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Physicochemical Properties and Shelf-Life of Regular-Fat Sausages with Various Levels of Grape Tomato Powder Prepared by Different Drying Methods

Zhuang Zhuang Qiu and Koo Bok Chin*

Department of Animal Science, Chonnam National University, Gwangju 61186, Korea

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*Corresponding author : Koo Bok Chin
Department of Animal Science, Chonnam
National University, Gwangju 61186, Korea
Tel: +82-62-530-2121
Fax: +82-62-530-2129
E-mail: kbchin@chonnam.ac.kr

*ORCID
Zhuang Zhuang Qiu
<https://orcid.org/0000-0002-1501-2034>
Koo Bok Chin
<https://orcid.org/0000-0002-8062-6331>

Abstract This study was aimed to investigate the physicochemical properties, texture, and antioxidant, and antimicrobial activities of regular-fat sausages (RFSs) mixed with 0.25 and 0.5% of oven-dried and freeze-dried grape tomato powder (GTP, 150 μ m) during storage at 4°C. RFSs were made by six treatments that included: control (CTL), REF (sausages with 0.1% ascorbic acid alone), F1GTPSs (F1) and F2GTPSs (F2) (sausages with 0.25% and 0.5% freeze-dried GTP), and O1GTPSs (O1) and O2GTPSs (O2) (sausages with 0.25% and 0.5% GTP oven-dried at 100°C). Sausages with added oven-dried grape tomato powders (OGTPs) showed decreased pH, lightness (L^*), total plate count (TPC), and thiobarbituric acid-reactive substances (TBARS) compared to the sausages mixed with freeze-dried GTP (FGTPSs), but also had the highest redness (a^*) and yellowness (b^*) values among the treatments. With increasing levels of GTP, the hardness and chewiness of the sausages gradually decreased and these were decreased more in the FGTPSs (F) than in the OGTPSs (O). Compared to the FGTPSs, OGTPSs had higher antioxidant and antimicrobial activities, which extend the shelf-life of meat products. Application of OGTP to RFSs resulted in higher lipid antioxidant, antimicrobial activities, improving physicochemical properties and extended the shelf-life.

Keywords grape tomato powder, physicochemical and textural properties, antioxidant and antimicrobial activities, regular-fat sausages

Introduction

Fresh and processed tomatoes are rich sources of bioactive compounds, including carotenes (lycopene, β -carotene), ascorbic acid, flavonoids, flavone, tocopherol, and phenolic compounds, and tomatoes are the most consumed vegetable in the world (Frusciante et al., 2007). Studies have reported that increased consumption of tomatoes prevents the incidence of chronic degenerative diseases, such as certain types of cancer and cardiovascular diseases (Giovannucci, 1999; Omoni and Aluko, 2005). Among the

bioactive compounds in tomato, lycopene is the major carotenoid compound, which gives the red color to the fruit and has been shown to exert strong antioxidant activity and high physical quenching rate constant with singlet oxygen (Agarwal and Rao, 2000; Mascio et al., 1989).

Grape tomatoes are convenient to eat, which taste sweet and flavorful, and could be regarded as a good source of lycopene and vitamins (Simonne et al., 2008). However, grape tomatoes have a high water loss because of their small size and they contain high concentration of sugar and acid, which is major contribute to the acceptable flavor and consumption (Cantwell et al., 2009). Taveira et al. (2010) studied on antimicrobial agent of *Lycopersicon esculentum* seeds, and they reported that extracts of tomato seeds displayed antimicrobial activities about gram-positive bacteria and fungi.

There were not many papers to report the differences between big tomato and grape tomato. However, many differences in chemical composition have been reported between traditional varieties (big tomatoes) and the new small-sized varieties (cherry tomatoes), which were characterized by higher dry matter and a soluble solid fraction, essentially due to the higher levels of sugars and organic acids (Muratore et al., 2005; Picha, 1986). Muratore et al. (2005) evaluated the chemical composition about various small-sized tomatoes, and they found that the level of polyphenols compounds in small-sized tomatoes was higher than those in normal-sized ones due to the greater skin/volume ratio (Muratore et al., 2005). They also reported that grape tomatoes had higher phenolic substances and lycopene contents than those of cherry tomatoes and simultaneously, sugars and health-promoting components (ascorbic acid, phenolic compounds and carotenoids) of grape tomatoes are displayed with high amounts (Muratore et al., 2005). Grape tomatoes, which are about half size of cherry tomatoes, are meatier, thicker skin, less watery, and less sweetness than cherry tomatoes (Christine, 2014).

There were many processes for the manufacture of food powders. Drying is the typical process for fruits and vegetables, since drying fruits and vegetables lead to water removal, which retards the growth of spoilage microorganisms, as well as the occurrence of enzymatic or non-enzymatic browning reactions in the material matrix, preserving the structure, sensory characteristics and nutritional value of the starting material for long periods (Aguilera, 2003; Argyropoulos et al., 2011; Zhang et al., 2006). However, drying has adverse effects on the final product quality, such as tissue browning and remarkable changes in the flavor profile (Lewicki et al., 2002). Among the drying methods, freeze-drying removes water from a frozen material mainly by sublimation to preserve the product quality (Ratti, 2001). However, this process is slow and requires expensive equipment, such as freeze-dryers (Utpal et al., 2014). Thus, it is rarely used for the preservation of cultivated grape tomatoes and is used for precious wild edible species and medicinal species (Bhatta et al., 2020). Oven-drying reduces the vitamin C content and increases the water-soluble, R-tocopherol, and Trolox analog antioxidant content (Lavelli et al., 1999). Phenolics in tomatoes remain stable under high temperature and contribute to the high level of antioxidant activity (Dewanto et al., 2002).

The improvements in the antioxidant activity, resulting in the extended shelf-life of meat and meat products, were reported by Kim and Chin (2016). Presently, consumers have become more conscious of healthy foods with decreased fat, salt, and cholesterol content in meat and meat products, as well as vegetables and fruits rich in dietary fiber (Yang et al., 2007). Enhancements of meat and meat products with vegetables, fruits, and their fibers could reduce production costs and improve the technological and nutritional quality of the products (Serdaroğlu et al., 2018). Grape tomato is one of the most important types of tomatoes for fresh consumption and its consumption grows every year due to the flavor (perfect sugar to acid balance for a rich), sweetness, hearty skin, high yield, and potential health benefits (Coker et al., 2018). In addition, grape tomatoes are different from traditional variety. Tomatoes dried at high temperatures displayed decreases in lightness and increased redness and yellowness because of a series of pigment degradation reactions (Ashebir et al., 2009). Simultaneously,

antioxidant activities were reportedly increased because the drying technique increased the percentage of total phenolic compounds, total flavonoids, and lycopene content (Dewanto et al., 2002). Therefore, the objective of this study was to investigate the physicochemical properties, as well as the antioxidant and antimicrobial activities of regular-fat sausages (RFSs) to which grape tomato powder (GTP) prepared by different drying methods was added.

Materials and Methods

Grape tomato powder preparations

Grape tomatoes were purchased from the local market and washed, chopped, and homogenized before drying by a freeze-dryer (FT5505, Ilshin, Daejeon, Korea) at -50°C and 7 mm Torr vacuum and a hot, dry oven (LDO-250F, Labtech, Jeonju, Korea) at 100°C (Kim and Chin, 2016), respectively. The time and yield of freeze-drying and oven-drying at 100°C were 72 h and 9 h, and 9.59% and 8.2%, respectively. Then, the powder was sieved by two particle sizes ($\geq 300\ \mu\text{m}$, $\leq 150\ \mu\text{m}$) and stored at -70°C .

Preparation of cooked pork regular-fat sausages

Pork ham and back fat were purchased from the local market (Samho, Gwangju, Korea). After 60% lean meat and 20% fat were ground by an M-12s grinder (Fujee Plant, Busan, Korea), they were mixed with non-meat ingredients (18% ice water, 1.3% salt, 0.4% sodium tripolyphosphate (STPP), 0.25% cured blend, 0.05% sodium erythorbate, 0.1% ascorbic acid, and different kinds of tomato powder) (Table 1). Then, approximately 40 g of the meat batter was stuffed into 50 mL of centrifuge

Table 1. Formulation of pork regular-fat sausages with different drying methods and levels of grape tomato powders

Ingredient (%)	Treatments					
	Control	Reference	F1	F2	O1	O2
Raw meat	60.0	60.0	60.0	60.0	60.0	60.0
Fat	20.0	20.0	20.0	20.0	20.0	20.0
Water	18.0	18.0	18.0	18.0	18.0	18.0
Non-meat ingredient	2.0	2.0	2.0	2.0	2.0	2.0
Salt	1.3	1.3	1.3	1.3	1.3	1.3
Sodium tripolyphosphate	0.4	0.4	0.4	0.4	0.4	0.4
Cure blend	0.25	0.25	0.25	0.25	0.25	0.25
Sodium erythorbate	0.05	0.05	0.05	0.05	0.05	0.05
Ascorbic acid	-	0.1	-	-	-	-
Tomato powder	-	-	0.25	0.5	0.25	0.5
Freeze drying	-	-	0.25	0.5	-	-
100°C oven drying	-	-	-	-	0.25	0.5
Total	100	100.1	100.25	100.5	100.25	100.5

REF, reference (0.1% ascorbic acid); F1, sausages mixed with 0.25% of freeze drying grape tomato powder ($\leq 150\ \mu\text{m}$ mesh) (F1GTPSs); F2, sausages mixed with 0.5% of freeze drying grape tomato powder ($\leq 150\ \mu\text{m}$ mesh) (F2GTPSs); O1, sausages mixed with 0.25% of oven dried grape tomato powder ($\leq 150\ \mu\text{m}$ mesh) at 100°C oven (O1GTPSs); O2, sausages mixed with 0.5% of oven dried grape tomato powder ($\leq 150\ \mu\text{m}$ mesh) at 100°C oven (O2GTPSs).

tube and centrifuged at 1,500×g for 2 min. The sausage mixtures were cooked in a water bath at 75°C for 30 min. All samples were taken out from tubes, then vacuum-packaged by food sealed plastic bags and stored in a refrigerator (10±1°C) for 28 days. The whole experiment was performed triplicates. The pork RFSs were manufactured with the addition of GTP except for control (without addition of powder) and REF (with addition of 0.1% ascorbic acid), according to the procedure of Lee and Chin (2009).

pH, color value, and microbial count

The pH values of the samples were determined by a pH meter (Mettler-Toledo, Schwarzenbach, Switzerland). Each sample was cut into 6 pieces and lightness (L*), redness (a*), and yellowness (b*) were measured by a Minolta color reader (Model # CR-10, Minolta, Tokyo, Japan). For the microbial count, 10 g of sanitized and homogenized sample was mixed with 90 mL of sterilized water (0.9%) using a Stomacher Lab Blender and serial dilutions were made. Then, about 0.1 mL of the diluted sample was dispersed onto the surface of violet red bile (VRB) and total plate count (TPC) agar and incubated at 37°C for 24–48 h.

Proximate composition

Moisture, crude fat, and crude protein (%) were conducted by following the AOAC guidelines (AOAC, 2005). The moisture contents were analyzed by dry-oven methods, whereby the materials were dried at 102°C for 16–24 h. The crude fat content was determined by the Soxhlet extraction method and crude protein analysis was performed by the Kjeldahl protein determination.

Texture profile analyses (TPA)

A universal testing machine (Model 3344, Canton, MA, USA) was used to perform texture profile analysis according to a method described by Caine et al. (2003). The sausage samples (1.30 cm length and 1.30 cm diameter) were compressed with a 500-N load cell at an operational speed of 300 mm/min. The TPA values were expressed in terms of the hardness (gf), springiness (cm), gumminess (kg/mm), chewiness (kg/mm), and cohesiveness (ratio) of sausages. Ten samples were used for single texture profile analysis result of every sausage.

Expressible moisture (EM, %)

Accurately 1.5 g sample was weighed and wrapped using the 3 pieces of 1/4 filter paper and then centrifuged (1,500×g) for 15 min (VS-5000N, Vision Scientific, Bucheon, Korea). Weights of both the filter paper and samples were measured again. The expressible moisture content of the samples was calculated as follows:

$$\text{Expressible moisture (\%)} = \Delta T \times 100 / A$$

Where ΔT was the thimble weight difference before and after centrifugation. A was the initial weight of the sample.

Thiobarbituric acid-reactive substances (TBARS)

The oxidative rancidity was evaluated by TBARS (Sinnhuber and Yu, 1977). Each sausage sample mixed with 2.5%

trichloroacetic acid (TCA, 3 mL) and 1% thiobarbituric acid (TBA, 17 mL) in a capped tube was accurately measured in grams. Then, the tubes were put into a boiling water bath for 30 min. The supernatant of each solution was mixed with 5 mL of chloroform and centrifuged at 670×g for 5 min (VS-5000N, Vision Scientific). Then, approximately 3 mL of petroleum was added to each supernatant and centrifuged. Finally, the clear solutions were analyzed by spectrophotometry (UV-1601, Shimadzu, Kyoto, Japan) at a wavelength of 532 nm.

Statistical analysis

The sausage samples were analyzed at 0, 3, 7, 14, 21, and 28-day intervals during 10°C chilled storage. Data were analyzed by two-way analysis of variance (ANOVA) using the SPSS 21.0 program for Windows. Duncan's multiple range test was used to determine significant differences at the 5% level.

Results and Discussion

pH and color

Table 2 shows the pH and color values of the RFSs with various amounts of GTP as affected by the different drying methods. Since the interaction between the treatments and storage time were not different ($p>0.05$), the data were pooled by treatment within each storage time and storage time within the treatment. The addition of GTP tended to decrease the pH values and the addition of oven-dried powder reduced the pH more than freeze-dried GTP. The reduced pH of the RFSs with

Table 2. pH and color value of pork regular-fat sausages as affected by different drying methods and levels of grape tomato powder

Treatments	Parameters			
	pH	CIE L*	CIE a*	CIE b*
CTL	6.11 ^a	74.80 ^a	10.71 ^d	5.76 ^e
REF	6.10 ^a	73.50 ^b	11.40 ^c	5.77 ^e
F1	6.08 ^b	72.50 ^{bc}	12.62 ^{ab}	7.34 ^d
F2	6.07 ^b	73.00 ^c	12.73 ^{ab}	8.51 ^c
O1	6.05 ^c	67.00 ^d	12.31 ^b	12.35 ^b
O2	6.04 ^c	63.00 ^e	13.10 ^a	14.32 ^a
Storage days				
0	6.07 ^B	70.62 ^A	12.31 ^A	8.89 ^A
3	6.02 ^C	70.52 ^A	12.14 ^A	8.87 ^A
7	6.08 ^B	70.53 ^A	12.43 ^A	9.58 ^A
14	6.08 ^B	70.81 ^A	12.02 ^A	8.90 ^A
21	6.10 ^A	70.53 ^A	12.12 ^A	8.99 ^A
28	6.10 ^A	70.84 ^A	12.13 ^A	8.83 ^A

^{a-c} Mean with different superscripts in the treatment are different ($p<0.05$).

^{A-C} Mean with different superscripts in the storage day are different ($p<0.05$).

RFS, regular-fat sausages CIE L*, lightness; CIE a*, redness; CIE b*, yellowness; CTL, control; REF, reference (0.1% ascorbic acid); F1, sausages mixed with 0.25% of freeze drying grape tomato powder ($\leq 150 \mu\text{m}$ mesh) (F1GTPSs); F2, sausages mixed with 0.5% of freeze drying grape tomato powder ($\leq 150 \mu\text{m}$ mesh) (F2GTPSs); O1, sausages mixed with 0.25% of oven dried grape tomato powder ($\leq 150 \mu\text{m}$ mesh) at 100°C oven (O1GTPSs); O2, sausages mixed with 0.5% of oven dried grape tomato powder ($\leq 150 \mu\text{m}$ mesh) at 100°C oven (O2GTPSs).

the addition of tomato powder might be due to the tomato powder itself (Candogan, 2002). The reason why the oven-dried powder reduced the pH more than the freeze-dried powder was that the Maillard reactions of the tomato powder during heating caused a browning reaction that decreased the pH (Baloch et al., 2000). Although the pH values of all treatments decreased on day 3, they increased thereafter toward to the end of storage. Candogan (2002) reported that the pH of tomato paste-added patties increased with storage time and the changes in pH might be due to microbial growth during the refrigerated storage. However, a decrease in the pH values during storage of frankfurters containing tomato paste was observed by Deda et al. (2007) who suggested that the decrease in pH was obviously due to an increase of lactic acid bacteria, which might grow during storage. However, no lactic acid bacteria might grow in this study due to little change in the pH values.

REF and CTL had higher lightness (L^*) values and lower redness (a^*) and yellowness (b^*) values. The addition of GTP tended to decrease lightness, but increased redness and yellowness. In the comparison of two drying methods, O turned darker and yellower than the F. Candogan (2002) reported that lycopene, the red substance and the corresponding pigment antioxidant, was affected by increasing tomato paste levels from 5% to 15%, which could result in beef patties that were yellower, redder, and darker. Since the O already underwent a series of Maillard reactions due to drying at high temperatures, the addition of O to the sausages turned them to be yellow and darker color (Cosmai et al., 2013). Salem (2013) reported that pH was a very important factor that was related to the meat color, water-holding capacity, and texture of meat. He also reported that beef patties mixed with optimum amounts of tomato peel powder had better color values, more acceptable by consumers. During the storage time, the addition of GTP affected the pH and color of the sausages and the oven-dried powder affected these more than freeze-dried powder.

Proximate composition

The proximate analyses of sausages with different amounts and drying methods of GTP are shown in Table 3. Processing and chemical changes are affected by the nutritional composition, such as protein, fat, and moisture during storage. During the storage period, neither moisture nor crude fat showed differences, but crude protein (%) was slightly increased compared to the control. Kim et al. (2011) did the study on low-fat sausages added with tomato powder, who found that protein content increased with the increased addition of tomato powder, simultaneously, fat and moisture were without any changes. They reported that increased protein contents were not only the tomato powder was added, but also because tomato has 10.3% of crude protein contents, which was agreement with our studies. Although the protein contents were different statistically, the proximate composition of the RFSs was not actually affected by GTP addition due to the small changes of the protein contents, regardless of the different drying methods and levels of GTP.

Texture profile analyses (TPA)

Table 4 shows the textural properties of RFSs added with GTP and no interaction between treatments and storage time was found in the textural properties. The textural characteristics of cooked meat products are generally considered to be heat-induced changes in connective tissue, soluble proteins, and myofibrillar proteins (Zayas and Naewbanij, 1986). The hardness and chewiness values were decreased by the addition of GPT and the addition of FGTP into the sausages tended to decrease these characteristics more than oven-dried grape tomato powders (OGTP). During the storage time, textural hardness and gumminess increased as the storage time increased. Na et al. (2012) reported that the addition of tomato powder decreased the texture of sausages. Thus, the addition of tomato peel and powder had different effects on texture due to their different

Table 3. Proximate composition of pork regular-fat sausages as affected by different drying methods and levels of grape tomato powder

Treatments	Parameters		
	Moisture (%)	Fat (%)	Protein (%)
CTL	64.3 ^a	19.3 ^a	13.9 ^d
REF	63.4 ^a	19.9 ^a	14.1 ^{cd}
F1	64.3 ^a	19.8 ^a	14.4 ^{bcd}
F2	64.5 ^a	19.5 ^a	14.6 ^{ab}
O1	63.0 ^a	20.9 ^a	15.0 ^a
O2	63.4 ^a	20.9 ^a	14.6 ^{abc}
Storage days			
0	65.2 ^A	18.6 ^B	14.7 ^A
3	64.1 ^{ABC}	19.6 ^{AB}	14.7 ^A
7	64.7 ^{AB}	20.2 ^{AB}	14.3 ^{AB}
14	62.8 ^C	20.2 ^{AB}	14.6 ^{AB}
21	62.6 ^C	20.9 ^A	14.1 ^B
28	63.4 ^{BC}	20.7 ^A	14.3 ^{AB}

^{a-d} Means with different superscripts in the treatment are different ($p < 0.05$).

^{A-C} Means with different superscripts in the storage time are different ($p < 0.05$).

CTL, control; REF, reference (0.1% Ascorbic acid); F1, sausages mixed with 0.25% of freeze drying grape tomato powder ($\leq 150 \mu\text{m}$ mesh) (F1GTPSs); F2, sausages mixed with 0.5% of freeze drying grape tomato powder ($\leq 150 \mu\text{m}$ mesh) (F2GTPSs); O1, sausages mixed with 0.25% of oven dried grape tomato powder ($\leq 150 \mu\text{m}$ mesh) at 100°C oven (O1GTPSs); O2, sausages mixed with 0.5% of oven dried grape tomato powder ($\leq 150 \mu\text{m}$ mesh) at 100°C oven (O2GTPSs).

functional characteristics. However, the opposite result was observed in a previous study from Salem (2013) who reported that hardness increased when tomato powder was added because of the increase in tomato peel fiber. The increase in hardness could be explained by the presence of insoluble acid detergent fiber, which is composed mainly of cellulose and lignin in tomato peel (Kim et al., 2011; Knoblich et al., 2005). Springiness was affected by the addition of F1GTP and O2GTP. However, no changes in springiness were found in O1 and F2. During the storage time, springiness decreased on 3 days of storage, increased on 21 days of storage and plateau thereafter. Gumminess changed slightly, only increasing a little on day 3 days of storage and decreased with the addition of F2GTP. Chewiness decreased with the addition of GTP, but no differences were observed during storage time. Cohesiveness decreased with the addition of GTP, except for O2GTP, which was increased during storage. During the storage time, cohesiveness tended to decrease with increased storage time. Thus, except for a few cases, most textural characteristics were affected by the addition of GTP, especially FGTP rather than OGTP and storage time.

TBARS

Since interaction between storage time and treatments was observed ($p < 0.05$), the data were separated by treatment within a storage time or storage time within a treatment (Table 5). Thiobarbituric acid-reactive substances (TBARS), which is used as an index for measuring the oxidative rancidity of meat and meat products, increased as storage time increased. The TBARS of REF was the lowest, and it was followed by the O1 at the initial day. However, the TBARS of O1 had the lowest value from 3 to 28 days of storage among all treatments. In addition, the TBARS of the OGTPSs was lower than that of

Table 4. Textural profile properties of pork regular-fat sausages as affected by different drying methods and levels of grape tomato powder

Treatments	Parameters				
	Hardness (N)	Springiness (mm)	Gumminess (kg/mm)	Chewiness (kg/mm)	Cohesiveness
CTL	38.64 ^a	6.25 ^b	24.7 ^a	146 ^a	8.65 ^b
REF	25.71 ^c	5.85 ^c	22.6 ^{ab}	117 ^{bc}	8.12 ^c
F1	26.30 ^c	5.74 ^c	22.7 ^{ab}	117 ^c	8.27 ^c
F2	28.43 ^d	6.28 ^b	21.0 ^b	115 ^c	7.78 ^d
O1	30.27 ^c	6.37 ^b	23.8 ^a	125 ^b	8.17 ^c
O2	32.52 ^b	6.65 ^a	26.3 ^a	121 ^{bc}	9.78 ^a
Days					
0	27.67 ^D	6.29 ^A	21.4 ^C	118 ^B	8.75 ^A
3	31.88 ^A	6.03 ^C	25.4 ^A	138 ^A	8.53 ^{AB}
7	29.93 ^C	6.12 ^{BC}	22.0 ^{BC}	118 ^B	8.32 ^B
14	30.58 ^{BC}	6.11 ^{BC}	23.3 ^{ABC}	122 ^B	8.38 ^B
21	30.63 ^{BC}	6.31 ^A	22.9 ^{BC}	122 ^B	8.42 ^{AB}
28	31.19 ^{AB}	6.27 ^{AB}	24.3 ^{AB}	123 ^B	8.38 ^B

^{a-d} Mean with different superscripts in treatment are different ($p < 0.05$).

^{A-D} Mean with different superscripts in the storage time are different ($p < 0.05$).

CTL, control; REF, reference (0.1% Ascorbic acid); F1, sausages mixed with 0.25% of freeze drying grape tomato powder ($\leq 150 \mu\text{m}$ mesh) (F1GTPSs); F2, sausages mixed with 0.5% of freeze drying grape tomato powder ($\leq 150 \mu\text{m}$ mesh) (F2GTPSs); O1, sausages mixed with 0.25% of oven dried grape tomato powder ($\leq 150 \mu\text{m}$ mesh) at 100°C oven (O1GTPSs); O2, sausages mixed with 0.5% of oven dried grape tomato powder ($\leq 150 \mu\text{m}$ mesh) at 100°C oven (O2GTPSs).

Table 5. TBARS of pork regular-fat sausages as affected by different drying methods and levels of grape tomato powder

Parameters	Treatment	Storage (day)					
		0	3	7	14	21	28
TBARS (mg MAD/kg)	CTL	0.2338 ^{fA}	0.2644 ^{eA}	0.3283 ^{dA}	0.4033 ^{cA}	0.4445 ^{bA}	0.4716 ^{aA}
	REF	0.1898 ^{bd}	0.1978 ^{abD}	0.1975 ^{abE}	0.2047 ^{abE}	0.2084 ^{aE}	0.2128 ^{aE}
	F1	0.2233 ^{fAB}	0.2472 ^{eB}	0.3079 ^{dB}	0.3433 ^{cB}	0.3810 ^{bB}	0.4026 ^{aB}
	F2	0.2033 ^{cC}	0.2360 ^{dB}	0.2595 ^{cC}	0.2858 ^{bC}	0.3110 ^{aC}	0.3275 ^{aC}
	O1	0.2090 ^{dC}	0.2191 ^{cdC}	0.2254 ^{dD}	0.2436 ^{bD}	0.2595 ^{aD}	0.2688 ^{aD}
	O2	0.2218 ^{fB}	0.2453 ^{eB}	0.2621 ^{dC}	0.2840 ^{cC}	0.3094 ^{bC}	0.3238 ^{aC}

^{a-f} Mean with different superscripts in a same storage time are different ($p < 0.05$).

^{A-E} Mean with different superscripts in the same treatment are different ($p < 0.05$).

TBARS, thiobarbituric acid-reactive substances (mg MAD/kg); CTL, control; REF, reference (0.1% Ascorbic acid); F1, sausages mixed with 0.25% of freeze drying grape tomato powder ($\leq 150 \mu\text{m}$ mesh) (F1GTPSs); F2, sausages mixed with 0.5% of freeze drying grape tomato powder ($\leq 150 \mu\text{m}$ mesh) (F2GTPSs); O1, sausages mixed with 0.25% of oven dried grape tomato powder ($\leq 150 \mu\text{m}$ mesh) at 100°C oven (O1GTPSs); O2, sausages mixed with 0.5% of oven dried grape tomato powder ($\leq 150 \mu\text{m}$ mesh) at 100°C oven (O2GTPSs).

freeze-drying at the same level of GTP. GTP dried by oven-drying had more total phenolics than those processed by freeze-drying, which could improve the oxidant activity. However, Dorta et al. (2012) did study on antioxidant activities of mango peel and seed by different drying treatments and they reported that mango seeds and peels could be stabilized by freeze drying without reducing antioxidant activities rather than the oven-drying. They explained that drying methods affected the

contents of phenol and anthocyanin, which contribute to antioxidant activities. Drying is a useful technique for a longer shelf-life of fruits and vegetables with better antioxidant and antimicrobial activities, and freeze-drying can remove water from frozen material mainly by sublimation to preserve the product quality (Ratti, 2001). Oven-drying reduced the vitamin C content and increased the water-soluble R-tocopherol Trolox analog antioxidant content (Lavelli et al., 1999). Thus, GTP might be useful to the lipid antioxidant for RFSs during storage, especially the O1GTP is most influential among all treatments except for REF.

Total plate counts (TPC) and expressible moisture (EM, %)

The microbial counts of total bacteria and Enterobacteriaceae, and expressible moisture (EM) of the GTPSs are listed in Table 6. EM decreased with the addition of GTP except for F2, and the EM in all treatments showed a gradually decreasing trend during storage. However, no differences were observed except for the O2. These results indicated that the water-holding capacity during storage might maintain or increase in the O2. Kerr et al. (2005) reported that the EM means the degree of juiciness retention in cooked sausages, and they also claimed the EM might be low with high cooking loss. In this study, the cooking losses (%) for the CTL, REF, F1, F2, O1, and O2 groups were 6.7%, 6.8%, 6.8%, 7.6%, 7.5%, and 7.1%, respectively, which showed opposite trends to the EM.

During storage, the total microbial counts increased rapidly up to 28 days of storage. The addition of GTP tended to reduce the microbial counts. The TPC of the O1 was not detected until 7 days of storage ($<10^2$ cells/g), and had the lowest TPC among all treatments. Thus, the O had better antimicrobial activities than that of other sausages, and the O1 had the best effect on microbial inhibition. TPC was reduced by the addition of GTP and oven-dried tomato powder had better antimicrobial effects with lower microbial counts than freeze-dried GTP. This observation was consistent with those of Kim

Table 6. Changes of expressive moisture and microbial counts of pork regular-fat sausages as affected by different drying methods and levels of grape tomato powder

Parameters	Treatments	Storage (day)					
		0	3	7	14	21	28
EM	CTL	21.14 ^{aBC}	21.42 ^{aA}	20.18 ^{aB}	20.61 ^{aA}	20.10 ^{aA}	19.50 ^{aA}
	REF	21.63 ^{aB}	19.60 ^{bcAB}	22.26 ^{aA}	19.69 ^{bA}	19.43 ^{bcA}	18.20 ^{cAB}
	F1	19.65 ^{aCD}	17.51 ^{bBC}	17.76 ^{abD}	19.01 ^{abA}	17.75 ^{abA}	17.68 ^{abAB}
	F2	23.58 ^{aA}	18.06 ^{bBC}	19.65 ^{bBC}	19.83 ^{bA}	18.03 ^{bA}	17.67 ^{bAB}
	O1	19.19 ^{abD}	16.89 ^{bC}	18.90 ^{abCD}	20.92 ^{aA}	19.00 ^{abA}	18.82 ^{abAB}
	O2	19.66 ^{abCD}	18.20 ^{abBC}	20.55 ^{aB}	20.31 ^{abA}	20.01 ^{abA}	17.28 ^{bb}
TPC	CTL	<2 ^{fA}	3.30 ^{eA}	3.83 ^{dA}	4.74 ^{eA}	5.08 ^{bA}	5.83 ^{aA}
	REF	<2 ^{fA}	2.95 ^{eC}	3.56 ^{dBC}	4.21 ^{eB}	4.53 ^{bb}	4.69 ^{aC}
	F1	<2 ^{fA}	3.24 ^{eB}	3.66 ^{dB}	4.26 ^{eB}	4.54 ^{bb}	4.79 ^{aB}
	F2	<2 ^{fA}	2.99 ^{dC}	3.46 ^{cCD}	4.05 ^{bBC}	4.32 ^{bbC}	4.69 ^{aC}
	O1	<2 ^{dA}	<2 ^{dE}	<2 ^{dE}	3.50 ^{eD}	3.95 ^{bd}	4.45 ^{aD}
	O2	<2 ^{fA}	2.58 ^{eD}	3.33 ^{dD}	3.94 ^{cC}	4.26 ^{bd}	4.52 ^{aD}

^{a-f} Mean with different superscripts in a same treatment are different ($p<0.05$).

^{A-E} Mean with different superscripts in the same storage day are different ($p<0.05$).

EM, expressive moisture; TPC, total bacterial counts (Log CFU/g).

et al. (2011) and Østerlie and Lerfall (2005), who reported that the lower pH of sausages with tomato powder reduced the microbial counts, demonstrating effective antimicrobial activity. Similarly, dried fruits and vegetables inhibited the growth of spoilage microorganisms because lower water content and powerful antimicrobial enzymatic or non-enzymatic browning reactions also could have occurred in the material matrix (Argyropoulos et al., 2011; Zhang et al., 2006). No microbial counts for *Enterobacteriaceae* (VRB) were observed during the storage time. Thus, the application of OGTP to meat products could be beneficial because of its antimicrobial activity.

Conclusion

GTPs improved the texture of RFSs and decreased pH, lightness, expressive moisture, total plate count, and TBARSs but increased the redness, yellowness and protein contents. More importantly, the RFSs added with oven-dried GTPs decreased the TPC and TBARS more than those mixed with FGTP. In addition, reference treatments showed least level of TPC and TBARS among all treatments. Thus, RFSs added with oven-drying GTP had better lipid antioxidant and antimicrobial activities, and oven-dried GTP dried at 100°C could be applied to meat products to extend shelf-life during storage time.

Conflicts of Interest

The authors declare no potential conflicts of interest.

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Author Contributions

Conceptualization: Qiu ZZ, Chin KB. Data curation: Qiu ZZ, Chin KB. Formal analysis: Qiu ZZ, Chin KB. Methodology: Qiu ZZ, Chin KB. Software: Qiu ZZ, Chin KB. Validation: Qiu ZZ, Chin KB. Investigation: Qiu ZZ, Chin KB. Writing - original draft: Qiu ZZ. Writing - review & editing: Qiu ZZ, Chin KB.

Ethics Approval

This article does not require IRB/IACUC approval because there are no human and animal participants.

References

- Agarwal S, Rao AV. 2000. Tomato lycopene and its role in human health and chronic diseases. *Can Med Assoc J* 163:739-744.
- Aguilera JM. 2003. Drying and dried products under the microscope. *Int J Food Sci Technol* 9:137-143.
- AOAC. 2005. Official methods of analysis. 18th ed. Association of Official Analytical Chemist International. Washington, DC, USA. p 392.

- Argyropoulos D, Heindl A, Müller J. 2011. Assessment of convection, hot-air combined with microwave-vacuum and freeze-drying methods for mushrooms with regard to product quality. *Int J Food Sci Technol* 46:333-342.
- Ashebir D, Jezik K, Weingartemann H, Gretzmacher R. 2009. Change in color and other fruit quality characteristics of tomato cultivars after hot-air drying at low final-moisture content. *Int J Food Sci Nutr* 60:308-315.
- Baloch WA, Baloch MK, Saleem SA, Baloch AK. 2000. Stability of tomato powder at intermediate moisture levels. *Pak J Biol Sci* 3:100-103.
- Bhatta S, Stevanovic Janezic T, Ratti C. 2020. Freeze-drying of plant-based foods. *Foods* 9:87.
- Caine WR, Aalhus JL, Best DR, Dugan MER, Jeremiah LE. 2003. Relationship of texture profile analysis and Warner-Bratzler shear force with sensory characteristics of beef rib steaks. *Meat Sci* 64:333-339.
- Candogan K. 2002. The effect of tomato paste on some quality characteristics of beef patties during refrigerated storage. *Eur Food Res Technol* 215:305-309.
- Cantwell M, Nie X, Hong G. 2009. Impact of storage conditions on grape tomato quality. 6th ISHS Postharvest Symposium, Antalya, Turkey. pp 1-8.
- Christine G. What's the difference between grape and cherry tomato? Available from: <https://www.thekitchn.com/whats-the-difference-between-grape-and-cherry-tomatoes-word-of-mouth-206683>. Accessed at Aug 11, 2014.
- Coker C, Ely M, Coggins P. 2018. Grape tomatoes as a potential crop for growers and consumers in the southeastern USA. *J Hortic* 5:1000225.
- Cosmai L, Summo C, Caponio F, Paradiso VM, Gomes T. 2013. Influence of the thermal stabilization process on the volatile profile of canned tomato-based food. *J Food Sci* 78:C1865-C1870.
- Deda MS, Bloukas JG, Fista GA. 2007. Effect of tomato paste and nitrite level on processing and quality characteristics of frankfurters. *Meat Sci* 76:501-508.
- Dewanto V, Wu X, Adom KK, Liu RH. 2002. Thermal processing enhances the nutritional value of tomatoes by increasing total antioxidant activity. *J Agric Food Chem* 50:3010-3014.
- Dorta E, Lobo MG, González M. 2012. Using drying treatments to stabilise mango peel and seed: Effect on antioxidant activity. *LWT-Food Sci Technol* 45:261-268.
- Frusciante L, Carli P, Ercolano MR. 2007. Antioxidant nutritional quality of tomato. *Mol Nutr Food Res* 51:609-617.
- Giovannucci E. 1999. Tomatoes, tomato-based products, lycopene and cancer: Review of the epidemiologic literature. *J Natl Cancer Inst* 91:317-331.
- Kerr WL, Wang X, Choi SG. 2005. Physical and sensory characteristics of low-fat Italian sausage prepared with hydrated oat. *J Food Qual* 28:62-77.
- Kim HS, Chin KB. 2016. Effects of drying temperature on antioxidant activities of tomato powder and storage stability of pork patties. *Korean J Food Sci Anim Resour* 36:51-60.
- Kim IS, Jin SK, Mandal PK, Kang SN. 2011. Quality of low-fat pork sausages with tomato powder as colour and functional additive during refrigerated storage. *J Food Sci Technol* 48:591-597.
- Knoblich M, Anderson B, Latshaw D. 2005. Analyses of tomato peel and seed byproducts and their use as a source of carotenoids. *J Sci Food Agric* 85:1166-1170.
- Lavelli V, Hippeli S, Peri C, Elstner EF. 1999. Evaluation of radical scavenging activity of fresh and air-dried tomatoes by three model reactions. *J Agric Food Chem* 47:3826-3831.
- Lee HC, Chin KB. 2009. Effect of transglutaminase, acorn, and mungbean powder on quality characteristics of low-fat/salt

- pork model sausages. *Korean J Food Sci Anim Resour* 29:374-381.
- Lewicki PP, Le HV, Pomarańska-Łazuka W. 2002. Effect of pre-treatment on convective drying of tomatoes. *J Food Eng* 54:141-146.
- Mascio DP, Kaiser S, Sies H. 1989. Lycopene as the most efficient biological carotenoid singlet oxygen quencher. *Arch Biochem Biophys* 274:532-538.
- Muratore G, Licciardello F, Maccarone E. 2005. Evaluation of the chemical quality of a new type of small-sized tomato cultivar, the plum tomato (*Lycopersicon lycopersicum*). *Ital J Food Sci* 17:75-81.
- Na Y, Kim S, Jung EK, Joo N. 2012. Processing optimization and antioxidant activity of sausage prepared with tomato powder. 2012 International Conference on Clean and Green Energy, Singapore. pp 129-136.
- Omoni AO, Aluko RE. 2005. The anti-carcinogenic and anti-atherogenic effects of lycopene: A review. *Trends Food Sci Technol* 16:344-350.
- Østerlie M, Lerfall J. 2005. Lycopene from tomato products added minced meat: Effect on storage quality and color. *Food Res Int* 38:925-929.
- Picha DH. 1986. Effect of harvest maturity on the final fruit composition of cherry and large-fruited tomato cultivars. *J Am Soc Hort Sci* 111:723-727.
- Ratti C. 2001. Hot air and freeze-drying of high-value foods: A review. *J Food Eng* 49:311-319.
- Salem RH. 2013. Quality characteristics of beef sausages with tomato peel as a colour and functional additive during frozen storage. *World Appl Sci J* 22:1085-1093.
- Serdaroğlu M, Kavuşan HS, İpek G, Öztürk B. 2018. Evaluation of the quality of beef patties formulated with dried pumpkin pulp and seed. *Korean J Food Sci Anim Resour* 38:1-13.
- Simonne E, Datar R, Simonne A, Hochmuth R, Gazula A. 2008. Sensory evaluation of red and yellow grape tomato varieties. *Proc Fla State Hort Soc* 121:178-182.
- Sinnhuber RO, Yu TC. 1977. The 2-thiobarbituric acid reaction, an objective measure of the oxidative deterioration occurring in fats and oils. *J Jpn Oil Chem Soc* 26:259-267.
- Taveira M, Silva LR, Vale-Silva LA, Pinto E, Valentão P, Ferreres F, Guedes de Pinho P, Andrade PB. 2010. *Lycopersicon esculentum* seeds: An industrial byproduct as an antimicrobial agent. *J Agric Food Chem* 58:9529-9536.
- Utpal KD, Ranjit B, Subha G. 2014. Freeze-drying technique and its wide application in biomedical and pharmaceutical sciences. *Res J Chem Environ Sci* 2:01-04.
- Yang HS, Choi SG, Jeon JT, Park GB, Joo ST. 2007. Textural and sensory properties of low fat pork sausages with added hydrated oatmeal and tofu as texture-modifying agents. *Meat Sci* 75:283-289.
- Zayas JF, Naewbanij JO. 1986. The influence of microwave heating on the textural properties of meat and collagen solubilization. *J Food Process Preserv* 10:203-214.
- Zhang M, Tang J, Mujumdar AS, Wang S. 2006. Trends in microwave-related drying of fruits and vegetables. *Trends Food Sci Technol* 17:524-534.