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Quality Characteristics of Beef Patties with the Addition of Juumyit (*Allium hookeri*) Powder

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Abstract

The purpose of this study was to investigate the antioxidative and antimicrobial activities of Juumyit (*Allium hookeri*). Also, the possibilities of using Juumyit (*Allium hookeri*) powder as a functional ingredient in beef patties were studied, and the soybean oil was used to reduce the level of the fat, and improve composition of the fatty acid profile. To determine the optimum mixing ratio of Juumyit (*Allium hookeri*) powder and soybean oil, the experiments were designed according to the central composite design of response surface methodology, which revealed 10 experimental points including two replicates for Juumyit (*Allium hookeri*) powder and soybean oil. Juumyit (*Allium hookeri*) patty formulation was optimized using rheology. Mechanical characteristics, including lightness, redness, yellowness and all texture parameters ($p < 0.05$) displayed a linear model pattern. Antioxidant activities displayed significant values in total phenol content and DPPH radical scavenging activity ($p < 0.05$). In addition, preference of color, appearance, flavor, pungency, juiciness and overall quality ($p < 0.05$) was measured as a sensory evaluation. These results showed that Juumyit (*Allium hookeri*) powder and soybean oil affects pH, cooking properties, hunter color values, texture, antioxidant activities and sensory properties. The optimum formulations processed by numerical and graphical optimization were determined at 8.83 g of Juumyit (*Allium hookeri*) powder and 5.88 g of soybean oil. The results obtained would be useful for meat industry which tends to decrease the fat contents in beef patty to a level.

Keywords: *Juumyit (Allium hookeri) powder; Beef patties; Antioxidants; Sensory properties; Response surface methodology*

Abbreviations: RSM: Response Surface Methodology; CCD: Central Composite Design; F-value: Fisher Test Value; R^2: Coefficient of Regression; JP: Optimized Patty with Juumyit (*Allium hookeri*) Powder; CP: Control Patty without Juumyit (*Allium hookeri*) Powder; VBN: Volatile Basic Nitrogen; TBA: 2-Thiobarbituric Acid; CFU: Colony Forming Units

Introduction

Juumyit (*Allium hookeri*) is a traditional herb which has been used as spices, foods and medicines in India and Myanmar. The roots are a part of the plant with commercial interest and are rich in organic acids, minerals, anthocyanins, and other phenolic compounds [1]. Juumyit (*Allium hookeri*) posses various biological functions that including antioxidative, antimicrobial, anticancer, antithrombotic and antihypertensive activities [2]. These biological functions may be due to the presence of organosulfur compounds and phenolic compounds. This study is concentrated on possibilities of Juumyit (*Allium hookeri*) powder as food ingredients.

Recently, the increase in consumer interest in reduced fat foods has created a growing need for low-fat meat products in market. But the eating quality of meat is highly dependent on the fat content, because fat contributes flavor, texture, and juiciness to meat products. With excessive fat reduction, these products become dry and bland, and the texture can be hard, rubbery or mealy [3]. Developing a ground lean meat product, while assuring the necessary palatability demanded by consumer, is not as simple as just removing fat [4]. Fat has recently been partially replaced with some non-meat ingredients in the formulations of ground meat products because of their potential health risks. However, such replacements for reducing fat and herb content result in some technological problems such as increased cooking losses and purge because of poor fat and water binding as well as undesired changes in color, texture and flavor of meat product [5].

The objective of this study was to examine the combined effects of Juumyit (*Allium hookeri*) powder in physicochemical and mechanical characteristics, antioxidant activities, and sensory properties of beef patties using the response surface methodology (RSM). Therefore, we studied the effect of Juumyit (*Allium hookeri*) powder (3.00~15.00 g) and soybean oil (1.00~13.00 g) on cooking properties of beef patties and to find the levels of Juumyit (*Allium hookeri*) powder and soybean oil to optimize the cooking parameters based on sensory score.

Materials and Methods

Experimental design and statistical analysis

In this study, the effects of Juumyit (*Allium hookeri*) and soybean oil on the dependent variables (pH, cooking loss, diameter and thickness reduction, total phenol content, DPPH radical scavenging activity, hunter color values, texture, and sensory properties) of beef patties after cooking were investigated using RSM. Ten experiments were performed in a completely random order according to central composite design (CCD). The data obtained from the CCD was calculated using the following equation;

$$Y = \beta_0 + \sum_{i=1}^{2} \beta_i X_i + \sum_{i=1}^{2} \beta_{ii} X_i^2 + \sum_{i} \sum_{j=i+1} \beta_{ij} X_i X_j$$

Here, Y is the estimated response; β_0 is a constant; β_i is the linear coefficient; β_{ii} is the quadratic coefficient; β_{ij} is the interaction coefficient; X_i and X_j and are the coded independent variables.

The majority of generated models adequately explain the variation of the responses with the fisher test value (F-value), coefficient of regression (R^2) and non significant lack-of-fit, which indicated that the most variations could be well explained by the quadratic models and can be considered adequate.

The computational work was performed using a SPSS 12.0 (Statistical Package for Social Science, SPSS Inc., Chicago, Illinois, USA). It was used to compute the estimated ridges of maximum and minimum responses for increasing radii from the center of the original design. The experimental design is given in Table 1.

Run No.	Variable Levels							
	Juumyit powder (g)	Soybean oil (g)	Bread crumbs (g)	Milk (mL)	Beef (g)	Sugar (g)	Salt (g)	Black pepper (g)
1	3.00	1.00	13.00	25.00	90.00	1.00	1.00	0.20
2	3.00	13.00	13.00					
3	15.00	1.00	1.00					
4	15.00	13.00	1.00					
5	9.00	1.00	7.00					
6	9.00	13.00	7.00					
7	3.00	7.00	13.00					
8	15.00	7.00	1.00					
9	9.00	7.00	7.00					
10	9.00	7.00	7.00					

Table 1: *Experimental design for beef patties with Juumyit (Allium hookeri) powder.*

Preparation of beef patties

Beef as boneless rounds were obtained from a local market (Jungilpum Co., Yongsan-Gu, Seoul, Korea) and ground through a 3 mm grinder. Spice mix (sugar 1.00g, salt 1.00g, black pepper 0.20g), milk (25.00 mL), and relevant proportions of Juumyit (*Allium hookeri*) powder, soybean oil, and bread crumbs were added into each batch as presented in Table 1. The each batch was mixed and kneaded for 8 min by using a commercial mixer (5KSM150, KitchenAid Co., Saint joseph, Michigan, USA) to obtain homogeneous dough batches. The dough batches were shaped into patty (diameter of 100 mm and height of 11 mm) by using a manual patty forming machine (MS00047, Spikomat Ltd., Nottingham, UK). The prepared beef patties were cooked in a preheated electric oven (Go1518SP Shunde Galanz, Convex Co., Seoul, Korea) set at 200~210°C for 10 min and cooled for 5 min at room temperature.

Physicochemical characteristics

Determination of pH

After 5.00g of the beef patties was diluted with 50.00 mL of distilled water, the diluted solution was homogenized by using a homogenizer (Poly Tron PT 2100, Kimematica Co., Luzern, Switzerland). pH of this solution was measured by a pH meter (F-51, Horiba Co., Tokyo, Japan).

Determination of cooking properties

Cooking loss was calculated using the following equation as reported by Elizabeth., *et al*. [6];

$$Cooking\ loss\,(\%) = \frac{(Uncooked\ patty\ weight - Cooked\ patty\ weight)}{Uncooked\ patty\ weight} \times 100$$

The reduction in diameter and thickness was calculated using the following equation as reported by Serdaroglu and Degirmencioglu [7];

$$Reduction\ of\ diameter\,(\%) = \frac{(Uncooked\ patty\ diameter - Cooked\ patty\ diameter)}{Uncooked\ patty\ diameter} \times 100$$

$$Reduction\ of\ thickness\,(\%) = \frac{(Uncooked\ patty\ thickness - Cooked\ patty\ thickness)}{Uncooked\ patty\ thickness} \times 100$$

Mechanical characteristics

Hunter color values measurement

Hunter color values (lightness, redness, yellowness) of the beef patties were measured by using a chroma meter (CR-300, Minolta Co., Osaka, Japan). Before each measurement, apparatus was standardized against a white plate.

Texture measurement

Texture of the beef patties was measured by using a texture analyzer (TA-XT, Stable Micro Systems Ltd., London, England). All texture parameters (hardness, adhesiveness, springiness, chewiness, gumminess, cohesiveness) were analyzed using the beef patties cut into 20 mm × 20 mm × 10 mm.

Antioxidant activities

Determination of total phenol content

Total phenolic compounds of the beef patties were determined using Folin & Ciocalteu's method [7]. After 0.50 mL of distilled water was mixed with the beef patties, 125.00 μL of 2 N Folin & Ciocalteu's phenol reagent were mixed, and then 1250.00 μL of 7.00% sodium carbonate was added. The mixture was shaken and left to stand for 90 min in dark. Absorbance at 760 nm was determined after 90 min with an UV-visible spectrophotometer (V-530, Jasco Co., Tokyo, Japan) and calculated as gallic acid (mg gallic acid/g).

Determination of DPPH radical scavenging activity

DPPH radical scavenging activity of the beef patties was determined using the method of Brand-Williams., *et al*. After 500.00 μL of DPPH (0.10×10^{-4} M, final concentration) was mixed with the beef patties, the mixture was homogenized and left to stand in dark for 30 min. Absorbance was measured by using a UV-visible spectrophotometer (V-530, Jasco Co., Tokyo, Japan) at 517 nm. DPPH radical scavenging activity of the beef patties was calculated using the following equation;

$$DPPH\ radical\ scavenging\ activity\ (\%) = [(A_0 - A_1) / A_0] \times 100$$

where A_0 is the absorbance of the control, and A_1 is the absorbance of the extract or standard.

Sensory analysis

The beef patties from each formulation were randomly assigned for sensory evaluation. The beef patties were served in random order to 25 member panels (Graduate students of Sookmyung Women's University, Department of Food and Nutrition). The beef patties were subjected to sensory evaluation using seven point hedonic scale (1 = dislike extremely, 7 = like extremely) for the preference of color, appearance, flavor, pungency, juiciness and overall quality.

Preparation of an optimized beef patty

According to the optimized levels of Juumyit (*Allium hookeri*) powder and soybean oil, the optimized beef patty with 8.83 g of Juumyit (*Allium hookeri*) powder (JP) and control patty without Juumyit (*Allium hookeri*) powder (CP) were prepared. Soybean oil (5.88 g), milk (25.00 mL), spice mix (sugar 1.00 g, salt 1.00 g, black pepper 0.20 g) and bread crumbs were added to the two different beef patties equally as described before, and physicochemical (pH, cooking loss, diameter and thickness reduction) and mechanical (hunter color values, texture) characteristics, antioxidant activities (total phenol, DPPH free radical scavenging), and sensory properties of the two different beef patties after cooking were examined.

Physicochemical and mechanical characteristics of an uncooked optimized beef patty with Juumyit (*Allium hookeri*) powder during storage

pH

pH was measured using the same method described in section 5.3.1.

Volatile basic nitrogen

Volatile basic nitrogen (VBN) was analyzed using the method of Edward [8]. Five g of the optimized beef patty with 25.00 mL distilled water was blended and filtered. 0.01 N H_2SO_4 was added to a center compartment and 1.00 mL of the filtered solution and saturated K_2CO_3 solution to an outer compartment of a micro-diffusion unit. The filtered solution and K_2CO_3 solution were mixed and titrated against 0.01 N NaOH. The concentration of VBN was calculated using the following equation;

$$VBN\ value\ (mg\%) = 0.14 \times \frac{(b-a)}{W} \times f \times 100 \times d$$

where a is the titration volume of patty solution (mL); b is the titration volume of blank (mL); d is a dilution factor; W is the weight of patty; f is a factor of 0.01 N NaOH.

2-Thiobarbituric acid

Lipid oxidation was assessed by 2-thiobarbituric acid (TBA) according to the TBA method of Tarladgis., *et al*. [10]. Ten g of the optimized beef patty was blended with 50.00 mL of 0.02 M TBA in 2.00 M phosphoric acid into a total volume of 100.00 mL. Five mL of the supernatant, obtained after centrifuging the mixture, and 5.00 mL of 0.005 M TBA were mixed and kept in dark. Absorbance was measured at 538 nm, and TBA levels were calculated as malondialdehyde mg/kg.

Hunter color values

Hunter color values were measured using the same method described in section 5.4.1.

Texture characteristics

Texture was measured using the same method described in section 5.4.2.

Antioxidant activities of uncooked optimized beef patty with Juumyit (*Allium hookeri*) powder during storage

Total phenol content

Total phenolic compounds were determined using the same method described in section 5.5.1.

DPPH radical scavenging activity

DPPH radical scavenging activity was determined using the same method described in section 5.5.2.

Total plate count

Five g of the optimized beef patty was diluted with 45.00 mL of distilled water resulting in a 10^3~10^4 dilution used by 0.10% buffer peptone water. Serial dilutions and 0.10 mL aliquots were plated onto a tryptic soy agar (Difco, Maryland, USA). The plates were incubated at 37°C for 24 hrs to determine bacterial cell counts on days 0, 3, 6, 9, 12 and 15 of storage. The results were expressed as $\log_{10}$ CFU (colony forming units)/g of the optimized beef patty.

Results and Discussion

Physicochemical and mechanical characteristics

The physicochemical and mechanical characteristics of the beef patties are shown in Table 2~7.

Sample No.	Juumyit powder (g)	Soybean oil (g)	Response			
			pH	Cooking loss (%)	Diameter reduction (%)	Thickness reduction (%)
1	3.00	1.00	5.80 ± 0.02	3.98 ± 0.08	3.11 ± 0.06	7.12 ± 2.50
2	3.00	13.00	5.74 ± 0.01	3.73 ± 0.08	4.25 ± 0.09	12.24 ± 2.42
3	15.00	1.00	5.52 ± 0.00	4.47 ± 0.09	4.14 ± 0.08	1.67 ± 2.89
4	15.00	13.00	5.51 ± 0.01	4.21 ± 0.09	3.11 ± 0.06	9.65 ± 1.10
5	9.00	1.00	5.74 ± 0.01	3.87 ± 0.08	5.18 ± 0.10	9.05 ± 1.26
6	9.00	13.00	5.65 ± 0.01	5.17 ± 0.10	4.14 ± 0.08	12.48 ± 2.58
7	3.00	7.00	5.68 ± 0.02	3.26 ± 0.07	1.04 ± 0.03	3.33 ± 2.89
8	15.00	7.00	5.48 ± 0.01	4.54 ± 0.09	1.04 ± 0.02	5.00 ± 0.00
9	9.00	7.00	5.64 ± 0.01	4.72 ± 0.07	5.63 ± 0.12	20.24 ± 2.81
10	9.00	7.00	5.55 ± 0.01	4.65 ± 0.10	5.49 ± 0.11	16.00 ± 1.13

Table 2: *Physicochemical and mechanical characteristics of the beef patties with Juumyit (Allium hookeri) powder.*

Response	Model	Mean ± S.D.	R^2 1)	F-value 2)	Prob > F	Polynomial equation 3)
pH	Linear	5.63 ± 0.06	0.7918	13.31**	0.0041	5.63-0.027A-0.12B
Cooking loss	Linear	4.26 ± 0.52	0.3351	1.76	0.2397	4.26 + 0.13A + 0.38B
Diameter reduction	Quadratic	3.71 ± 1.37	0.6974	1.84	0.2866	$4.56-0.16A-0.018B-0.54AB + 1.11A^2-2.51B^2$
Thickness reduction	Quadratic	9.68 ± 4.75	0.6978	1.85	0.2860	$15.02 + 2.75A-1.06B + 0.72AB-1.15A^2-7.75B^2$

Table 3: *Analysis of predicted model equation for physicochemical and mechanical characteristics of the beef patties with Juumyit (Allium hookeri) powder.*

1) $0 \leqq R^2 \leqq 1$*, close to 1 indicates the regression line fits the model.*

*2) *p<0.05, **p<0.01, ***p<0.001.*

3) A: Juumyit (Allium hookeri) powder, B: Soybean oil

pH

The addition of Juumyit (*Allium hookeri*) powder and soybean oil affected the pH of the beef patties significantly ($p < 0.01$). Increasing the level of Juumyit (*Allium hookeri*) powder and soybean oil decreased the pH of the beef patties, because the pH of Juumyit (*Allium hookeri*) powder was 6.02. The R^2 value was calculated as 0.7918, and indicated that the model equation had good prediction capability.

Cooking properties

Cooking loss varied between 3.26~5.17%. The beef patties were fit to a linear model on the cooking loss, whereas no significant increases were detected ($p > 0.05$). The rate of reduction in diameter and thickness varied between 1.04~5.63% and 1.67~20.24%. The beef patties were fit to a quadratic model on the diameter and thickness reduction, whereas no significant differences were detected ($p > 0.05$).

In general, cooking loss of a meat product is influenced by its ability to retain moisture and fat during cooking [11]. Patties also tend to shrink during cooking, due to the denaturation of meat proteins and loss of water and fat. Alakali., *et al*. [12] also found that patties shrunk after cooking due to the denaturation of muscle proteins and partly from the evaporation of water and loss of melted fat and juice.

Hunter color values

The addition of Juumyit (*Allium hookeri*) powder and soybean oil to the beef patties significantly affected the hunter color values ($p < 0.05$) with satisfactory R^2 values. Increasing the level of Juumyit (*Allium hookeri*) powder and soybean oil increased lightness (L) and yellowness (b) of the beef patties. The bright yellow color of Juumyit (*Allium hookeri*) powder presumably caused the higher L and b values of the beef patties. The redness (a) indicated that the addition of Juumyit (*Allium hookeri*) powder and soybean oil decreased the value.

Thus, the increase in Juumyit (*Allium hookeri*) powder resulted in the increase in lightness of mainly determined by the presence of denatured-globin hemochromes, which are formed as results of high temperatures, colored maillard products upon heating, physicochemical state of proteins and other meat components [13]. Garcia., *et al*. [14] reported similar results for burgers with added tomato powder and concluded that these differences could be a consequence of the color changes caused by the maillard reaction during cooking.

Sample No.	Soybean oil (g)	Juumyit powder (g)	Response		
			L	a	b
1	1.00	3.00	36.35 ± 1.09	10.05 ± 0.20	13.22 ± 0.39
2	13.00	3.00	41.58 ± 0.41	6.32 ± 0.18	16.81 ± 0.50
3	1.00	15.00	36.35 ± 0.72	9.71 ± 0.29	12.91 ± 0.38
4	13.00	15.00	41.86 ± 1.25	6.08 ± 0.18	16.68 ± 0.50
5	1.00	9.00	36.71 ± 0.47	9.67 ± 0.29	12.88 ± 0.38
6	13.00	9.00	41.83 ± 1.10	6.10 ± 0.18	16.94 ± 0.33
7	7.00	3.00	39.80 ± 1.19	8.02 ± 0.24	14.48 ± 0.43
8	7.00	15.00	39.91 ± 0.79	7.77 ± 0.23	14.74 ± 0.44
9	7.00	9.00	39.21 ± 0.78	7.63 ± 0.22	14.59 ± 0.43
10	7.00	9.00	39.25 ± 1.17	7.91 ± 0.23	14.21 ± 0.42

Table 4: *Hunter color values of the beef patties with Juumyit (Allium hookeri) powder.*

Response	Model	Mean ± S.D.	R^{2} 1)	F-value 2)	Prob > F	Polynomial equation 3)
L	Linear	39.28 ± 0.37	0.9779	154.90***	0.0001	39.29 + 2.64A + 0.065B
a	Linear	7.93 ± 0.15	0.9925	460.49***	0.0001	7.93-1.82A-0.14B
b	Linear	14.75 ± 0.30	0.9716	119.54***	0.0001	14.75 + 1.90A-0.030B

Table 5: *Analysis of the predicted model equation for hunter color values of the beef patties with Juumyit (Allium hookeri) powder.*

1) $0 \leqq R^2 \leqq 1$, *close to 1 indicates the regression line fits the model.*

*2) *p<0.05, **p < 0.01, ***p < 0.001.*

3) A: Juumyit (Allium hookeri) powder, B: Soybean oil

Texture characteristics

The beef patties were fit to a linear model on all texture parameters, and the differences were significant ($p < 0.05$) with satisfactory R^2 values. The addition of Juumyit (*Allium hookeri*) powder significantly increased hardness of the beef patties and other related parameters such as adhesiveness and cohesiveness, whereas soybean oil significantly decreased. The springiness of the beef patties significantly decreased with the increase in Juumyit (*Allium hookeri*) powder and soybean oil. Juumyit (*Allium hookeri*) powder and soybean oil also significantly decreased the chewiness and gumminess as seen in the springiness.

Since fat positively influences the binding capacity and texture properties of meat products, reduction of the fat levels can lead to unacceptable texture, especially in emulsifies patties [15]. Aleson-Carbonell., *et al*. [16] also suggested that the texture properties of a meat product are determined by the ability of its protein matrix to retain the water and bind fat.

Sample No.	Soybean oil (g)	Juumyit powder (g)	Response					
			Hardness (N)	Adhesiveness (g×s)	Springiness (mm)	Chewiness (N×mm)	Gumminess (N)	Cohesiveness
1	1.00	3.00	4065.70 ± 16.56	-457.45 ± 9.86	0.90 ± 0.03	2517.51 ± 10.96	3361.15 ± 14..71	0.43 ± 0.07
2	13.00	3.00	4907.95 ± 14.58	-59.15 ± 6.18	0.78 ± 0.03	1303.82 ± 12.89	1838.61 ± 12.32	0.54 ± 0.11
3	1.00	15.00	3901.10 ± 12.99	-359.55 ± 18.17	0.86 ± 0.02	1948.66 ± 19.24	2390.20 ± 12.45	0.46 ± 0.01
4	13.00	15.00	4993.15 ± 12.19	-149.40 ± 16.52	0.80 ± 0.01	1288.85 ± 12.58	1874.29 ± 13.20	0.54 ± 0.09
5	1.00	9.00	4214.55 ± 15.19	-341.70 ± 12.74	0.85 ± 0.04	1925.87 ± 13.98	2178.13 ± 19.48	0.45 ± 0.07
6	13.00	9.00	4943.20 ± 16.65	-105.15 ± 12.61	0.75 ± 0.04	1551.30 ± 12.34	1493.58 ± 17.76	0.55 ± 0.07
7	7.00	3.00	4777.50 ± 15.88	-190.15 ± 14,92	0.82 ± 0.01	1818.32 ± 12.06	2137.14 ± 12.69	0.55 ± 0.12
8	7.00	15.00	4389.20 ± 17.37	-269.75 ± 18.06	0.81 ± 0.07	1690.20 ± 14.42	1905.39 ± 12.47	0.50 ± 0.16
9	7.00	9.00	4521.30 ± 13.24	-244.10 ± 14.75	0.84 ± 0.03	1780.20 ± 11.84	2049.79 ± 12.23	0.48 ± 0.07
10	7.00	9.00	4545.20 ± 14.35	-222.15 ± 14.99	0.81 ± 0.07	1792.19 ± 15.31	2086.45 ± 11.35	0.48 ± 0.06

Table 6: *Texture characteristics of the beef patties with Juumyit (Allium hookeri) powder.*

Response	Model	Mean ± S.D.	R^2 1)	F-value 2)	Prob > F	Polynomial equation 3)
Hardness	Linear	4525.89 ± 120.45	0.9231	41.99***	0.0001	4525.88 + 443.83A-77.95B
Adhesiveness	2FI	-239.86 ± 31.64	0.9554	42.85***	0.0002	-239.85 + 140.83A-11.99B-47.04AB
Springiness	Linear	0.82 ± 0.021	0.8079	14.72**	0.0031	0.82-0.047A-(5.000E + 003)B
Chewiness	Linear	1761.69 ± 166.25	0.8273	16.77**	0.0021	1761.69-374.68A-118.66B
Gumminess	Linear	2131.47 ± 324.50	0.6649	6.95*	0.0218	2131.47-453.83A-194.50B
Cohesiveness	Linear	0.50 ± 0.024	0.7841	12.71**	0.0047	0.50 + 0.048A-(3.333E + 003)B

Table 7: *Analysis of the predicted model equation for texture characteristics of the beef patties with Juumyit (Allium hookeri) powder.*

1) $0 \leqq R^2 \leqq 1$, *close to 1 indicates the regression line fits the model.*

*2) *p < 0.05, **p < 0.01, ***p < 0.001.*

3) A: Juumyit (Allium hookeri) powder, B: Soybean oil

Antioxidant activities

The antioxidant activities of the beef patties are shown in Table 8~9.

Sample No.	Soybean oil (g)	Juumyit powder (g)	Response	
			Total phenol (mg/g)	DPPH radical scavenging activity (%)
1	1.00	3.00	1.36 ± 0.07	14.33 ± 0.72
2	13.00	3.00	3.36 ± 0.17	40.60 ± 1.22
3	1.00	15.00	1.48 ± 0.07	14.24 ± 0.73
4	13.00	15.00	2.92 ± 0.09	36.95 ± 1.85
5	1.00	9.00	2.18 ± 0.10	13.89 ± 0.74
6	13.00	9.00	3.20 ± 0.10	40.74 ± 2.04
7	7.00	3.00	2.54 ± 0.08	28.22 ± 1.41
8	7.00	15.00	2.84 ± 0.14	29.41 ± 1.47
9	7.00	9.00	2.76 ± 0.14	27.97 ± 1.40
10	7.00	9.00	2.80 ± 0.11	32.45 ± 1.62

Table 8: *Antioxidant activities of the beef patties with Juumyit (Allium hookeri) powder.*

Response	Model	Mean ± S.D.	R^2 1)	F-value 2)	Prob > F	Polynomial equation 3)
Total phenol	Linear	2.54 ± 0.34	0.8079	14.72**	0.0031	2.54 + 0.74A-(3.333E + 003)B
DPPH radical scavenging activity	Linear	27.88 ± 2.35	0.9612	86.74***	<0.0001	27.88 + 12.64A-0.43B

Table 9: *Analysis of predicted model equation for antioxidant activities of the beef patties with Juumyit (Allium hookeri) powder.*

1) $0 \leqq R^2 \leqq 1$, *close to 1 indicates the regression line fits the model.*

*2) *p < 0.05, **p < 0.01, ***p < 0.001.*

3) A: Juumyit (Allium hookeri) powder, B: Soybean oil.

Total phenol content

The beef patties were fit to a linear model on the total phenol content, and with the satisfactory R^2 value (0.8079). The addition of Juumyit (*Allium hookeri*) powder significantly increased total phenol content of the beef patties ($p < 0.01$), and Juumyit (*Allium hookeri*) powder had a greater effect on total phenol content of the beef patties than soybean oil.

DPPH radical scavenging activity

The beef patties were fit to a linear model on DPPH radical scavenging activity, and with the satisfactory R^2 value (0.9612). The addition of Juumyit (*Allium hookeri*) powder significantly increased DPPH radical scavenging activity of the beef patties (0.001), and Juumyit (*Allium hookeri*) powder had a greater effect on DPPH radical scavenging activity of beef patties than soybean oil.

Sensory properties

Sensory properties of the beef patties are shown in Table 10~11. All formulations scored well, and significant differences were seen with quadratic effect of Juumyit (*Allium hookeri*) powder and soybean oil on all sensory parameters ($p < 0.05$).

The preference of color was significantly increased with a satisfactory R^2 value (0.8940), and the effects were curvilinear due to a significant interaction term. The preference of color was low initially, and gradually increased to moderate levels of Juumyit (*Allium hookeri*) powder and soybean oil, then decreased after that moderate levels (Figure 1). The quadratic effect of Juumyit (*Allium hookeri*) powder and soybean oil on preference of appearance, flavor, pungency and juiciness were also found to be significant ($p < 0.05$) as seen in color.

The preference of overall quality was significant ($p < 0.05$) with a satisfactory R^2 value (0.9024). Ridge analysis indicated that maximum overall quality preference score (6.13) could be obtained at 7.00 g of Juumyit (*Allium hookeri*) powder and 9.00 g of soybean oil.

Sample No.	Juumyit powder (g)	Soybean oil (g)	Response					
			Color	Appearance	Flavor	Pungency	Juiciness	Overall quality
1	3.00	1.00	3.57 ± 1.03	3.95 ± 1.47	3.81 ± 1.25	4.38 ± 1.16	4.10 ± 1.48	4.19 ± 1.33
2	3.00	13.00	4.10 ± 0.89	4.38 ± 1.36	3.71 ± 1.45	4.29 ± 1.06	4.14 ± 1.06	4.52 ± 1.08
3	15.00	1.00	3.62 ± 1.20	3.71 ± 0.85	3.86 ± 0.96	3.48 ± 1.54	3.24 ± 1.14	3.33 ± 1.06
4	15.00	13.00	3.81 ± 0.81	3.38 ± 1.16	3.86 ± 1.42	3.29 ± 1.06	3.62 ± 1.28	3.62 ± 1.07
5	9.00	1.00	4.48 ± 0.98	4.38 ± 1.40	4.29 ± 1.31	4.33 ± 1.24	4.05 ± 1.16	4.48 ± 0.98
6	9.00	13.00	3.90 ± 1.26	4.00 ± 0.84	3.90 ± 1.34	4.24 ± 1.37	3.95 ± 1.53	4.43 ± 1.50
7	3.00	7.00	4.05 ± 1.43	4.43 ± 1.40	4.81 ± 1.12	4.48 ± 0.93	4.48 ± 1.36	4.24 ± 1.37
8	15.00	7.00	4.14 ± 1.71	4.05 ± 1.32	4.95 ± 1.12	4.05 ± 1.80	4.19 ± 1.72	4.00 ± 1.52
9	9.00	7.00	5.05 ± 0.97	5.05 ± 1.20	5.00 ± 1.26	4.90 ± 1.22	4.81 ± 1.08	5.05 ± 1.12
10	9.00	7.00	5.24 ± 0.89	4.86 ± 1.01	4.71 ± 1.19	5.10 ± 1.09	5.29 ± 0.90	5.05 ± 0.97

Table 10: *Sensory properties of the beef patties with Juumyit (Allium hookeri) powder.*

	Model	Mean ± S.D.	R^2 1)	F-value 2)	Prob > F	Polynomial equation 3)
Color preference	Quadratic	4.17 ± 0.23	0.9834	47.53**	0.0012	$5.92 + 0.067A + 0.22B - 0.14AB - 1.22A^2 - 1.70B^2$
Appearance preference	Quadratic	4.22 ± 0.23	0.9820	43.63**	0.0014	$5.93 + 0.03A + 0.22B - 0.08AB - 1.21A^2 - 1.65B^2$
Flavor preference	Quadratic	4.24 ± 0.23	0.9825	44.83**	0.0013	$5.94 + 0.04A + 0.28B - 0.06AB - 1.18A^2 - 1.66B^2$
Pungency preference	Quadratic	4.24 ± 0.23	0.9834	47.44**	0.0012	$5.96 + 0.04A + 0.25B - 0.09AB - 1.24A^2 - 1.63B^2$
Juiciness preference	Quadratic	4.15 ± 0.20	0.9882	66.74***	0.0006	$5.99 + 0.03A + 0.29B - 0.17AB - 1.37A^2 - 1.69B^2$
Overall quality preference	Quadratic	4.23 ± 0.20	0.9870	60.61***	0.0007	$5.99 + 0.06A + 0.24B - 0.12AB - 1.23A^2 - 1.69B^2$

Table 11: *Analysis of predicted model equation for sensory properties of the beef patties with Juumyit (Allium hookeri) powder.*

1) $0 \leqq R^2 \leqq 1$, close to 1 indicates the regression line fits the model.

*2) *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.*

3) A: Juumyit (Allium hookeri) powder, B: Soybean oil.

Optimization of beef patty

Contour analysis was used to find the optimum formulation of the beef patty. The optimum levels of Juumyit (*Allium hookeri*) powder and soybean oil were determined by superimposing the significant contour plots of selected quality attributes (Figure 2). The optimum formulation of the beef patty was 8.83 g of Juumyit (*Allium hookeri*) powder and 5.88 g of soybean oil and all influencing variables were as follows; sensory scores for color, appearance, flavor, pungency, juiciness and overall quality preferences were 5.73, 5.73, 5.75, 5.75, 5.76 and 5.80. The desirability function approach is one of the most widely used methods for optimization, specifically when it concerns several response variables. The concept of desirability, introduced by Harrington [17], is a method for multicriteria optimization in industrial quality management. The basic idea of the desirability function approach is to transform a multiple response into a single response problem by means of mathematical transformations.

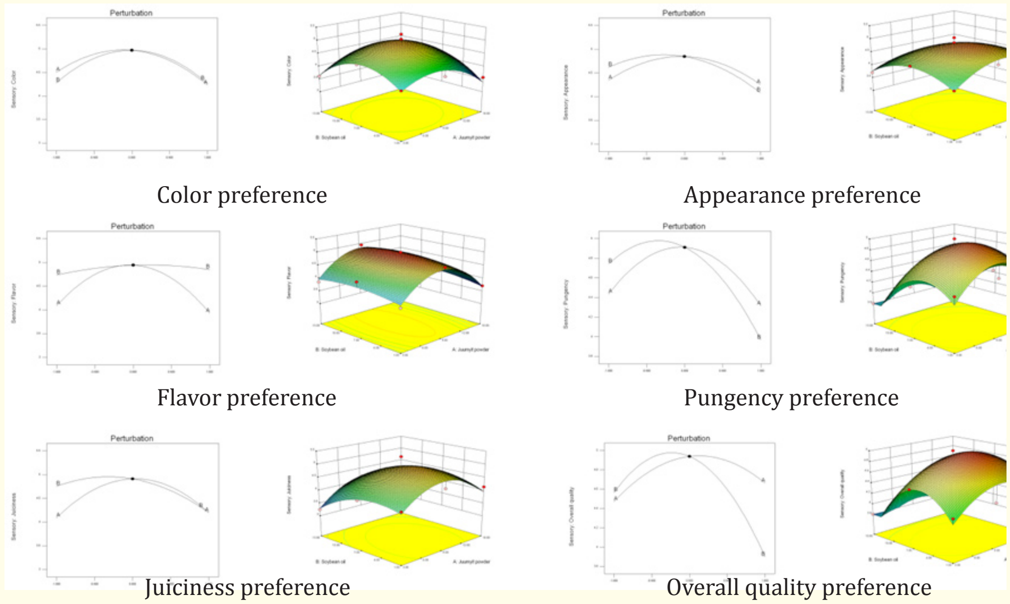
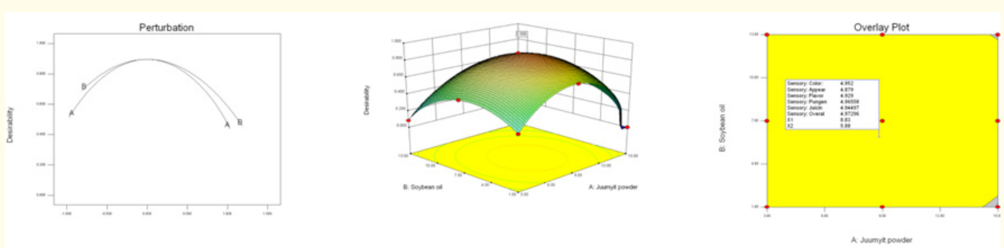


Figure 1: *Perturbation plot and response surface plot for the effect of Juumyit (Allium hookeri) powder (A) and soybean oil (B) on the sensory properties of the beef patties.*



Desirability

Figure 2: *Perturbation plot, response surface plot and overlay plot of an optimized beef patty with Juumyit (Allium hookeri) powder.*

Physicochemical and mechanical characteristics of an optimized beef patty with Juumyit (*Allium hookeri*) powder

The physicochemical and mechanical characteristics of an optimized beef patty with Juumyit (Allium hookeri) powder are shown in Table 12~13.

pH

The pH of JP (5.65) was slightly lower than CP (5.91), and significant difference ($p < 0.001$) was found in the pH. These results occurred because pH of the acidic Juumyit (*Allium hookeri*) powder was 6.02.

Characteristic	JP[1)]	CP	t-value[2)]
pH	5.65 ± 0.17	5.91 ± 0.02	0.14***
Cooking loss (%)	4.68 ± 0.10	6.11 ± 0.38	4.28*
Diameter reduction (%)	5.78 ± 0.59	10.54 ± 1.56	2.57*
Thickness reduction (%)	18.76 ± 0.50	21.97 ± 1.32	5.34*

Table 12: *Physicochemical characteristics of an optimized beef patty with Juumyit (Allium hookeri) powder.*
[1)]JP (Juumyit patty), an optimized beef patty added with Juumyit (Allium hookeri) powder; CP, beef patty without antioxidant.
*[2)]*p < 0.05, **p < 0.01, ***p < 0.001.*

	Characteristic	JP[1)]	CP	t-value[2)]
Hunter color	L	37.36 ± 1.40	39.39 ± 0.30	2.98*
	a	10.74 ± 0.34	10.28 ± 0.26	0.04*
	b	15.43 ± 1.23	13.82 ± 0.63	7.36*
Texture	Hardness (N)	4740.25 ± 133.92	6560.75 ± 150.28	7.69***
	Adhesiveness (g×s)	-175.88 ± 4.54	-158.38 ± 4.26	1.11**
	Springiness (mm)	0.80 ± 0.03	0.94 ± 0.02	1.04***
	Chewiness (N×mm)	1596.20 ± 46.88	2698.70 ± 77.15	0.16***
	Gumminess (N)	1935.04 ± 51.05	3082.54 ± 86.58	4.17***
	Cohesiveness	0.60 ± 0.03	0.65 ± 0.02	4.00*

Table 13: *Mechanical characteristics of an optimized beef patty with Juumyit (Allium hookeri) powder.*
[1)]JP (Juumyit patty), an optimized beef patty added with Juumyit (Allium hookeri) powder; CP, beef patty without antioxidant.
*[2)]*p < 0.05, **p < 0.01, ***p < 0.001.*

Cooking properties

Cooking loss of JP (4.68%) was lower than CP (6.11%), and significant difference ($p < 0.05$) was observed in the cooking loss. The rate of reduction in diameter and thickness of JP (5.78% and 10.54%) was lower than CP (10.54% and 21.97%), and significant differences were found ($p < 0.05$). In general, shrinkage in patties during heating is caused by muscle protein denaturation and partly from the evaporation of water and drainage of melted fat and juices. These physical changes are influenced by the meat product properties [12].

Hunter color values

JP was slightly lighter (37.36) and redder (10.74) than CP, and the b value was higher in JP (15.43) compared to CP (13.82). The L, a, and b values were significantly different between JP and CP ($p < 0.05$).

Texture characteristics

All texture parameters (hardness, adhesiveness, springiness, chewiness, gumminess, cohesiveness) were significantly lower in JP (4740.25, -175.88, 0.80, 1596.20, 1935.04, 0.60) than CP ($p < 0.05$). Thus, JP had a softer texture than CP. These results suggested that the addition of Juumyit (*Allium hookeri*) powder to beef patty can improve their texture due to the ability of Juumyit (*Allium hookeri*) powder to keep moisture and fat in patty matrix.

Antioxidant activities of an optimized beef patty with Juumyit (*Allium hookeri*) powder

The antioxidant activities of the beef patties are shown in Table 14.

Characteristic	JP[1)]	CP	t-value[2)]
Total phenol (mg/g)	2.77 ± 0.14	0.39 ± 0.02	16.829*
DPPH radical scavenging activity (%)	31.30 ± 1.57	6.65 ± 0.33	15.365*

Table 14: *Antioxidant activities of an optimized beef patty with Juumyit (Allium hookeri) powder.*
[1)]JP (Juumyit patty), an optimized beef patty added with Juumyit (Allium hookeri) powder; CP, beef patty without antioxidant.
[2)]$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.*

Total phenol content

Total phenol content of JP was higher (2.77) than CP (0.39), and significant difference was observed ($p < 0.05$). Phenolic compounds are prevalent as secondary metabolites. They exist as various structures and molecular weights and are related to the innate flavor of food. Phenol compounds easily bind with proteins and induce various physiologic activities in microbes that retard microbial growth [18].

DPPH radical scavenging activity

DPPH radical scavenging activity of JP was higher (31.30) than CP (6.65), and significant difference was observed ($p < 0.05$). DPPH radical scavenging activity is the most widely used for determination of the antioxidant activity. When DPPH is scavenged and transformed into DPPH-H, the color of the solution turns from purple to yellow and the degree of change can be detected by the degree of decay [19].

Sensory properties of an optimized beef patty with Juumyit (*Allium hookeri*) powder

Sensory properties of an optimized beef patty with Juumyit (*Allium hookeri*) powder are shown in Table 15. There were significant differences ($p < 0.05$) between JP and CP. There was a higher sensory score of color (4.95), flavor (4.90), pungency (4.90), juiciness (4.86) and overall quality (4.71) preference, than CP. These results suggested that the addition of Juumyit (*Allium hookeri*) powder to beef patty can improve their sensory properties because Juumyit (*Allium hookeri*) powder produce sulfury odor which in foods is not considered as off-odor.

	JP[1)]	CP	t-value[2)]
Color preference	4.95 ± 1.07	4.10 ± 1.04	0.10*
Appearance preference	4.00 ± 0.95	5.29 ± 1.01	3.59*
Flavor preference	4.90 ± 0.77	4.24 ± 1.09	2.88*
Pungency preference	4.90 ± 1.00	4.14 ± 0.96	0.02*
Juiciness preference	4.86 ± 1.28	4.05 ± 1.28	0.15*
Overall quality preference	4.71 ± 0.96	4.10 ± 1.00	0.10*

Table 15: *Sensory properties of an optimized beef patty with Juumyit (Allium hookeri) powder.*
[1)]JP (Juumyit patty), an optimized beef patty added with Juumyit (Allium hookeri) powder; CP, beef patty without antioxidant.
[2)]$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.*

Physicochemical and mechanical characteristics of uncooked optimized beef patty with Juumyit (*Allium hookeri*) powder during storage

The physicochemical and mechanical characteristics of uncooked optimized beef patty with Juumyit (*Allium hookeri*) powder during storage are shown in Table 16~18.

Storage time (Day)		Sample		t-value3)
		JP1)	CP	
pH	0	5.47 ± 0.02B2)	5.71 ± 0.01B	-15.18*
	3	5.59 ± 0.01A	5.78 ± 0.01A	37.00*
	6	5.61 ± 0.00A	5.82 ± 0.02A	-13.67*
	9	5.40 ± 0.00C	5.30 ± 0.01C	21.00*
	12	4.98 ± 0.01D	4.95 ± 0.01D	5.66*
	15	4.75 ± 0.02E	4.86 ± 0.02E	-5.19*
F-value		1578.12***	2009.31***	
VBN4)	0	14.28 ± 0.23B	15.28 ± 0.23B	-4.33*
	3	14.44 ± 0.23B	15.57 ± 0.28B	-4.46*
	6	14.54 ± 0.27B	15.77 ± 0.29B	-4.38*
	9	15.40 ± 0.25AB	16.42 ± 0.23AB	-4.32*
	12	15.94 ± 0.33A	16.56 ± 0.33AB	-1.87
	15	16.04 ± 0.33A	17.16 ± 0.36A	-3.25
F-value		16.40**	11.85**	
TBA5)	0	0.15 ± 0.01E	0.31 ± 0.01E	-14.76*
	3	0.21 ± 0.01D	0.42 ± 0.01D	-19.23*
	6	0.26 ± 0.01D	0.52 ± 0.02C	-16.44*
	9	0.32 ± 0.01C	0.58 ± 0.02BC	-14.15**
	12	0.43 ± 0.01B	0.65 ± 0.01B	-20.13**
	15	0.52 ± 0.02A	0.91 ± 0.03A	-15.80**
F-value		272.81***	224.23***	

Table 16: *Changes in physicochemical characteristics of uncooked beef patties with Juumyit (Allium hookeri) powder during storage.*

1)JP (Juumyit patty), an optimized beef patty added with Juumyit (Allium hookeri) powder; CP, beef patty without antioxidant.

2)A, B, C, D, E means in a row followed by different superscripts are significantly different ($p < 0.05$) by Duncan's multiple range test.

3)$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.*

4)VBN, Volatile basic nitrogen (mg/%)

5)TBA, 2-thiobarbituric acid (MA mg/kg)..

Storage time (Day)		Sample		t-value3)
		JP1)	CP	
L	0	40.78 ± 0.94A2)	39.23 ± 0.98B	3.08*
	3	36.41 ± 2.04AB	41.29 ± 1.28AB	-3.50*
	6	33.72 ± 1.61B	41.56 ± 2.25AB	-4.90*
	9	34.40 ± 1.01B	39.71 ± 1.26B	-5.71**
	12	36.91 ± 0.66AB	41.00 ± 1.00AB	-5.91**
	15	39.82 ± 1.64A	45.13 ± 1.28A	-4.42*
F-value		12.23***	6.55**	

a	0	8.65 ± 0.13A	10.55 ± 0.26A	-11.47**
	3	7.01 ± 0.33B	8.52 ± 0.43B	-4.85*
	6	5.52 ± 0.17C	7.44 ± 0.09C	-17.69***
	9	4.41 ± 0.29D	6.72 ± 0.18C	-11.62**
	12	3.84 ± 0.26D	5.37 ± 0.25D	-7.35**
	15	3.01 ± 0.18E	3.83 ± 0.25AE	-4.69*
F-value		233.48***	241.80***	
b	0	15.23 ± 0.45D	12.19 ± 0.63B	6.77**
	3	16.26 ± 0.15C	13.81 ± 0.36AB	10.86**
	6	17.47 ± 0.40B	14.47 ± 0.44A	8.75**
	9	18.06 ± 0.19B	13.98 ± 0.64AB	10.56**
	12	18.00 ± 0.09B	14.17 ± 0.70A	9.36*
	15	19.59 ± 0.28A	13.54 ± 0.51AB	17.99***
F-value		82.81***	6.10**	

Table 17: *Changes in hunter color values of uncooked beef patties with Juumyit (Allium hookeri) powder during storage.*

1)JP (Juumyit patty), optimized beef patty added with Juumyit (Allium hookeri) powder; CP, beef patty without antioxidant.

2)A, B, C, D, E, means in a row followed by different superscripts are significantly different (p < 0.05) by Duncan's multiple range test.

*3)*p < 0.05, **p < 0.01, ***p < 0.001.*

Storage time (Day)		**Sample**		**t-value3)**
		JP1)	**CP**	
Hardness (N)	0	4740.25 ± 133.92B2)	6560.32 ± 150.28B	-9.044*
	3	5034.14 ± 151.02AB	7828.29 ± 234.84AB	-10.007*
	6	5191.88 ± 145.37AB	7910.45 ± 213.58AB	-10.522*
	9	5557.46 ± 161.16AB	7674.43 ± 214.88AB	-7.881*
	12	5723.75 ± 154.54AB	6781.50 ± 203.44A	-4.140
	15	5809.38 ± 174.28A	6386.98 ± 197.99A	-2.190
F-value		7.516*	11.365**	
Adhesiveness (g×s)	0	-175.88 ± 4.54AB	-159.38 ± 4.26	-2.650
	3	-160.49 ± 4.81A	-154.29 ± 4.78	-1.071
	6	-164.17 ± 4.76AB	-152.69 ± 4.12	-1.824
	9	-166.10 ± 4.81AB	-148.02 ± 4.73	-2.680
	12	-195.76 ± 6.09BC	-147.87 ± 4.73	-6.211*
	15	-212.78 ± 6.59C	-146.42 ± 3.95	-8.637*
F-value		15.245**	1.241	

Springiness (mm)	0	0.80 ± 0.03^{ABC}	0.94 ± 0.02	-3.883
	3	0.87 ± 0.03^{A}	0.97 ± 0.05	-1.715
	6	0.85 ± 0.02^{AB}	0.98 ± 0.05	-2.414
	9	0.84 ± 0.03^{AB}	1.01 ± 0.03	-4.007
	12	0.69 ± 0.02^{BC}	1.02 ± 0.04	-7.379*
	15	0.63 ± 0.03^{C}	1.03 ± 0.03	-9.428*
F-value		12.982**	0.802	
Chewiness	0	$1596.20 \pm 46.88^{A2)}$	2698.70 ± 77.15^{B}	-12.212*
	3	1760.28 ± 52.81^{A}	3304.28 ± 99.13^{A}	-20.634**
	6	1779.89 ± 53.40^{A}	3356.56 ± 97.34^{A}	-14.201*
	9	1944.19 ± 52.49^{A}	3129.42 ± 97.01^{AB}	-10.745*
	12	1940.10 ± 54.32^{A}	2890.02 ± 86.70^{AB}	-9.416*
	15	1938.05 ± 56.20^{A}	2779.47 ± 86.16^{B}	-8.180*
F-value		7.098*	9.284**	
Gumminess	0	1935.04 ± 51.05	3082.54 ± 86.58^{C}	-11.417*
	3	2027.62 ± 60.83	4242.40 ± 127.27^{AB}	-15.701*
	6	2070.77 ± 55.91	4307.69 ± 116.30^{A}	-17.335*
	9	1965.31 ± 58.96	4086.88 ± 122.61^{AB}	-15.594*
	12	1898.58 ± 58.85	3965.26 ± 122.92^{AB}	-15.165*
	15	1834.11 ± 55.02	3488.23 ± 108.13^{BC}	-13.634*
F-value		2.652	17.484**	
Cohesiveness	0	0.60 ± 0.03	0.65 ± 0.02	-1.387
	3	0.58 ± 0.03	0.64 ± 0.03	-1.414
	6	0.56 ± 0.04	0.64 ± 0.04	-1.414
	9	0.59 ± 0.03	0.64 ± 0.02	-1.387
	12	0.56 ± 0.04	0.63 ± 0.02	-1.565
	15	0.56 ± 0.02	0.63 ± 0.03	-1.941
F-value		0.295	0.074	

Table 18: *Changes in texture characteristics of uncooked beef patties with Juumyit (Allium hookeri) powder during storage Mean ± S.D.*

1)JP (Juumyit patty), optimized beef patty added with Juumyit (Allium hookeri) powder; CP, beef patty without antioxidant.

2)A, B, C, D, E, means in a row followed by different superscripts are significantly different (p < 0.05) by Duncan's multiple range test.

*3)*p < 0.05, **p < 0.01, ***p < 0.001.*

pH

The pH of JP ranged from 4.75 to 5.61, and there were significant differences ($p < 0.05$) between JP and CP. The pH of JP significantly decreased after 6 days of storage, and pH of CP showed a similar trend during storage. The decrease in pH was due to the protonation of the basic amino groups of the meat protein during cooking process [20]. The addition of various powder resulted in pH diminution on raw patties, and it is observed in decrease on storage day 10 of raw patties.

Volatile basic nitrogen

The significant differences ($p < 0.05$) between JP and CP were observed after 0, 3, 6 and 9 days of storage, but VBN values of JP and CP were not significantly different at day 12 and 15. VBN value of JP had significantly ($p < 0.01$) increased from 14.28 to 16.04 with increasing storage time, and CP also increased significantly ($p < 0.01$). VBN compounds in meat contain mainly ammonia, trimethylamine and dimethylamine, and the levels of total VBN compounds increase with spoilage by either bacterial or enzymic degradation [21]. Total VBN content in meat, as an important reference index, is used to evaluate freshness of meat.

2-Thiobarbituric acid

TBA values of JP and CP increased ($p < 0.001$) by the end of storage. Overall, JP had significantly ($p < 0.05$) lower TBA values than CP, and ranged from 0.15 to 0.52 during the observation period, while control remained at the higher TBA values. These results indicate that Juumyit (*Allium hookeri*) powder significantly ($p < 0.05$) affected TBA values of uncooked patties upon refrigerated storage, and could increase the shelf life of foods, especially of lipids and lipid containing foods [22].

Hunter color values

There were significant differences ($p < 0.05$) between JP and CP during storage. The L values of JP significantly ($p < 0.001$) decreased from 40.78 to 33.72, and increased after 6 days of storage. The values significantly ($p < 0.001$) decreased with an increase in storage time, while control had the higher values ($p < 0.001$). The b values of JP significantly ($p < 0.001$) increased from 15.23 to 19.59 at longer storage times, while CP had the lower b values ($p < 0.01$). It is important to color for meat product as a criterion of judgment in consumers purchase. Morales and Jimenez-Perez [23] found that discoloration of meat was caused by oxidation processes and enzymatic reducing systems.

Texture characteristics

Hardness and chewiness of JP was significantly ($p < 0.05$) increased with an increase in storage time, while CP was decreased ($p < 0.01$) at longer storage times. Adhesiveness of JP and control were increased, while gumminess and cohesiveness of JP and CP were decreased with no significant differences during storage. Springiness of JP were significantly ($p < 0.01$) decreased, while CP was increased with no significant differences. All texture parameters of JP were lower than control in storage time, but there were no significant differences except on hardness and chewiness ($p < 0.05$).

Antioxidant activities of uncooked optimized beef patty with Juumyit (*Allium hookeri*) powder during storage

The antioxidant activities of uncooked optimized beef patty with Juumyit (*Allium hookeri*) powder during storage are shown in Table 19.

Total phenol content

The total phenolic compounds in JP were significantly ($p < 0.05$) higher than CP during the observation period. These results indicate that Juumyit (Allium hookeri) powder has antioxidative effect through interactions with the phenol ring and has a resonance stabilization effect. Phenol compounds easily bind with proteins and induce various physiologic activities in microbes that retard microbial growth [18].

DPPH radical scavenging activity

DPPH scavenging activity is the most widely used for determination of the antioxidant activity of extracts [24]. DPPH radical scavenging activity of JP and CP were significantly ($p < 0.05$) increased with an increase in storage time. DPPH radical scavenging activity of JP was significantly ($p < 0.05$) higher than CP during the observation period.

Storage time (Day)		Sample		t-value[3)]
		JP[1)]	CP	
Total phenol (mg/g)	0	2.77 ± 0.14	0.39 ± 0.02	16.829*
	3	2.79 ± 0.14	0.41 ± 0.03	16.623*
	6	2.84 ± 0.11	0.39 ± 0.02	21.913*
	9	2.79 ± 0.14	0.40 ± 0.02	16.900*
	12	2.80 ± 0.13	0.44 ± 0.03	17.689*
	15	2.82 ± 0.13	0.41 ± 0.01	18.484*
F-value		0.035	0.671	
DPPH radical scavenging activity (%)	0	31.30 ± 1.57[A2)]	6.65 ± 0.33[A]	15.365*
	3	25.10 ± 1.26[AB]	4.55 ± 0.14[B]	16.210*
	6	25.05 ± 0.75[AB]	2.86 ± 0.09[C]	31.362*
	9	23.78 ± 0.71[B]	2.57 ± 0.13[C]	29.385*
	12	23.06 ± 1.15[B]	2.53 ± 0.10[C]	30.457*
	15	22.41 ± 1.12[B]	2.42 ± 0.12[C]	17.747*
F-value		8.043*	96.801***	
Total plate count	0	12.39 ± 0.25	16.54 ± 0.34[B2)]	-13.83**
	3	12.62 ± 0.26	16.70 ± 0.35[B]	-13.29**
	6	12.76 ± 0.27	17.48 ± 0.36[AB]	-14.83**
	9	12.80 ± 0.27	17.66 ± 0.37[AB]	-15.09**
	12	12.90 ± 0.12	18.38 ± 0.38[A]	-19.38*
	15	13.40 ± 0.28	18.89 ± 0.29[A]	-19.40**
F-value		3.69	13.87**	

Table 19: *Changes in antioxidant activities of uncooked beef patties with Juumyit (Allium hookeri) powder during storage Mean ± S.D.*

[1]JP (Juumyit patty), optimized beef patty added with Juumyit (Allium hookeri) powder; CP, beef patty without antioxidant.

[2]A, B, C, D, E, means in a row followed by different superscripts are significantly different (p < 0.05) by Duncan's multiple range test.

*[3]*p < 0.05, **p < 0.01, ***p < 0.001.*

Total aerobic plate count

The populations of aerobic bacteria in JP showed an increase with no significant differences, which was significantly ($p < 0.05$) lower than CP, reaching at 13.40 $\log_{10}$ CFU/g by the end of storage. In contrast, populations of aerobic bacteria in control were significantly increased ($p < 0.01$). These results showed that Juumyit (*Allium hookeri*) powder had antimicrobial activities, and the shelf life of uncooked patties could be extended by the addition of Juumyit (*Allium hookeri*) powder. These results may be due to the presence of organosulfur compounds in Juumyit (*Allium hookeri*) powder, which are known to possess antibacterial properties [25].

Conclusions

The purpose of this study was to determine the optimum mixing ratio of Juumyit (*Allium hookeri*) powder and soybean oil for the production of a particular type of low-fat functional patty, namely Juumyit (*Allium hookeri*) patties, by considering physicochemical and mechanical characteristics, antioxidant activities and sensory properties. The following quality attributes were significantly affected by Juumyit (*Allium hookeri*) powder and soybean oil; pH, cooking loss, the rate of reduction in diameter and thickness, hunter color values, texture, antioxidant activities and sensory properties of beef patties. Specifically, optimized beef patty produced with 5.88g of soybean oil and 8.83g of Juumyit (*Allium hookeri*) powder exhibited higher cooking yields and overall acceptability than control ($p < 0.05$). As results, Juumyit (*Allium hookeri*) powder added to a beef patty was kept as possible while keeping satisfactory eating quality. Juumyit (*Allium hookeri*) powder could be used as a preventive agent with a respect to limiting the effects of free-radicals, which can result in health problems. Also, it is possible to use Juumyit (*Allium hookeri*) powder in beef or other food products to inhibit contamination from aerobes and free radical oxidation, as well as obstruct lipid oxidation. These results obtained would be useful for meat industry which tends to decrease the fat contents in beef patty to a level.

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