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Processing Optimization and Antioxidant Activity of Sausage Prepared with Tomato Powder

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Abstract. The purpose of this study was to determine the optimal mixing conditions for two different amounts of tomato powder and starch to prepare sausage having antioxidant activity with added tomato powder. The experiment was designed according to the central composite response surface design, which demonstrated 10 experimental points including two replicates for tomato powder and starch. The physiochemical, mechanical, and sensory properties of the test were measured and these values were applied to the mathematical models. The results of the physiochemical, mechanical analysis of each sample, including pH, moisture content, total phenolic content and DPPH free radical scavenging activity, color L^*, color a^*, color b^*, hardness, chewiness and cohesiveness, showed significant differences. The sensory measurements were significantly different in color, flavor, chewiness, overall quality. The optimum formulation calculated by numerical and graphical method was 4.26 g tomato powder and 7.51 g starch. There were significant differences in total phenolic content and DHHP free radical scavenging activity between control sausage (CS) and optimized sausage prepared with tomato powder (TS). Also, sensory evaluation showed significantly higher preference in color, flavor, tenderness, and overall quality at the optimized sausage than control sausage.

Keywords: sausage, tomato powder, sensory evaluation, response surface method (RSM), optimization, antioxidant activity

1. Introduction

Interests of the consumer in functional foods for health and prevention of various disease has been growing recently. Tomatoes, which contain large amounts of carotenoids, are being grown throughout the world as one of vegetables. In particular of the components of tomatoes, the lycopene is a powerful antioxidant that scavenges free radicals 1,000 times better than the vitamins do and it has been reported that it also does excellent effects toward various cancers and diseases [1]. Development of meat industry has been continuously developed due to westernization of diets and the food service industry with growing consumption of meat. Korea Meat Industries Association (2011) surveyed from 2006 to 2010 growth rate of 44,156 tons 55,207 tons of sausage sales have increased 25 percent [2]. While improving the quality of life of consumers, domestic meat industry has developed at the same time, which means the quality and functionality of healthful meat and meat products became to have the tendency to satisfy the preferences of the consumer. However, adding of fat, spices, and food additives to the manufactured meat, which is to satisfy the consumers, is actually an important factor for the consumers to avoid the meat product [3, 4]. Eventually, studies have been brisk to combine the sausages (meat product) with natural functional food instead of the artificial food additives, making recent changes in the former trend. This study will deduct the sensory optimum point by adding rich-in-antioxidant tomato powder to sausage. And by studying the antioxidant activity and characteristic of the optimized sausage, the potential of the tomato powder as natural antioxidant that can be applied on meat products.

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2. Materials and Methods

2.1. Materials

Tomato powder used in this experiment were purchased from Baekjangsaeng Co. (www.100js.com), Ltd.,(Spain), and meat (fresh ham of pork) and fat from butcher (Jungilpum, Yongsan-Gu, Seoul, Korea, 2011). Also, potato-starch (Tureban, Korea), salt (Baiksul, Korea), garlic (Korea), pepper and nutmeg were used.

2.2. Experimental design

The Design Expert 8.0 program was used to plan the study, for optimization analysis as well as data analysis of sausage prepared with tomato powder. The experiment was designed according to the ventral composite design of response surface, which showed 10 experimental points including 2 replicates. Tomato powder (A) and starch (B) were chosen as two factors of independent variables. As dependent variables, physiochemical, mechanical, and sensory characteristics were chosen. Through pre-examination, the maximum and minimum range of tomato powder and starch were determined to be 1~8 g, 2~12 g, respectively. There was experimental design for sausage with the addition of tomato powder by response surface design (Table 1).

Table 1: Experimental design for sausage with the addition of tomato powder by response surface method

Sample No.	Factors		Meat(g)	Fat(g)	Garlic(g)	Salt(g)	Pepper(g)	Nutmeg(g)
	Tomato powder (g)	Starch (g)						
1	5	10	500	75	3	12	1.25	0.25
2	40	10						
3	5	60						
4	40	60						
5	5	35						
6	40	35						
7	22.5	10						
8	22.5	60						
9	22.5	35						
10	22.5	35						

2.3. Preparation of sausage

First, grinded meat (fresh ham of pork) with garlic, salt, pepper and nutmeg was stored at 4℃ for an hour. And then it was put into the Food mixer (SF-100, Samwoo, Korea), added with ice (5 % of total weight of meat). Next, tomato powder, starch and fat were added and mixed at a rapid speed for 4 min and then at a low speed for 3 min. Then the meat batter was stuffed into the collagen casing (Collagen Sausage Casing, Nippi Collagen Ind. Ltd., Japan), using a sausage stuffer (sausage stuffer kit, KitchenAid, USA).

2.4. Measuring quality properties and sensory evaluation

Manufactured sausages were measured of physiochemical characteristics including pH, sweetness, salinity, moisture content, total phenol content [5], DPPH radical scavenging activity [6], color L, color a color b, texture, and of sensory characteristics including color, flavor, tenderness, chewiness and overall quality. Sensory evaluation was performed according to the seven point hedonic scale. A panel consisting of 25 students at Sookmyung Women's University was chosen. The sausage prepared for each test sample was corded with a random digit number. The panellists were asked to evaluate the preference of color, flavour, tenderness, chewiness, and overall quality of sausage prepared with tomato powder by giving a score ranging from 1 (dislike extremely) to 7 (like extremely). Also all properties were measured of control sausage (CS) and optimized sausage prepared with tomato powder (TS).

2.5. Statistical analysis of sausage

Statistical analysis of variance (ANOVA) and multiple regressions were performed using the Design-Expert 8.0 program (Stat-Easy Co., Minneapolis, MN, USA) to fit the equation. Also, quality result of between optimized sausage prepared with tomato powder and control sausage was analysed using SPSS 12.0(statistical package for Social Science, SPSS Inc., USA) and performed T-test.

3. Results and Discussion

3.1. Physiochemical and mechanical characteristics

The model equations and the coefficients of determination of the model equation are described in Table 2. The pH was evaluated to have the tendency to decrease as addition of tomato powder increase ($p<0.001$). This result is considered as the effect of the low pH of tomato powder (pH 4.6). The moisture content of sausage prepared with tomato powder was highly affected by the amount of starch addition, and increase of starch addition significantly decreased moisture content ($p<0.001$). The total phenolic content was significantly increased with increasing tomato powder addition ($p<0.001$), and DPPH free radical scavenging activity displayed similar tendency ($p<0.001$). The regression coefficient R^2 of the regression equation for total phenolic content was 0.99 and the significance was found at the probability level of 0.001(α=0.001). These results show that increased tomato powder addition significantly increased antioxidant activity. In color values, the color a^* was highly different among each sample. Further and further addition of tomato powder increased color a^*, and that is considerable because the red color of tomatoes are due to the lycopene [7]. The results of texture parameters were significant in hardness ($p<0.05$), chewiness ($p<0.05$), and cohesiveness ($p<0.01$). The addition of starch had a positive effect on the texture analyzer. Increased starch significantly increased the texture parameters, and increased tomato powder significantly decreased them.

Table 2: Analysis of predicted model equation of sausage prepared with tomato powder for physiochemical and mechanical test

Response	Model	Mean±S.D.	R-squared[1)]	F-value	Prob>F[2)]	Polynomial equation[3)]
pH	Linear	5.46±0.08	0.9141	37.27***	0.0002	-0.27A-3.333E-003B+5.46
Moisture content	Linear	61.13±0.57	0.8725	23.95***	0.0007	-0.82A-1.38B+61.13
Total phenolic content	Quadratic	0.66±0.01	0.9978	359.23***	<0.0001	+0.22A-0.023B-0.035AB-0.032A^2-7.143E-003B^2+0.69
DPPH free radical scavenging activity	Linear	35.92±4.04	0.9151	37.74***	0.0002	+14.12A-2.45B+35.92
Color a^*	Quadratic	14.49±0.29	0.9980	399.28***	<0.0001	+5.22A+0.45B+0.020AB-1.94A^2+0.12B^2+15.57
Hardness	Quadratic	4472.08 ±300.21	0.9416	12.89*	0.0141	-260.79A+661.25B-27.50AB-1058.23A^2-81.74B^2+5156.06
Chewiness	2FI	7036.21±2793.96	0.7478	5.93*	0.0316	-2939.27A+2616.04B-3390.65AB+7036.21
Cohesiveness	Linear	0.81±0.027	0.7965	13.70**	0.0038	-0.052A+0.023B+0.81

[1)] $0 \leqq R^2 \leqq 1$, close to 1 means more significant

[2)] * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

[3)] A : Tomato Powder, B : Starch

3.2. Sensory characteristics

The model equations and coefficients of determination of the model equation are given in Table 3. The sensory evaluation results showed significant values in color ($p<0.05$), flavor ($p<0.05$), chewiness ($p<0.05$), overall quality ($p<0.05$). All contents of sausage prepared with tomato powder were highly affected by the amount of tomato powder. Also, it was shown that the increased addition of tomato powder initially improved the overall quality of the sausage, but at some point, additional tomato powder caused sharp declines, especially in chewiness and overall quality.

Table 3: Analysis of predicted model equation of sausage prepared with tomato powder for sensory test

Response	Model	Mean±S.D.	R-squared[1)]	F-value[2)]	Prob>F	Polynomial equation[3)]
Color	Quadratic	4.05 ±0.35	0.9399	12.52*	0.0148	+0.11A-6.667E-003B-0.21AB-1.46A^2-0.74B^2+5.37
Flavor	Quadratic	4.29 ±0.38	0.9409	12.73*	0.0144	-0.080A+0.17B+0.010AB-1.83A^2-0.33B^2+5.59
Tenderness	Quadratic	4.30 ±0.62	0.8297	3.90	0.1060	-1.10A+0.12B+0.000AB-1.54A^2-0.64B^2+5.61
Chewiness	Quadratic	4.11 ±0.59	0.8980	7.05*	0.0409	-0.82A+0.20B-1.000E-002AB-1.63A^2-0.61B^2 +5.45
Overall quality	Quadratic	4.18 ±0.48	0.9385	12.21*	0.0155	-0.33A+0.13B+0.080AB-2.13A^2-0.69B^2+5.86

[1)] $0 \leqq R^2 \leqq 1$, close to 1 means more significant

[2)] * $p < 0.05$

[3)] A : Tomato Powder, B : Starch

3.3. Optimization of sausage prepared with tomato powder

The optimal amounts of tomato powder and starch were selected through numerical optimization of a canonical model and through graphical optimization. The sensory evaluation results showed significant values in color, flavor, chewiness and overall quality. The optimum formulation acquired by numerical and graphical methods was calculated as tomato powder 4.26 g, and starch 7.51 g. Figure 1 shows graphical optimization and perturbation plot and figure 2 shows the characteristics of dependent variables at optimization point.

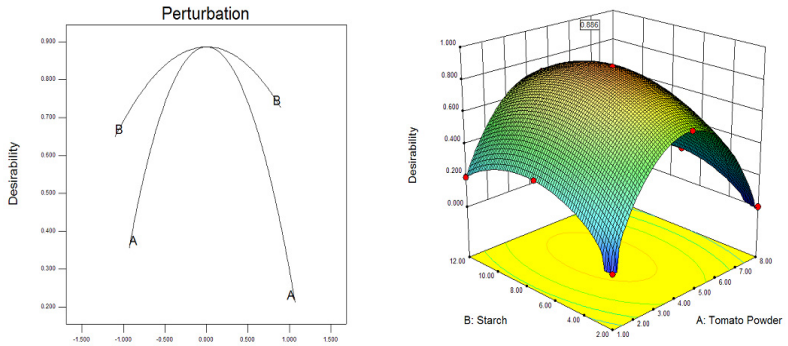

Fig. 1: The effect of tomato powder(A), and starch(B) on desirability

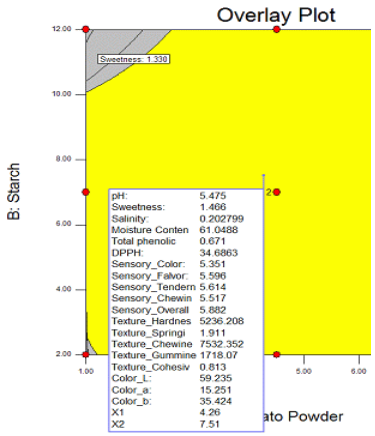

Fig. 2: Overlay plot of optimized of sausage prepared with tomato powder sausage prepared with tomato powder

3.4. The physiochemical, mechanical and sensory characteristics of optimized sausage prepared with tomato powder

Physicochemical and mechanical characteristics of optimized sausage prepared with tomato powder and control sausage are shown in Table 4. The results of antioxidant activity were shown to be significantly higher on the optimized sausage prepared with tomato powder (TS) than on the control sausage (CS). The total phenolic content of TS was 0.58±0.03 mg/g and that of CS was 0.33±0.03 mg/g, respectively ($p<0.001$). And the DPPH free radical scavenging activity of TS and CS were 70.44±0.34 %, 6.46±1.24 % each, respectively. This result shows that adding of tomato powder to the sausage can reinforce antioxidant activity. Sensory characteristics of optimized sausage with tomato powder and control sausage are shown in Table 5. All of the items except chewiness showed similar results, and TS showed better preference that CS does in all items. This result can be analyzed as the addition of tomato powder does not change the quality of products and it has the potential to reinforce the functionality and preference of the products.

Table 4: Physiochemical and mechanical characteristics of control sausage(CS) and optimized sausage prepared with tomato powder(TS)

Mean±S.D.

Characteristics	CS[1)]	TS[2)]	t-value[3)]
pH	6.59±0.00	6.18±0.00	0.00
Moisture content	63.39±0.73	62.90±0.12	1.15
Total phenolic content	0.33±0.03	0.58±0.03	-9.99***
DPPH free radical scavenging activity	6.46±1.24	70.44±0.34	-85.98***
Color a*	5.28±0.10	14.84±0.37	-43.68
Hardness	3094.67±207.06	2832.17±387.90	1.03
Chewiness	2577.37±621.40	2111.72±161.99	1.27
Cohesiveness	0.82±0.26	0.75±0.06	1.83

[1)] Sausage prepared without tomato powder (CS)
[2)] Sausage prepared with tomato powder (TS)
[3)] *** $p < 0.001$

Table 5: Sensory preference of control sausage (CS) and optimized sausage prepared with tomato powder(TS)

Mean±S.D.

Characteristics	CS[1)]	TS[2)]	t-value[3)]
Color	3.60 ± 1.443[4)]	5.72 ± 1.242	5.57***
Flavor	3.48 ± 1.418	5.48 ± 1.388	5.04***
Tenderness	4.40 ± 1.527	5.64 ± 1.468	2.93**
Chewiness	4.52 ± 1.584	5.08 ± 1.630	1.23
Overall quality	3.76 ± 1.451	5.60 ± 1.443	4.49***

[1)] Sausage prepared without tomato powder (CS)
[2)] Sausage prepared with tomato powder (TS)
[3)] ** $p < 0.01$, *** $p < 0.001$

From such results, the sausage prepared with tomato powder is expected to have enough aspects of functionality, quality and preference. It is discovered that the potential to satisfy consumers' needs of strengthening of antioxidant activity and preferences and these results will provide the basic references for future research.

4. References

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