimental diets are given in Table 2.

Table 2
Fatty acid contents (g/100 g of total FA) of the tomato pomace (TP) and experimental diets.

	TP[a]	0% TP[b]	3% TP[b]	6% TP[b]
C14:0	0.12	0.14	0.17	0.18
C16:0	14.11	12.93	13.62	13.63
C16:1	0.24	0.16	0.24	0.33
C17:0	0.14	0.22	0.20	0.09
C18:0	5.88	2.89	3.19	3.32
C18:1 n − 9	20.18	19.48	19.51	19.94
C18:1 n − 7	0.83	1.03	1.07	1.04
C18:2 n − 6	53.33	49.27	50.30	51.23
C18:3 n − 3	2.65	6.46	6.34	5.69
C18:4 n − 3	0.00	0.62	0.54	0.43
C20:0	0.40	0.31	0.30	0.30
C20:1 n − 9	0.12	0.38	0.37	0.35
C20:4 n − 6	0.00	0.29	0.28	0.00
Unidentified FAs	1.99	5.84	3.88	3.48

[a] Means of 3 replicates.
[b] Means of 2 replicates.

The lipid fraction of TP showed a high degree of unsaturation; in particular, linoleic acid (LA, C18:2n− 6) was the major unsaturated FA followed by oleic acid (OA, C18:1n− 9), as also reported by Cantarelli, Regitano-d'Arce, and Palma (1993) in tomato seed oil. Similar LA content (55% of total FA) was found by Lazos and Kalathenos (1988) in tomato processing wastes. Cámara, Del Valle, Torija, and Castilho (2001) studied the FA profile in TP, in which total unsaturated FA content was between 75% and 80%, corresponding to 53% PUFA and 23%MUFA. In their study no great differences were obtained from samples collected at different steps during tomato processing. The LA content in the experimental diets increased while α-linolenic acid (ALA, C18:3n − 3) decreased as TP inclusion increased (Table 2). The trend of ALA was opposite to those found in mixed feed with perilla (Perilla frutescens L.) seed (Peiretti, Gasco, Brugiapaglia, & Gai, 2011), chia (Salvia hispanica L.) seed (Peiretti & Meineri, 2008) and false flax (Camelina sativa L.) seed supplements (Peiretti, Mussa, Prola, & Meineri, 2007).

Carcass characteristics and meat quality

Carcass characteristics are reported in Table 3.

Table 3
Carcass characteristics (means ± S.E.; n = 10) of rabbits fed the experimental diets (% of tomato pomace – TP).

	0% TP	3% TP	6% TP
Slaughter weight (SW), g	2835 ± 28[a]	2969 ± 31[b]	2921 ± 44[ab]
Skin & paws, %SW	17.2 ± 0.32	17.3 ± 0.22	17.4 ± 0.41
Full gastrointestinal tract, %SW	16.2 ± 0.77	15.6 ± 0.35	16.2 ± 0.49
Chilled carcass weight (CCW), g	1699 ± 21[a]	1795 ± 17[b]	1741 ± 33[ab]
Dressing out, %	60.0 ± 0.67	60.5 ± 0.47	59.6 ± 0.53
Liver, % CCW	3.59 ± 0.14	3.49 ± 0.10	3.65 ± 0.16
Kidneys, % CCW	1.03 ± 0.03	0.96 ± 0.02	1.01 ± 0.03
TTHL, % CCW	1.95 ± 0.10	1.69 ± 0.07	2.17 ± 0.11

[a,b] Means in the same row with unlike superscripts differ (P < 0.05).

The only parameters that differed in the current study were SW and CCW, with higher SW and CCW values being found with a 3% TP diet. There were no significant differences in the dressing-out percentage and proportions of the organs and carcass parts of the rabbits between different experimental groups. These results agreed with those found by Sayed and Abdel-azeem (2009), who did not find any significant differences in the weight percentages of liver, kidneys, heart and lungs. The present results are also in accordance with those reported by Alicata, Bonanno, and Giaccone (1988) who found no differences in carcass yield between two groups fed a mixed ration based on barley without or with 20% TP partly replacing alfalfa meal. The dressing out percentage obtained in the present study are similar to those found by Sayed and Abdel-azeem (2009) in the carcasses of rabbit groups fed on diets containing 0, 10 and 20% TP and higher than those found in the rabbit group fed 30% TP. El-Razik (1996) studied the effect of replacing corn with TP (0, 5 and 10%) in growing rabbit diets on growth performance and carcass traits and concluded that TP can satisfactorily substitute corn grains Concerning pH_{24} in LD muscle, there was no significant differences among the three experimental groups (Table 4), which fell in the normal range for rabbit meat (Blasco & Piles, 1990).

Table 4
Longissimus dorsi muscle traits (means ± S.E.; n = 10) of rabbits fed experimental diets (% of tomato pomace – TP).

	0% TP	3% TP	6% TP
pH_{24}	5.74 ± 0.02	5.78 ± 0.05	5.71 ± 0.02
L*	56.1 ± 0.7	55.1 ± 0.6	56.9 ± 1.0
a*	2.78 ± 0.21	3.04 ± 0.39	3.81 ± 0.40
b*	3.76 ± 0.22[a]	3.46 ± 0.26[a]	4.54 ± 0.25[b]
C*	4.70 ± 0.26[a]	4.65 ± 0.42[a]	6.03 ± 0.28[b]
H*	53.5 ± 1.98	51.0 ± 3.59	50.7 ± 3.51
Cooking losses, %	31.8 ± 0.6	30.5 ± 0.7	29.3 ± 0.7

[a,b,c] Means in the same row with unlike superscripts differ (P < 0.05).
L*, a*, b*; C* and H*: color variables in meat.

These results are in agreement with the observation of Tedesco, Galletti, Rossetti, and Morazzoni (2005) who found that lycopene did not affect the ultimate pH of rabbit meat. Meat color parameters were not affected significantly by TP supplementation, with the exception of yellowness and chroma (Table 4). The effect of TP on meat color is not clear but could be related to its lycopene and β-carotene content. Dried tomato pulp dietary incorporation up to a level of 10% significantly improved carcass color without any adverse effect on growth in quail (Nikolakakis et al., 2003). Delta E* between 0%TP and TP supplemented groups, increased with increasing supplementation of TP in the diet. The 3% and 6% TP groups showed a color difference from the 0% TP group of 1.08 and 1.52, respectively. These differences were slight and obvious only to a trained eye according to the scale proposed by Abril et al. (2001). No significant differences were found in cooking losses among the three groups, even though there is a decreasing trend with increasing TP supplementation (Table 4). The chemical composition of the longissimus dorsi muscle was not significantly affected by the dietary treatment (Table 5).

Table 5
Chemical composition on fresh matter basis (%) and oxidative status (TBARS, mg malonyldialdehyde/kg freeze dried meat) of the *longissimus dorsi* muscle of rabbits (means ± S.E.; n = 5) fed experimental diets (% of tomato pomace – TP).

	0% TP	3% TP	6% TP
Moisture	74.7 ± 0.16	74.6 ± 0.14	74.8 ± 0.14
Protein	23.8 ± 0.27	23.8 ± 0.19	23.4 ± 0.17
Ether extract	0.88 ± 0.09	1.00 ± 0.11	0.68 ± 0.08
Ash	1.26 ± 0.02	1.30 ± 0.01	1.25 ± 0.02
TBARS	0.70 ± 0.07	0.81 ± 0.07	0.93 ± 0.04

In agreement with the results obtained in this work, Waheed (2005) showed that the chemical analysis of rabbit meat was not significantly affected by increasing the level of TP (0, 8, 16 and 24%). As far as the average TBARS values determined after three months storage at −20 °C are concerned, a slight, but not significant, increase with increasing TP supplementation was observed (Table 5). This could well be due to the reduction in total carotenoid content in the diet and/or to the increase in polyunsaturated fatty acid content in the rabbit tissues with increasing TP supplementation. No data were found to compare the effect of TP on the susceptibility to lipid oxidation in the LDmuscle of growing rabbits, but Tedesco et al. (2005) found that treatment with lycopene and green tea extract had positive effects on the oxidative status of rabbit meat. Botsoglou et al. (2004) analyzed the effect of dietary dried tomato pulp (containing lycopene and β-carotene at 281 and 24.3 mg/kg of dry weight, respectively) on the oxidative stability of Japanese quail (Coturnix coturnix) meat. They suggested that the inclusion of dried tomato pulp in feed at a level of 5% exerted an antioxidant effect on quail meat, whereas addition at a level of 10% exerted a pro-oxidant effect. In another study carried out on Japanese quails, lycopene supplementation at different doses (50, 100 and 200 mg/kg of diet) improved live weight gain, feed efficiency and carcass traits and exerted positive effects on antioxidant components. In particular, MDA levels in serum, liver, and heart linearly decreased in control and heat-stressed bird groups as dietary lycopene supplementation increased and lowered vitamin C, E and A concentrations were reversed when lycopene was supplemented in the diet of the quail heat-stressed groups (Sahin et al., 2006). King and Zeidler (2004) studied TP supplementation in chicken diets to determine whether α-tocopherol in the TP would retard. lipid oxidation in stored meat. They found that some combination of TP and α-tocopherol would

be beneficial to prevent lipid oxidation in stored unheated and heated poultry meat. TBARS values for the meat from poultry fed TP were significantly lower (30%) than the control when lipid oxidation was accelerated by heat and pro-oxidants. Doménech-Asensi et al. (2013) showed that the addition of TP improves the stability of mortadella during the shelf-life period by significantly reducing the lipid oxidation.

Fatty acid profile of the meat and perirenal fat

As expected, the FA profile of the meat and perirenal fat (Tables 6 and 7, respectively) was influenced by the FA composition of the diet, in fact the lipids of TP are poor in ALA (2.6%) but rich in LA (53.3% of total FAs).

Table 6
Fatty acid composition (g/100 g of total FA; means ± S.E.; n = 10) in the *longissimus dorsi* muscle of rabbits fed the experimental diets (% of tomato pomace – TP).

	0% TP	3% TP	6% TP
C14:0	2.34 ± 0.08	2.33 ± 0.09	2.13 ± 0.07
C15:0	0.54 ± 0.02[a]	0.46 ± 0.02[b]	0.42 ± 0.03[b]
C16:0	28.4 ± 0.50[a]	26.1 ± 0.49[b]	27.2 ± 0.39[ab]
C16:1n − 7	4.93 ± 0.36	5.09 ± 0.34	4.29 ± 0.42
C17:0	0.64 ± 0.08[a]	0.39 ± 0.04[b]	0.56 ± 0.03[a]
C18:0	6.25 ± 0.13	6.48 ± 0.17	6.28 ± 0.11
C18:1n − 9	24.1 ± 0.45	24.4 ± 0.40	23.8 ± 0.42
C18:1n − 7	1.33 ± 0.04	1.40 ± 0.04	1.37 ± 0.02
C18:2n − 6	24.3 ± 0.46[a]	26.7 ± 0.82[b]	26.9 ± 0.75[b]
C18:3n − 3	2.69 ± 0.13	2.44 ± 0.09	2.67 ± 0.08
C20:4n − 6	3.15 ± 0.32	2.82 ± 0.27	3.27 ± 0.24
Unidentified FAs	1.32 ± 0.17	1.34 ± 0.22	1.18 ± 0.16
SFA[A]	38.2 ± 0.7	35.8 ± 0.6	36.5 ± 0.4
MUFA[B]	30.4 ± 0.8	30.9 ± 0.7	29.5 ± 0.8
PUFA[C]	30.1 ± 0.5	31.9 ± 1.0	32.8 ± 1.0
n − 6/n − 3[D]	10.4 ± 0.6[a]	12.2 ± 0.3[b]	11.3 ± 0.3[ab]

[ab] Means in the same row with unlike superscripts differ (P < 0.05).
[A]SFA: saturated fatty acid.
[B]MUFA: monounsaturated fatty acid.
[C]PUFA: polyunsaturated fatty acid.
[D] n − 6/n − 3: PUFA n − 6/PUFA n − 3 ratio.

Table 7
Fatty acid composition (g/100g of total FA; means ± S.E.; n = 10) in the perirenal fat of rabbits fed the experimental diets (% of Tomato pomace - TP).

	0% TP	3% TP	6% TP
C10:0	0.21 ± 0.05	0.26 ± 0.05	0.21 ± 0.05
C12:0	0.28 ± 0.07	0.30 ± 0.04	0.25 ± 0.04
C14:0	2.54 ± 0.07[a]	2.26 ± 0.06[b]	2.27 ± 0.03[b]
C15:0	0.61 ± 0.02[a]	0.50 ± 0.02[b]	0.54 ± 0.02[b]
C16:0	27.0 ± 0.64[a]	24.1 ± 0.48[b]	24.9 ± 0.46[b]
C16:1n − 9	0.30 ± 0.01	0.30 ± 0.01	0.30 ± 0.01
C16:1n − 7	3.51 ± 0.20	3.39 ± 0.31	3.13 ± 0.36
C17:0	0.67 ± 0.02[a]	0.56 ± 0.02[b]	0.58 ± 0.02[b]
C17:1	0.35 ± 0.01[a]	0.29 ± 0.01[b]	0.31 ± 0.01[b]
C18:0	5.90 ± 0.11	6.24 ± 0.14	6.18 ± 0.16
C18:1n − 9	24.2 ± 0.38	24.1 ± 0.40	23.6 ± 0.35
C18:1n − 7	1.19 ± 0.04	1.23 ± 0.04	1.18 ± 0.02
C18:2n − 6	28.5 ± 0.55[a]	32.2 ± 0.87[b]	31.7 ± 0.93[b]
C18:3n − 3	3.65 ± 0.09[a]	3.33 ± 0.06[b]	3.68 ± 0.08[a]
C20:1n − 9	0.31 ± 0.02	0.30 ± 0.02	0.33 ± 0.01
C20:2	0.27 ± 0.02	0.29 ± 0.02	0.32 ± 0.02
Unidentified FAs	0.88 ± 0.11	0.95 ± 0.12	0.91 ± 0.10
SFA[A]	37.2 ± 0.7 [a]	34.2 ± 0.5[b]	35.0 ± 0.4[b]
MUFA[B]	29.9 ± 0.5	29.6 ± 0.7	28.9 ± 0.7
PUFA[C]	32.5 ± 0.6[a]	35.8 ± 0.9[b]	35.7 ± 1.0[b]
n − 6/n − 3[D]	7.84 ± 0.14[a]	9.65 ± 0.13[c]	8.61 ± 0.12[b]

[a,b,c] Means in the same row with unlike superscripts differ (P < 0.05).
[A]SFA: saturated fatty acid.
[B]MUFA: monounsaturated fatty acid.
[C]PUFA: polyunsaturated fatty acid.
[D]n − 6/n − 3: PUFA n − 6/PUFA n − 3 ratio.

As a consequence, the meat and fat of rabbits fed a diet containing TP had a higher proportion of LA than the tissues of rabbits fed a 0% TP diet. The increase in LA might be explained on the basis of the FA composition of the seed content of TP. These results are in agreement with those found by Alicata et al. (1988), comparing rabbits fed a TP diet with rabbits fed an alfalfa-based diet. As far as the saturated FAs (SFA) content was concerned, a decrease in the meat and perirenal fat with increasing TP inclusion level was found for C15:0, C16:0, C17:0, and total SFA, while no significant differences (P b 0.05) were detected among the treatments for C18:0. The most abundant MUFA (OA, C16:1n 7, and C18:1n − 7) and total MUFA content in the rabbit tissues did not show significant differences (P b 0.05) among the treatments. Botsoglou et al. (2004) showed that meat of Japanese quails fed 10% dried tomato pulp had a higher content oftotal PUFA and a greater unsaturated/saturated FA ratio compared to control. These authors found that the only statistically significant difference in the FA profile of breast meat among the dietary treatments was LA content, which increased linearly with the level of dried tomato pulp in the diet. In the present study, the n − 6/n − 3 ratio ranged from 10.4 and 7.8 in the meat and perirenal fat of the rabbits fed the 0% TP diet, to 12.2 and 9.7 in the meat and perirenal fat of the rabbits fed 3% TP. 3.4.

Consumer tests

Results of the consumer tests are summarized in Table 8.

Table 8
Preferences of meat expressed as Rank sums and as R-indices in terms of difference from Control and in terms of difference between adjacently ranked meat.

Meat	Rank sums	R-index (%), differences from control	R-index (%), differences between adjacent meat
Most preferred			
6% TP	83 a	65.36 *	
			61.72 *
3% TP	99 ab	55.47 ns	
			55.47 ns
0% TP	106 b	–	
Least preferred			

Ranks in the same column with different letters are significantly different ($P < 0.10$)

The preference test indicated that meat samples from rabbits fed with 6% TP were the most preferred (rank sum = 83), followed by meat from the 3% TP group (rank sum = 99) and from the 0% TP group (rank sum = 106). Data analysis found no significant differences between product ranks at 0.05 level (P b 0.05). A significant difference was found at 0.10 level. In this case, consumers were only capable of significantly differentiating between meat from the 6% TP group and meat from the 0% TP group which reached the highest rank sum. Because the meat from the 0% TP group was the least preferred, this group was chosen as the “noise” or control sample for R-index calculation. In this study, an R-index of 50% suggests that the consumer's preferences between two samples were close to chance, which means that the two samples were essentially identical in terms of preference. An R-index that is close to 100% indicates that one sample was strongly preferred over another. The meat from the 6% TP group was perceived to be significantly different from 0% TP (R-index = 65.36%) and preferred by consumers, while meat from the 3% TP group was no different from 0% TP (R-index = 55.47%). An R-index of 0.65 indicates that 65% of consumers would prefer the meat of 6% TP group and 35% would prefer the 0% TP group; whereas an R-index of 0.55 (3% TP meat) indicates that 55% of consumers would prefer the meat of the 3% TP group and 45% would prefer the 0% TP group. To highlight the differences between groups, the R-Indices were calculated pairwise indicating the spacing between ranks. Instead of control being the referent noise for every R-index calculation, the referent noise was always the adjacent sample. The consumers significantly differentiated only the meat from the 6% TP group from the 3% TP group. In this case the probability of choosing 6% TP group over 3% TP group in a paired preference test was 61.72% (P b 0.05). Similarly, according to our sensorial evaluations, tomato powder improved the consumer acceptability of beef frankfurter sausages added with tomato powder; its addition increased the internal and external color scores, and frankfurters were found to be more acceptable by the panellists (Eyiler & Oztan, 2011). Similar acceptability values were also found in low fat pork sausages added with tomato powder up to 1.5%. The scores of overall acceptability in tested groups were significantly higher than those of control samples after 30 days of refrigerated storage. García, Calvo, and Dolores Selgas (2009) found that taste and overall acceptability were significantly modified even when only 1.5% dry tomato peel (DTP) was added in raw beef hamburgers. The taste modifications found in hamburgers containing DTP were caused by the tomato flavor, which produced a taste different from the normal one expected for this meat product. Overall acceptability was significantly higher for control samples than for samples

containing DTP. Nevertheless, scores higher than 5were found in hamburgers containing up to 4.5% (w/w) DTP. By contrast, the results of the hedonic test carried out on dry fermented sausages enriched with lycopene from tomato peel did not show significant differences between samples for all parameters, although color significantly influenced preference, all samples showing good overall acceptability; in all cases, values were higher than 6 (Calvo, García, & Selgas, 2008).

Conclusions

It is concluded that TP can be fed to rabbits at levels of up to 6% of the diet without adverse effects on carcass characteristics and meat quality, with a higher preference for meat from rabbits fed TP diets than for meat from the 0% TP group. Moreover, the enrichment of the rabbit diet with TP allows the production of rabbit meat with a good degree of unsaturation and low saturation, which constitutes an important nutritional benefit to humans. Furthermore, our results indicate that a diet integrated with 6% TP or higher could positively affect the overall preference of meat. Further research is needed to clarify the metabolic mechanism of lycopene and β-carotene contained in TP. In addition, more specific studies on the effects of these antioxidants on meat quality should be carried out to evaluate the potential of TP in animal feeds.

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References

Abril, M., Campo, M. M., Önenç, A., Saňudo, C., Alberti, P., & Negueruela, A. I. (2001). Beef colour evolution as a function of ultimate pH. Meat Science, 58(1), 69–78.

Alicata, M. L., Bonanno, A., & Giaccone, P. (1988). Use of tomato skins and seeds in the feeding of meat rabbits. Rivista di Coniglicoltura, 25(1), 33–36.

AMSA (1991). Guidelines for meat color evaluation. Reciprocal Meat Conference Proceedings, 44, 1–17.

AMSA (1995). American meat science association & national livestock and meat board. Research guidelines for cookery, sensory evaluation and instrumental tenderness measurements of fresh meat. Chicago, IL: AMSA.

AOAC (1990). Official methods of analysis (15th ed.). Washington, DC, USA: Association of Official Analytical Chemists.

Bi, J., & O'Mahony, M. (1995). Table for testing the significance of the R-index. Journal of Sensory Studies, 10, 431–437.

Bi, J., & O'Mahony, M. (2007). Updated and extended table for testing the significance of the R-index. Journal of Sensory Studies, 22, 713–720.

Blasco, A., Ouhayoun, J., & Masoero, G. (1993). Harmonization of criteria and terminology in rabbit meat research. World Rabbit Science, 1, 3–10.

Blasco, A., & Piles, M. (1990). Muscular pH of the rabbit. Annales de Zootechnie, 39, 133–136.

Bono, G., Gai, F., Peiretti, P. G., Badalucco, C., Brugiapaglia, A., Siragusa, G., & Palmegiano, G. B. (2012). Chemical and nutritional characterization of the Central Mediterranean Giant red shrimp (Aristaeomorpha foliacea): Influence of trophic and geographical factors on flesh quality. Food Chemistry, 130, 104–110.

Botsoglou, N., Papageorgiou, G., Nikolakakis, I., Florou-Paneri, P., Giannenas, I., Dotas, V., & Sinapis, E. (2004). Effect of dietary dried tomato pulp on oxidative stability of Japanese quail meat. Journal of Agricultural and Food Chemistry, 52, 2982–2988.

Calvo, M. M., García, M. L., & Selgas, M. D. (2008). Dry fermented sausages enriched with lycopene from tomato peel. Meat Science, 80(2), 167–172.

Cámara, M., Del Valle, M., Torija, M. E., & Castilho, C. (2001). Fatty acid composition of tomato pomace. Acta Horticulturae, 542, 175–180.

Cantarelli, P. R., Regitano-d'Arce, M. A. B., & Palma, E. R. (1993). Physicochemical characteristics and fatty acid composition of tomato seed oils from processing wastes. Scientia Agricola, 50, 117–120.

CIE (1976). Recommendations on uniform colour spaces-colour difference equations, psychometric colour terms. Supplement no.2 to CIE publication no.15 (E-1.3.1) 1978, 1971/(TC-1-3). Paris, France: Commission International de l'Eclairage.

Del Valle, M., Cámara, M., & Torija, M. E. (2006). Chemical characterization of tomato pomace. Journal of the Science of Food and Agriculture, 86, 1232–1236.

Doménech-Asensi, G., García-Alonso, F. J., Martínez, E., Santaella, M., Martín-Pozuelo, G., Bravo, S., & Peragio, M. J. (2013). Effect of the addition of tomato paste on the nutritional and sensory properties of mortadella. Meat Science, 93, 213–219.

Dotas, D., Zamanidis, S., & Balios, J. (1999). Effect of dried tomato pulp on the performance and egg traits of laying hens. British Poultry Science, 40, 695–697.

EEC (1972). Analytical determination of starch. Official Journal of European Communities, L123/7 (Brussels: EEC).

El-Razik, W. A. (1996). Effect of substitution of tomato pomace for corn in growing rabbit diets on growth performance and carcass traits. Egyptian Journal of Rabbit Science, 6, 79–86.

Eyiler, E., & Oztan, A. (2011). Production of frankfurters with tomato powder as a natural additive. Food Science and Technology, 44, 307–311.

García, L. M., Calvo, M. M., & Dolores Selgas, M. (2009). Beef hamburgers enriched in lycopene using dry tomato peel as an ingredient. Meat Science, 83(1), 45–49.

Karadas, F., Grammenidis, E., Surai, P. F., Acamovic, T., & Sparks, C. (2006). Effects of carotenoids from lucerne, marigold and tomato on egg yolk pigmentation and carotenoid composition. British Poultry Science, 47, 561–566.

King, A. J., & Zeidler, G. (2004). Tomato pomace may be a good source of vitamin E in broiler diets. California Agriculture, 58(1), 59–62.

Knoblich, M., Anderson, B., & Latshaw, D. (2005). Analyses of tomato peel and seed by-products and their use as a source of carotenoids. Journal of the Science of Food and Agriculture, 85, 1166–1170.

Lazos, E. S., & Kalathenos, P. (1988). Composition of tomato processing wastes. International Journal of Food Science and Technology, 23, 649–652.

Meilgaard, M. C., Civille, G. V., & Carr, B. T. (1999). Sensory evaluation techniques (3nd Edition). : CRC Press.

Nikolakakis, I., Banakis, D., Florou-Paneri, P., Dotas, V., Giannenas, I., & Botsoglou, N. (2003). Effect of dried tomato pulp on the performance and carcass characteristics of growing quail. Archiv fur eflugelkunde, 67, 1–5.

O'Mahony, M. (1992). Understanding discrimination tests: A user friendly treatment of response bias, rating and ranking R-index tests and their relationship to signal detection. Journal of Sensory Studies, 7, 1–47.

Peiretti, P. G., Gai, F., Rotolo, L., & Gasco, L. (2012). Effects of diets with increasing levels of dried tomato pomace on the performances and apparent digestibility of growing rabbits. Asian Journal of Animal veterinary Advances, 7, 521–527.

Peiretti, P. G., Gasco, L., Brugiapaglia, A., & Gai, F. (2011). Effects of perilla (Perilla frutescens L.) seeds supplementation on performance, carcass characteristics, meat quality and fatty acid composition of rabbits. Livestock Science, 138, 118–124.

Peiretti, P. G., & Meineri, G. (2008). Effects on growth performance, carcass characteristics, and the fat and meat fatty acid profile of rabbits fed diets with chia (Salvia hispanica L.) seed supplements. Meat Science, 80, 1116–1121.

Peiretti, P. G., Mussa, P. P., Prola, L., & Meineri, G. (2007). Use of different levels of false flax (Camelina sativa L.) seed in diets for fattening rabbits. Livestock Production, 107, 192–198.

Ramírez, J. A., Oliver, M. A., Pla, M., Guerrero, L., Ariňo, B., & Blasco, A. (2004). Effect of selection for growth rate on biochemical, quality and texture characteristics of meat from rabbits. Meat Science, 67, 617–624.

Sahin, K., Onderci, M., Sahin, N., Gursu, M. F., Khachik, F., & Kucuk, O. (2006). Effects of lycopene supplementation on antioxidant status, oxidative stress, performance and carcass characteristics in heat-stressed Japanese quail. Journal of Thermal Biology, 31(4), 307–312.