Turkish Journal of Veterinary and Animal Sciences

http://journals.tubitak.gov.tr/veterinary/

Research Article

Turk J Vet Anim Sci
(2021) 45: 281-287
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doi:10.3906/vet-2004-114

Dried tomato pomace in rabbit nutrition: effects on carcass characteristics and meat quality

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Received: 22.04.2020 • **Accepted/Published Online:** 22.11.2020 • **Final Version:** 22.04.2021

Abstract: This study was conducted to assess the effect of dried tomato pomace (DTP) feeding on the carcass characteristics and the quality of the meat of growing rabbits. For this purpose, 54 weaned rabbits (40 days old) were divided into three equal groups and fed isoproteic and isoenergetic diets. The first group was the control group (CON), while the other two groups were fed 10 (DTP-10), and 20 (DTP-20) percent DTP for 6 weeks. Eighty-three-day-old rabbits were slaughtered then, the carcass characteristics, mechanical and sensorial tenderness of the meat were determined. Rabbits fed with DTP-10 had the highest final weight at slaughter (2100 g) and the highest hot and cold carcass yields. Whereas, the highest weight of full gastrointestinal tracts and liver were observed within the DTP-20. Besides, optical property showed that rabbits, which were fed DTP-10, provided the reddest meat. Interestingly, DTP ameliorated textural quality. Indeed, rabbit meat became more tender and appreciated by consumers. In conclusion, the incorporation of the DTP into the rabbit's ration has improved remarkably the rabbit meat quality. Thus, DTP can be fed to rabbits at levels of up to 20% of the diet.

Key words: Diet, longissimus dorsi, meat quality, rabbit

1. Introduction

Tomato pomace is the major solid waste stream from tomato paste processing, composed of skins, pulp, and seeds that are separated from the juice before evaporation. In Tunisia, the tomato processing factories generate about 35 thousand tons of by-products per year [1]. The nonuse of this by-product, available in large quantities and abandoned in nature, is a loss of valuable components. This valuable by-product of preserved tomatoes is a rich source of fiber, protein, fat and bioactive compounds that are endowed with significant antioxidant activity [2,3]. Because of its nutritive value, DTP can be used, as local food resources, in animal feeding. Dietary supplementation, such as DTP, may be a simple and convenient strategy to improve meat quality. Nowadays, the meat quality concept is changed. The consumer is interested in hedonistic quality, sensory properties, cooking easiness, and swiftness [4]. Moreover, The most important attributes of rabbit meat to consumers are colour, texture, and flavour [4]. Several studies investigate the effect of DTP on growth performance in the rabbit. It was claimed that tomato pomace can be incorporated into the rabbit diets with positive effects on zootechnical performances, carcass characteristics [5–7], and sensorial quality [8]. However, few studies focus on the meat quality and little information is available on the effect of DTP on the meat quality, especially texture. Therefore, the objective of this study was to test the impacts of different levels of DTP (*Solanum lycopersicum* L.) inclusions in the rabbit diet on the carcass characteristics and the mechanical and sensorial tenderness of the meat.

2. Materials and method

2.1. Animals, diets and experimental design

The study was carried out at the experimental rabbitry of the Department of Animal Production of the National Agronomic Institute of Tunisia (INAT). Fifty-four weaned rabbits of 40 days old crossbreed (New Zealand × Californian) were randomly divided into three groups of eighteen weighing 892 ± 11 g as initial body weight.

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Rabbits were housed in four cages containing four and one cage containing two rabbits for each treatment. Cages were wire (76 × 48 × 30 cm height). The temperature in the rabbitry was 24 ± 3 °C. Rabbits had free access to clean water. The experience lasted 42 days. Two groups were fed diets with DTP-10 and DTP-20. The third one was CON. All diets were isoproteic and isoenergetic and they were fed ad libitum. The tomato was obtained from a private tomato processing factory in Tunisia in August 2015. The tomato pomace, obtained from a private tomato processing factory (Sicam, Sirroco, Tunisia), was air-dried, ground, and thoroughly mixed with other ingredients and pelleted in the food by-product enhancement company (SABA, Monastir, Tunisia).

2.2. Chemical proximate analysis

The proximate composition of the DTP and diets was analyzed as per the procedure of AOAC [9]. Dry matter (DM) content was determined at 103 °C for 24 h according to AOAC [9]. Ash content was determined by ignition to 550 °C, Crude Protein (CP) was determined by the Kjeldahl method using a Behr System, apparatus (behr Labor-Technik, Düsseldorf, Germany), and ether extract (EE) was determined by the Soxhlet method using a Foss extraction system (FOSS, Hilleroed, Denmark). The digestible energy (DE) was estimated based on chemical analyses as described by Lebas [10] following Eq. (1):

$$\mathrm{DE} = 15.627 + 0.001\mathrm{CP}^2 + 0.040\mathrm{EE}^2 - 0.011\mathrm{Ash}^2 - 0.169\ \text{Acid Detergent Fiber} + 1.250\,\frac{\mathrm{MJ}}{\mathrm{Kg}}\,\mathrm{DM} \qquad (1)$$

All measurements were performed in triplicate.

2.3. Slaughter procedures and sample collection

At the end of the experiment, at 83 days of age, six rabbits per group, chosen randomly, were weighed and then slaughtered according to the halal slaughtering procedure in a slaughterhouse in the experimental rabbitry of INAT. After complete bleeding, carcasses were weighed. Dissection and cutting were carried out according to the method of Blasco et al. [11]. Skin, genital organs, urinary bladder, digestive tract, and the distal part of the legs were removed. Then, the weight of the hot carcass was calculated. The weights of the skin, paws, and tail, and digestive tract were recorded and expressed as a percentage of slaughter weight (SW). Carcasses were chilled at +4 °C for 24 h and then the chilled carcass weight (CCW), head, liver, kidneys and thymus, trachea, heart, and lungs (TTHL) were recorded and expressed as a percentage of CCW.

2.4. Meat analysis

2.4.1. Sample preparation

After chilling, the carcasses were divided. The rear middle part was frozen at –20 °C to determine cooking losses and texture. The right thigh was used to measure pH and colour. The left one was used to evaluate sensory analysis.

2.4.2. pH measurement

Ultimate pH measurements (24h) were taken in triplicate using a portable pH meter (HI 8424 Microcomputer, Hanna Instruments, Woonscoket, RI, USA) by directly inserting the electrode into the muscles.

2.4.3. Colour measurements

The colour of the thigh was measured in triplicate at the slaughter day after 24 h postmortem using a chroma meter (Konica Minolta CR-410, Konica Minolta Sensing Inc., Osaka, Japan) in the system lightness (L*), redness (a*), and yellowness (b*) [12]. L*, a* and b* were recorded as colour data.

2.4.4. Cooking losses

Longissimus dorsi (LD) samples of each treatment were weighed individually, vacuum packed in a plastic bag, and then cooked in a water bath at 80 °C for 1 h [8]. Then, the samples were cooled under tap water for 10 min and reweighed. The cooking losses were determined as follows Eq. (2):

$$\text{Cooking losses} = \frac{(\text{mass of raw sample} - \text{mass of cooked sample})}{\text{mass of raw sample}} \times 100 \qquad (2)$$

2.5. Texture analysis

The tenderness of rabbits' meat was measured on the LD muscle. The analysis was performed on the raw and cooked samples. A shear test was performed by a TA.XTplus Texture Analyzer, (Stable Micro Systems, Godalming, UK), previously calibrated with masses of 2000 and 5000 g, and connected to a computer. The blade (HDP/BSK, Blade Set Guillotine) was programmed to penetrate the meat at a depth of 10 mm, at a speed of 2 mm/s for raw samples, and at a speed of 100 mm/min for cooked samples. The results were presented in the form of curves. The analysis of these curves gives the maximum shear force, which represents the ordinate of the maximum peak of the curve, and the work provided (area) given by the numerical calculation of the area under the curve.

2.6. Tasting test

After 3 days of slaughter, nine selected and trained consumers (male and female) have evaluated the different rabbits. The panel was made up of INAT students, consumers of rabbit's meat. They evaluated through the rating test, the tenderness, the juiciness, the colour, the flavour, the smell and gave their overall appreciation. The tasting sample was the left thigh, cooked without any additive (salt or spices) in an oven at 240 °C for 45 min. After cooking, the thigh is divided into equal sizes and coded with a random number. The distribution of the samples was carried out: each taster received a plate containing three pieces of meat from the three different groups. The tasters were invited to observe and taste the samples, in order to note them on a scale ranging from 0 (the lowest note) to 10 (the most pronounced note). The rating test was performed in the sensory assessment room apartment of INAT. Panelists were called to rinse their mouths with water between each sample.

2.7. Statistical analysis

The statistical analyses were performed using the IBM SPSS software package (version 23.00 for Windows; IBM Corp., Armonk, NY, USA). To evaluate the effects of different levels of DTP on the carcass characteristics, texture and tasting analysis of the rabbit meat, data were subjected to one-way analysis of variance (ANOVA) and means were separated by Duncan test ($P < 0.05$).

3. Results

The ingredients and chemical composition of the DTP and of the three diets are shown in Table 1 (data previously reported by [7]).

3.1. Carcass characteristics

Carcass characteristics and carcass yields were registered in Tables 2 and 3, respectively. As can be depicted in Table 2, the values of carcass parts were affected by the experimental rations. Rabbits receiving DTP-20 recorded the highest values of paws and tail ($P < 0.05$), full gastrointestinal tract ($P < 0.05$) and liver ($P < 0.05$). Nonetheless, they recorded the lowest skin values ($P < 0.05$). There were no significant differences in the slaughter weight, the kidney percentage, and the TTHL percentage. Rabbits fed with DTP-10 recorded the highest hot, cold, and reference carcass yields ($P < 0.05$) compared to the group fed with DTP-20 (Table 3).

3.2. Postmortem measurement

The pH is an important indicator of meat quality. pH values were reported in Table 4. There were no significant differences regarding pH24h for the different experimental groups (Table 4).

The colour plays a key role in the appearance, presentation, and acceptability of rabbit meat. Colour parameters were described in Table 4. The DTP inclusion had a significant positive effect on the luminance and the redness ($P < 0.05$). In fact, DTP-10 intake increased meat lightness and meat redness. In addition, yellowness was influenced by the incorporation of DTP. The more the rate

Table 1. Ingredients and chemical composition of the DTP and the experimental rabbits' diets.

Item	Diets			
	DTP	CON	DTP-10	DTP-20
Ingredients (%) Corn		34.17	39.06	43.95
Soybean meal		14.77	14.00	13.23
Dehydrated alfalfa		42.34	30.11	17.87
Dehydrated tomato pomace		0.00	10.00	20.00
Soya oil		3.02	1.56	0.10
Salt		0.50	0.50	0.50
DL-methionine		1.20	0.77	0.35
Premix		4.00	4.00	4.00
Proximate composition (% of DM[1]) DM	90.89	88.79	88.57	87.85
Ash	7.44	11.58	9.84	9.77
EE	4.7	25.77	4.08	3.44
CP	16.29	17.75	17.65	17.65
NDF	45.98	33.46	30.66	28.05
ADF	43.35	13.16	16.68	18.14
ADL	38.33	11.36	13.27	13.35
DE[2] (MJ/KgDM)	9.27	13.59	13.33	13.08
Polyphenols [GAE[3] (mg/g)]	214.75	32.16	26.51	17.85

[1]DM: dry matter, [2]DE: digestible energy calculated as: $15.627 + 0.001\ CP^2 + 0.004\ EE^2 - 0.011\ MX^2 - 0.169\ ADF + 1.250$ MJ/kgDM, [3]GAE: gallic acid equivalents (GAE) per g of dry weight, DTP: dried tomato pomace, CON: control group, DTP-10: dried tomato pomace 10%, DTP-20: dried tomato pomace 20%, EE: ether extract, CP: crude protein, NDF: neutral detergent fiber, ADF: acid detergent fiber, ADL: acid detergent lignin.

Table 2. Carcass characteristics of the rabbits fed the experimental diets.

Item	Diets				
	CON	DTP-10	DTP-20	SEM	P-value
Slaughter weight (g)	2001	2100	2065	22.10	0.185
Skin (%SW[1])	13.35[a]	13.04[b]	12.23[c]	0.12	0.000
Paws and tail (%SW)	4.05[b]	4.06[b]	4.36[a]	0.05	0.002
FGT[2] (%SW)	16.24[b]	17.19[c]	18.69[a]	0.25	0.000
Chilled carcass weight (g)	1363 [a]	1270[b]	1185[c]	19.75	0.000
Liver (%CCW[3])	3.82[b]	3.93[b]	4.10[a]	0.03	0.000
Kidneys (%CCW)	1.01	1.01	0.99	0.02	0.786
TTHL[4](% CCW)	1.68	1.60	1.54	0.04	0.289

[1]SW: slaughter weight, [2]FGT: full gastrointestinal tract, [3]CCW: chilled carcass weight, [4]TTHL: thymus, trachea, heart and lungs.
a; b; c: Means in the same row with unlike superscripts differ (P < 0.05).

Table 3. The effect of the incorporation of DTP at different rates on the rabbits' carcass yields.

Item	Diets				
	CON	DTP-10	DTP-20	SEM	P-value
Hot carcass yield (%)	61.31[a]	62.21[b]	60.39[c]	0.21	0.000
Cold carcass yield (%)	58.39 [ab]	59.31[a]	57.21[b]	0.31	0.009
Reference carcass yield (%)	50.03[a]	50.77[a]	48.52[b]	0.32	0.006

a; b; c: Means in the same row with unlike superscripts differ (P < 0.05).

of incorporation of DTP is increasing, the more the colour of the rabbit meat is becoming yellow.

3.3. Texture and cooking losses

3.3.1. Texture

Two texture parameters have been studied and recorded in Table 5. The maximum shear force represents the highest peak of the curve. The work represents the area under the shear curve of raw and cooked meat. As shown in Table 5, the maximum shear force of raw and cooked meat LD samples decreased significantly with the adding of DTP into the rabbit's ration (P < 0.05). Moreover, Table 5 clearly showed that the inclusion of DTP-20 in the rabbit's ration has significantly decreased the work provided by the raw and the cooked LD compared to the other groups. The texture variables showed that the tenderness of the rabbit's meat was favoured by the addition of the DTP in the rabbit's diet for the raw and the cooked meat. In fact, the maximum shear force estimates the meat's hardness due to the collagen presented in it. The total work provided during the deformation gives an idea of the degree of meat's maturation.

3.3.2. Cooking losses

The cooking losses inform about the water retention of rabbit meat. The more the cooking loss decreases, the more the water retention increases. As far as the cooking loss was concerned, a decreasing propensity in the meat with a DTP-10 inclusion level was observed (Table 6). During cooking, the meat from rabbits fed with DTP-10 has preserved their juiciness and subsequently their tenderness compared to CON. This result correlated with shear force measurements, presented above (Table 5).

3.4. Sensory analysis

Sensory properties are the main criteria that influence consumer choice, particularly with regard to meat tenderness and flavour. The sensorial parameters were defined in Table 6. There was no significant difference in sensorial parameters. The hedonic test showed no significant effect of the treatment on the consumers' preferences (data not shown). Table 6 revealed that the meat of rabbits fed with DTP-10 was more tender and juicy than those of the other groups. Moreover, the inclusion of DTP-10 in the rabbit's diet gave the meat the most pronounced

Table 4. Thigh traits of rabbits fed with different levels of DTP.

Item	Diets				
	CON	DTP-10	DTP-20	SEM	P-value
pH24	5.42	5.47	5.47	0.04	0.827
L*	56.96^{b}	60.50^{a}	58.95^{a}	0.47	0.002
a*	11.94^{b}	13.21^{a}	12.16^{b}	0.16	0.000
b*	6.12^{b}	6.23^{b}	7.72^{a}	0.24	0.002

a;b: Means in the same row with unlike superscripts differ ($P < 0.05$).

odour. Nevertheless, the meat from the group consuming DTP-20 recorded the palest colour compared to the other groups. This was confirmed by colour measurements that indicated that meat's yellowness was the highest at a level of DTP-20. The flavour was comparable.

4. Discussion

4.1. Carcass characteristics

The inclusion of DTP did not affect SW, kidney percentage, and TTHL percentage. [5] reported similar behavior. However, [8] and [13] did not find any significant differences in the proportions of various carcass parts and organs of the rabbits fed with tomato pomace and chia seed.

The highest cold carcass yield recorded for rabbits fed with DTP-10 maybe related to the decrease in neutral detergent fiber (NDF) content in the experimental diets. In fact, according to [14], decreasing NDF in the rabbit rations from 35% to 32% improves carcass yield. Moreover, according to [15], the increase of the cold carcass yield maybe assigned to the difference in body gains between different treatments and to the high nutritive value of the tomato pomace. This result was in accordance with that recorded by [8] for rabbits fed with diets that contained 0, 3, and 6% ensiled tomato pomace. However, the values of carcass yield are higher than those found in other experiments [5,6]. This difference may be due to the breed, age, and amount of fat.

Hence, carcass yield, which is economically important for the rabbits' manufacturers, seemed to be improved with DTP-10 inclusion.

4.2. Postmortem measurement

pH24h did not differ between experiment groups, which was the same result concluded by [8] who found that tomato pomace feeding did not touch on the ultimate pH of the rabbit meat fed with ensiled tomato pomace. Muscle ultimate pH influences meat quality. It is related to the rate of glycogen breakdown and the liberation of lactate postslaughter. Besides, pH affects the tenderness of cooked meat. pH24 is a little lower than 6. This was considered to be necessary for good meat quality. A pH greatly lower than 6 (e.g., 5) would make the meat too firm and dry because water holding capacity would decrease [16].

The redness was enhanced by the addition of DTP in rabbit rations. This parameter increased by 10.63% and 1.84% for rabbits fed with DTP-10 and DTP-20 respectively compared to CON. This result could be due to a change in myoglobin presentation, which is the pigment responsible for meat colour [17]. This result is in line with [8], who worked on ensiled tomato pomace and who found a significant difference only in yellowness. In another feeding trial carried out on laying hens, egg yolk colour score was significantly affected by tomato pomace for the laying hens consuming 15% tomato pomace compared to those fed 8% and to the control [18].The meat colour

Table 5. Variation of the texture of the raw and cooked rabbits' LD muscles at different treatments.

Item	Diets				
	CON	DTP-10	DTP-20	SEM	P-value
Raw LD Maximum shear force (N)	33.14^{a}	22.44^{b}	22^{b}	1.30	0.000
Area (N, sec)	31.86^{a}	30.68^{a}	25.40^{b}	0.77	0.000
Cooked LD					
Maximum shear force (N)	31.91^{a}	23.92^{b}	20.23^{c}	1.24	0.000
Area (N, sec)	59.65^{a}	54.39^{b}	47.88^{c}	1.30	0.000

LD: longissimus dorsi.
a; b; c: Means in the same row with unlike superscripts differ ($P < 0.05$).

Table 6. The average sensory scoresof the rabbit's meat between the experimental groups and cooking losses.

Item	Diets				
	CON	DTP-10	DTP-20	SEM	P-value
Colour	7.33	7.67	5.67	0.605	0.367
Odour	4.83	7.67	6.00	0.731	0.293
Juiciness	9.00	9.17	8.83	0.768	0.986
Tenderness	8.33	9.67	9.00	0.816	0.813
Flavour	9.50	8.83	9.67	0.662	0.872
Cooking losses	27.35	26.79	27.46	0.2901	0.712

depends on the level of myoglobin, oxido-reduction, the degree of oxidation of iron atoms, and on a possible denaturation of globin [16].

4.3. Texture and cooking losses

Incorporating DTP in rabbits' diets affect the tenderness. The findings indicate that DTP was effective in increasing tenderness. A linear increase was observed with increasing dietary inclusion of DTP. Tenderness, which is an important food texture attribute, is the main evaluation parameter in the meat field. It has also been a criterion used for meat consumption. It informs about shear force during processing. The shear force measures the tenderness of the meat in an objective way [19]. This test measures the force (Newtons) needed to shear a piece of meat. A lower shear force implies more tender meat.

From an extensive review of the literature, there has been no recorded data about the effect of the tomato pomace on the rabbit's meat texture. It is worthy to point out that, meat tenderness is associated with many factors involving chemical composition and structural muscle changes, diet, protein breakdown preslaughter stress, and carcass refrigeration conditions, processing time, and especially diet [20]. It also varies between species and race, between different muscles, and at different distances from the muscle surface due to temperature gradients when converting muscle to meat [20]. The mechanical tenderness evolution of the meat, after cooking, results from the relative contribution of two components (myofibrillar and conjunctiva) and their interaction [21].

The inclusion of DTP decreased the cooking loss of rabbit meat. Similarly, [8] raised the same result. This noticeable DTP effect on cooking loss can be attributed to the increase in pH values [22]. The reduction of the cooking loss can only be requested by the consumers. On the other hand, the increase in cooking loss contributes to unacceptable products due to nutrient loss. An increasing propensity in the meat with a DTP-20 inclusion level may be explained by the difference in protein denaturation rate between different groups [23]. The pale colour of meat samples from rabbits fed with DTP-20 reflected this denaturation [22]. Besides, the rabbit meat showed that juiciness and cooking loss are negatively correlated. Overall, these results lead to the conclusion that DTP incorporation in the rabbit diet ameliorates the carcass yield, induces better water and nutrient retention, and improves tenderness.

4.4. Sensory analysis

The sensory evaluation of colour, flavour, odour, tenderness, and juiciness showed no statistically significant differences with a tendency to consider meat from DTP-10 as the most tender, juicy, and having the most pronounced odour and colour. These results suggest that the inclusion of DTP in the rabbit's diet imprints a change in the sensory qualities of rabbit meat, however, this effect does not make a significant change in its overall liking and attributes. The myoglobin protein is responsible for meat colour. This macromolecule containing heme continues to react in myofibre postmortem sarcoplasm. The amount and redox stability of myoglobin affect its perceived colour, and its properties are influenced by several factors endogenous and exogenous to meat such as temperature, species, race, sex, age, type of muscle, and especially nutrition [24]. Rabbit meat is delicately flavoured according to Lawrie and Ledward [24].

The obvious conclusion to be drawn is that the incorporation of DTP in rabbit diets is beneficial for meat quality. Meat quality attributes, which are crucial for the consumer's choice were evaluated, in terms of appearance (colour) and texture (tenderness): DTP seems to improve the redness and tenderness of rabbit's meat. Moreover, DTP increases hot and cold carcass yields obtained from rabbit feeding DTP-10. The incorporation of a rate of DTP-10 gives better quality. Hence, further research is needed to understand the lycopene effect on sensory and textural quality. Besides, it is necessary to understand the phytochemical metabolism in the rabbit and the effect of these dietary compounds on human health.

Acknowledgments

The authors are thankful to GICA for the raw material supply and to Mrs. Hafawa Samti and Mrs. Nahla Fitouhi for the technical support.

Disclaimer/conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper. This research was supported by the National Agency for the Promotion of Scientific Research.

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