Substitution of peanut protein for soy protein as a non-meat binder in emulsion-type sausage production

Hien Thi Nguyen, Minh Nguyen Tang, Dong Phuong Doan, Van Viet Man Le

***Abstract* — In this study, peanut protein concentrate (PPC) was substituted for soy protein concentrate (SPC) in Vietnam emulsion-type sausage manufacture. Peanut protein concentrates yielded from the conventional and the combined ultrasonic and enzymatic extraction were used in the preparation of sausage samples PPC1 and PPC2, respectively. Soy protein concentrate was used in the sausage sample SPC as a control. Ten sausage samples including PPC1, PPC2, SPC and seven commercial samples in which soy protein (SP) was used were tested in three experiments. Instrumental Texture Profile Analysis (TPA), Flash Profile, and 9-point hedonic scale were conducted to observe sample differences. The instrumental TPA results indicated that PPC1 and PPC2 were insignificantly different from the control and one of the SP-added samples for hardness, springiness, and adhesiveness; but significantly for cohesiveness. In the first two sensory dimensions, assessors discriminated samples into three distinct directions in which PPC1 and PPC2 were positioned closely to SPC and two commercial SP-added sausages. Preference map further showed the same percentage of satisfied consumers - clustered with partial least square (PLS) regression - toward PPC1, PPC2, SPC, and the two commercial SP-added sausages. In general, the results proposed the potential use of PPC as a substitute for SP in Vietnam emulsion-type sausage production.**

***Index Terms* — emulsion-type sausages, peanut protein concentrate, soy protein, texture properties, preference map.**

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1 INTRODUCTION

Emulsion-type sausage is made from comminuted and well-homogenized cured meats, fatty tissue, water and seasonings [22]. It is a membrane matrix of denatured protein gel in which fat particles and moisture are entrapped. The retention of this structure is mainly dependent on the binding capacity of meat protein. Due to the use of filler meats for lower production cost and the necessity of cutting down the amount of calories and animal fat from meat, non-meat binders such as starch, milk or soy protein are used to compensate for the loss of salt-soluble myofibrillar meat proteins. These non-meat binders are expected to show desirable functional properties (binding characteristics, gelation, and emulsifying properties) to enhance a meat emulsion [14]. In Vietnam emulsion-type sausages, soy protein (SP) is widely used as a non-meat binder.

Peanut oil extraction yields defatted peanut flour (DPF) that is rich in protein (approximate 57.0% protein content [4]) and used in animal feed or fertilizer in developing countries. However, the utilization of this protein-rich source in food products for human consumption is more effective than conversing it into animal protein [17]. Many studies on nutritive value of peanut protein showed its potential use in protein-fortified products. True digestibility, indices of protein quality of peanut flour and those of soy protein isolate (protein efficiency ratio and relative nutritive value) were also comparable [24]. Peanut amino acid profile is considered as a good choice when matched with cereal products such as breads [13], muffins [18], vegetable protein mixtures for infants after weaning and preschool children [17]. The fact that the amino acid profiles of peanut protein was also comparable to that of soy protein also suggested the resemblance in functional properties between the two [30]. However, peanut protein concentrates prepared by ultrafiltration showed considerably higher water absorption capacities than similarly produced soy protein concentrates [3]. Prepared from DPF, peanut protein concentrate (PPC) containing 80% protein in a weight basis would be a potential protein ingredient [23, 30].

Before this study, PPC applications have been little observed in sausage products although peanut protein has been studied in meat systems. In the work of Aguilera, Rossi, Hiche and Chichester (1980)[1], DPF was extruded to yield texturized peanut protein whose water binding property was comparable to that of textured soy protein. The textured peanut proteins were then formularized in meat patties to evaluate organoleptic properties, which were not different from the all-meat control. Ziprin et al. (1981) [31] investigated the rancidity prevention and sensory quality of cooked beef patties extended with SPC and PPC. PPC showed higher antioxidative effectiveness than the control and the SPC in patties prepared from freshly ground beef. No significant differences were found in the flavor, juiciness, texture, and overall satisfaction of the beef-PPC patties and the beef-SPC. The increase of relative consistency of raw meat batters exchanged from zero to 30% with low-fat peanut flour showed the corporation of the protein additive in comminuted meat systems [27].

In this study, peanut protein was used as a non-meat binder in emulsion sausage product. A Control sample was also performed with soy protein. The obtained emulsion sausage products were then compared to emulsion sausage brands using soy protein. The comparison was based on textural, organoleptic, and hedonic characteristics of the final products.

2 MATERIALS AND METHODS

2.1 Materials

DPF was prepared from peanut kernels (Arachis hypogaea Linn, variety VD1) purchased from Research Institute for Oil and Oil Plants, HCMC, Vietnam. The preparation used included dehulling, drying, grinding, oil extracting using petroleum ether, fine grinding, and screening. DPF (8.61% moisture and 36.4% protein) was further processed to develop PPC (6.25% moisture and 78.17% protein) using alkali solution and isoelectric precipitation (coded PPC1). Another peanut protein preparation (PCC2 with 6.35% moisture and 84.35% protein) was also yielded from the same procedure assisted by ultrasound pretreatment (at 30 W/g, 50^{o}C in 15 mins) and enzyme pretreatment using IndiAge Neutra L (with the concentration of 30 IU/g at 50^{o}C in 60 mins) to improve peanut protein content in the extract. Major steps in the PPC production were described in the material of Altschul et al. (2013) [3].

To make emulsion sausage samples, PPC1, PPC2 and the commercial SPC (6.05% moisture and 79.24% protein; purchased from the Solae Company, St.Louis, Missouri, USA) were alternatively added to ground pork while mixing based on a commercial formulation. These three samples were processed at a manufacturer in Ho Chi Minh city, Vietnam. The used amounts of PPC1, PPC2 and SPC in sausage samples which were based on proposed ratios in the material of Savic (1985) were adjusted so that the same amount of the oilseed protein was obtained in the final samples. The process was as proposed by Savic (1985) with an adjustment: the sausages were finally heated in an oven to simulate the cooking process utilized by Vietnam emulsion sausage manufacturers. Seven other common sterilized sausages in the Ho Chi Minh market named Soy.A, Soy.B, Soy.C, Soy.S, Soy.T, Soy.V and Soy.X (being made from pork meat and used SPC as an additive) were also used to provide a commercial SP-added sausage space in which the three developed samples would be positioned.

2.2 Methods

The following list outlines the different types of graphics published in IEEE journals. They are categorized based on their construction, and use of color / shades of gray:

2.2.1 TPA

Texture Analyser LFRA 1000G (Brookfield) and TexturePro Lite v1.1 software were used to measure texture parameters of the samples. A cylindrical probe (35 mm height and 10 mm diameter) was set to apply force onto the samples in two cycle compression. 20% deformation was set up for all TPA tests. TPA parameters (hardness, cohesiveness, springiness, chewiness, adhesiveness, and gumminess) was calculated from the force-time curve in which hardness was defined as the first peak force rather than the area under the curve. The interpretation of these parameters can be found in de Huidobro, Miguel, Blázquez and Onega (2005) [6].

All the samples were cut into identical 15x15x20 mm^3 (LxWxH) cubes before instrumental tests. Each of the ten samples was tested four times using the four successive segments of the same tube of sausage.

2.2.2 Flash Profile

In this study, Flash Profile (FP) rather than conventional profiling was chosen to characterize sensory attributes of the emulsion-type sausage samples. One reason was that FP produces product spaces close to those from conventional profiling [2, 5, 8, 9]. In addition, the FP acceptance of using consumers for profiling products allows the exploitation of information on product perception through consumer vocabulary. This practice in which profiles provided by consumers permit to straightly connect hedonic judgments with sensory characteristics [11] and are comparable to those from trained panels [15, 29] is desirable in certain stages of product development process. FP can, therefore, be used as an adequate method in the context of consumer-centric perspective. [12, 28].

In the study, FP was carried out following the procedure proposed by Dairou et al. (2002)[5]. Ten consumers (18-23 yrs, 6 female) with the adequate frequency of using pork emulsion sausages assessed the samples arranged according to 10x10 Latin-square design. Bottle water and slicing cucumbers (peeled and removed the interior core) were served for palate cleansing. Giving the same rank to samples was open if no difference was perceived. Each sample was evaluated two times by each assessor in separate booths.

2.2.3 Preference test

A hundred and forty nine students (18-29 yrs, 89 female) consuming emulsion-type sausages at least once a week were recruited to evaluate overall liking of 10 sausage samples. Samples were rated individually using 9-point hedonic scale [19]. Bottle water and slicing cucumbers (peeled and removed the interior core) were also served for mouth cleaning between samples.

2.2.4 Statistical analysis

In the context that statistical power is decisive and the number of samples is greater than three, performing ANOVA followed by a large number of unplanned pairwise comparisons would increase the risk of making either type I or type II error. To compromise the two type of error, t-test presented in Ruxton and Beauchamp (2008) was performed on TPA data and hedonic scores to compare the three PPC1, PPC2, SPC to each other and to each of the commercial sausages (comparisons between commercial sausage samples were not of interest) [21].

For FP data, a two-factor ANOVA without interaction ($Attribute\_i = \varepsilon\_i + Product\_i + Judge\_i$) was run to identify descriptors for which there was a product effect (p-value≤0.05). The other descriptors (p-value>0.05) were eliminated from the original data. The reduced data was finally analyzed by Generalized Procrustes Analysis (GPA) [10] to obtain a product space. Product confidence intervals were visualized through ellipses [7], and product differences in 2-dimension space were tested by Hotelling's T2 test.

Partial least square (PLS) regressions described in the work of Tenenhaus, Pages, Ambroisine and Guinot (2005) were carried out to classify consumers based on how their hedonic judgments associated with the organoleptic properties. Finally, external preference mapping focused on an interested consumer segment was run.

All the statistical analyses were carried out using a trial version of XLSTAT (Version 2016.02.29253).

3 RESULTS AND DISCUSSION.

3.1 TPA

Texture parameters' means and standard errors of each sample are given in Table 1. There was no significant difference between SPC and PPC1 for hardness, adhesiveness, and springiness (P>0.05). Due to the fact that protein content affects hardness [20], this result was expected because protein content in the three final samples was kept unchanged. For gumminess, chewiness, and cohesiveness, significant differences were observed between SPC and PPC1. These parameters associate with the chewing and the breaking of a food which suggest insights into internal structures making the body of a product [16, 25]. This suggested that molecular links making up the body of PPC1 might be different from those of SPC. However, there was no difference detected between PPC2 and SPC for all the texture parameters.

PPC1 and PPC2 were different from Soy.A, Soy.S and Soy.T for most of the parameters. The least difference was between PPC1, PPC2 and Soy.V. The control samples were found non-significant different from Soy.A, Soy.C, Soy.V for all the parameters.

3.2 Flash Profile

Among 60 attributes used in characterizing the samples, there were 24 attributes significantly discriminating the samples (P<0.05). Data with these attributes were retained and analyzed by GPA. Descriptors signed with "1" referred to textural attributes which were evaluated by the senses of touch before chewing; and those with "2" referred to evaluation during chewing.

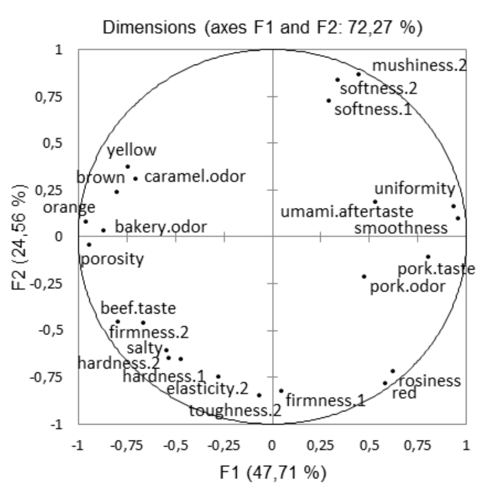

Figure 1. Sensory attribute correlation

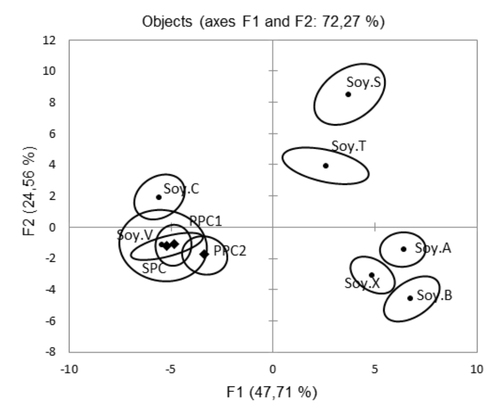

Figure 2. The distribution of 10 samples in sensory space

Table 1

Pair comparisons between PPC1, PPC2, SPC and commercial sausages for TPA parameters*

	Hardness	Adhesiveness	Gumminess	Chewiness	Cohesiveness	Springiness
			N		dimensionless	
PPC1	1.7803	0.0920	1.1052	0.9926	0.6200	0.8975
PPC2	1.8908	0.1605[PPC1]	1.0755	0.9556	0.5675[PPC1]	0.8875
SPC	1.7985	0.1193	0.9716[PPC1]	0.8699[PPC1]	0.5400[PPC1]	0.8950

Soy.A	1.6513^{PPC2}	0.1695^{PPC1}	$0.8638^{PPC1, PP2}$	$0.7848^{PPC1, PPC2}$	$0.5225^{PPC1, PPC2}$	0.9075
Soy.B	$2.0720^{PPC1, SPC}$	$0.2073^{PPC1, SPC}$	1.0741	0.9888^{SPC}	$0.5175^{PPC1, PPC2}$	$0.9225^{PPC2, SPC}$
Soy.C	1.7565	0.1735^{PPC1}	$0.9331^{PPC1, PPC2}$	$0.8365^{PPC1, PPC2}$	$0.5325^{PPC1, PPC2}$	0.9000
Soy.S	$1.0188^{PPC1, PPC2, SPC}$	0.0878^{PPC2}	$0.5111^{PPC1, PPC2, SPC}$	$0.4492^{PPC1, PPC2, SPC}$	$0.5000^{PPC1, PPC2, SPC}$	0.8800
Soy.T	$1.2643^{PPC1, PPC2, SPC}$	0.1260	$0.6441^{PPC1, PPC2, SPC}$	$0.5669^{PPC1, PPC2, SPC}$	$0.5075^{PPC1, PPC2, SPC}$	0.8800
Soy.V	1.9668	0.1678^{PPC1}	1.0332	0.9275	$0.5250^{PPC1, PPC2}$	0.8950
Soy.X	1.7760	0.1743^{PPC1}	$0.9246^{PPC1, PPC2}$	0.8532^{PPC1}	$0.5225^{PPC1, PPC2}$	$0.9225^{PPC2, SPC}$
SE	0.058	0.016	0.036	0.032	0.008	0.007

* Samples with means, within a column, followed by different superscripts are significantly different from the samples having their codes subscripted (P< 0.05).

Table 2

Hotelling's T-squared test statistic for the difference in two multivariate means*

	PPC1	PPC2	SPC	Soy.A	Soy.B	Soy.C	Soy.S	Soy.T	Soy.V
PPC1	1	0.08079	0.9112	2.16E-11	6.68E-12	0.007515	7.5E-09	1.15E-08	0.8572
PPC2	0.08079	1	0.07373	8.09E-10	2.17E-10	0.000186	1.44E-08	1.86E-08	0.1858
SPC	0.9112	0.07373	1	8.83E-10	1.44E-11	0.001147	1.76E-08	3.99E-08	0.9835
Soy.A	**2.16E-11**	**8.09E-10**	**8.83E-10**	1	0.00261	1.55E-11	5.08E-09	2.52E-06	2.99E-08
Soy.B	**6.68E-12**	**2.17E-10**	**1.44E-11**	**0.00261**	1	1.13E-12	1.12E-10	2.95E-08	1.25E-08
Soy.C	**0.007515**	**0.000186**	**0.001147**	**1.55E-11**	**1.13E-12**	1	5.52E-08	7.74E-07	0.06565
Soy.S	**7.5E-09**	**1.44E-08**	**1.76E-08**	**5.08E-09**	**1.12E-10**	**5.52E-08**	1	0.000909	1.29E-07
Soy.T	**1.15E-08**	**1.86E-08**	**3.99E-08**	**2.52E-06**	**2.95E-08**	**7.74E-07**	**0.000909**	1	1.38E-06
Soy.V	0.8572	0.1858	0.9835	**2.99E-08**	**1.25E-08**	0.06565	**1.29E-07**	**1.38E-06**	1
Soy.X	**1.12E-10**	**6.37E-09**	**6.47E-09**	**0.01017**	**0.01825**	**1.13E-10**	**5.34E-09**	**1.38E-07**	**1.84E-07**

* P-values in bold numbers indicate statistically significant differences (P<0.05)

The first dimension was a measure of color, odor, and appearance (orange color, bakery odor, porosity, uniformity, and smoothness) (Figure 1). Textural attributes (firmness.1, toughness.2, softness.2, and mushiness.2) mainly composed the second dimension. A total of 72.27% variation was explained by the first two principal components. There were redundant descriptors implying counterpart perceptions or resembling sensations. However, a variety of descriptors is beneficial for interpreting consumer perception and high correlations between these descriptors affected the results inconsiderably if the redundant terms were eliminated.

The samples were grouped and positioned into three areas of the sensory space (Figure 2). PPC1, PPC2, SPC together with two commercial samples (Soy.C, Soy.V) were in close spatial proximity. Confidence ellipses of these samples were overlapped extensively except for Soy.C. These signified that PPC1, PPC2 exhibited organoleptic properties resembling those of SPC and a commercial sausage (Soy.V). P-values from Hotelling's T2 tests (Table 2) verified whether or not two samples were significantly different in a 2-dimension space. The panel well discriminated all the commercial sausages except for Soy.C and Soy.V (P-value=0.066). However, there were no significant differences between PPC1, PPC2, SPC, and Soy.V. This group (PPC1, PPC2, SPC, Soy.V) was primarily characterized by the first dimension. Few textural attributes contributed to the distinguishing of individuals within this group.

3.3 *Preference test*

Hedonic means and standard error of each sample were given in Table 3. Means of PPC1, PPC2, and SPC were tested whether or not one was significantly different from another, and from those of commercial samples.

Preference scores of PPC1, PPC2, and SPC were non-significantly different from each other. There was no significant difference found between preference toward PPC1, PPC2, SPC and that toward Soy.V. However, an amount of preference information was lost due to the fact that all the consumers were considered homogeneous. To closely observe specific consumer segments whose preference could be toward to different groups of sausage samples, PLS regression was run to cluster consumers based on how much their preference was explained by sensory attributes.

Table 3

Means and standard error of hedonic scores*

	Hedonic score
PPC1	5.322 ± 0.154
PPC2	5.476 ± 0.158
SPC	5.530 ± 0.156
Soy.A	5.577 ± 0.152
Soy.B	5.181 ± 0.141
Soy.C	5.839 ± 0.152^{PPC1}
Soy.S	4.550 ± 0.151$^{PPC1, PPC2, SPC}$
Soy.T	4.886 ± 0.154$^{PPC2, SPC}$
Soy.V	5.228 ± 0.147
Soy.X	4.658 ± 0.140$^{PPC1, PPC2, SPC}$

* Samples with means ± standard error followed by different superscripts are significantly different from the samples having their codes subscripted (P < 0.05).

There typically are four groups of consumers segmented according to Tenenhaus et al. (2005)[26]. The target one whose preference was toward peanut protein add samples was selected for further observation. Figure 3 showed the PLS re-analysis of the target consumer group (Group I). Group I consisted of 32 consumers whose preference was less variant and toward the same group of samples. A preference map was built to visualize the proportion of consumers in group I satisfied with each of the samples (Figure 4). 100% percent of consumers in this group judged PPC1 and PPC2 to be satisfying and to show organoleptic attributes close to those of SPC, Soy.V and Soy.C.

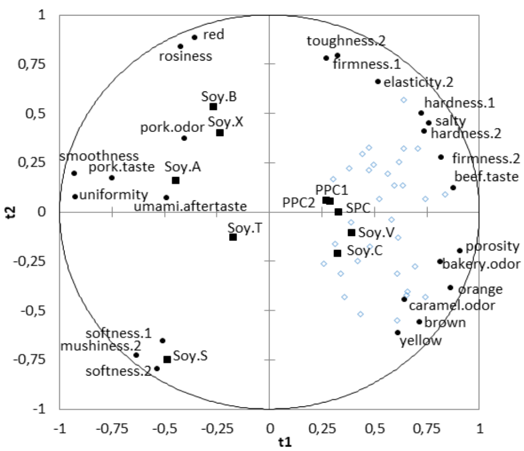

Figure 3. PLS regression of the target group, correlation circle of the products, characteristics, and consumers.

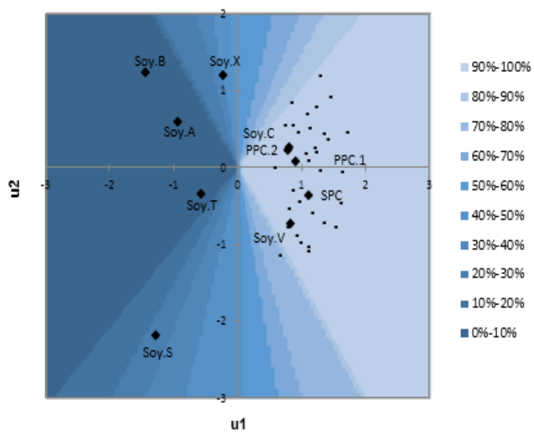

Figure 4. Preference map of the first segment of consumers

A PLS regression of component u1 on sensory attributes further expressed how a characteristic contributed to the liking/disliking of consumers in group I (Figure 5). The regression model (R2 = 0.936, Q2 (cum) = 0.785 for a single component) was expressed as follow:

$$u_1 = \sum \alpha_i \times attribute_i + \beta$$

Where β is the intercept (-1.851) and α_i is the coefficient of the corresponding attribute i.

Attributes with high positive coefficients were valued by group I while those with high negative coefficients reduced hedonic responses. Orange, porosity, bakery odor, and beef taste were likely to be drivers of preference of group I while smoothness and uniformity were not appreciated, and sausage samples with these characteristics were unfavorable.

4 CONCLUSIONS.

In this study, peanut protein concentrate was substituted for soy protein concentrate in emulsion-type sausages. Seven commercial emulsion sausages were also used in order to draw a product space where peanut protein added samples were compared to commercial ones. In terms of instrumental texture, the sausage sample using peanut protein concentrate yielded from the combined ultrasonic and enzymatic extraction was more comparable from the control sample than the one using peanut protein concentrate from the conventional method. It was also noticed that the peanut protein added samples were comparable to one commercial product. Sensory profiling and preference testing found no significant differences between peanut protein added samples, the control, and 2 commercial sausage products. Peanut protein, therefore, showed itself a promising substitute for soy protein.

A group of consumers who favor sausages using peanut protein was recognized, and sensory characteristics that were keys to preference toward peanut protein added sausages were identified. That information is critical in further developing emulsion-type sausages using peanut protein and understanding hedonic judgments of consumers appreciating peanut protein added sausages.

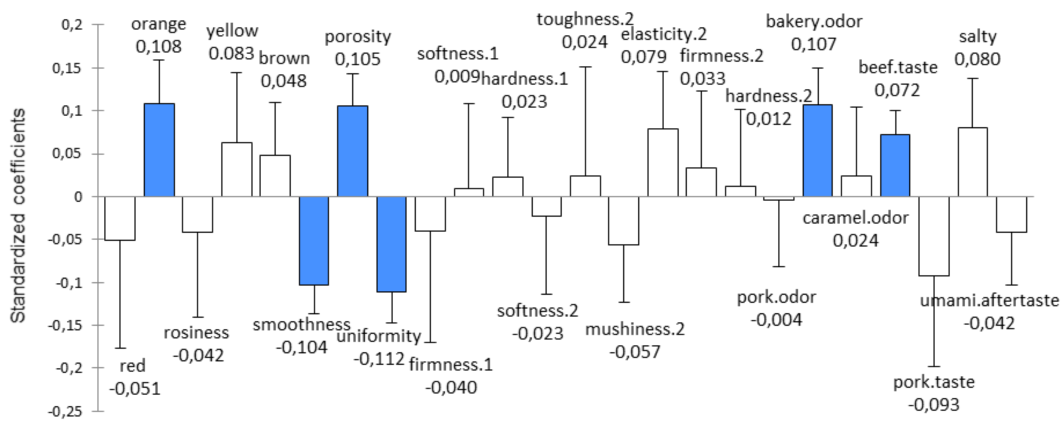

Figure 5. The PLS regression coefficients (95% confidence intervals) in the PLS regression of component u1 on organoleptic characteristics.

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Khả năng thay thế protein đậu nành bằng protein đậu phộng để tạo cấu trúc trong sản xuất xúc xích

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***Tóm tắt* —** Trong nghiên cứu này, khả năng thay thế protein đậu nành bằng protein đậu phộng trong sản xuất xúc được khảo sát. Hai loại protein đậu phộng đậm đặc được thu hồi từ đậu phộng bằng phương pháp trích ly truyền thống và phương pháp trích ly có hỗ trợ bằng sóng siêu âm và enzyme được sử dụng để sản xuất xúc xích, tương ứng là mẫu PPC1 và PPC2. Protein đậu nành được sử dụng cho mẫu đối chứng (SPC). PPC1, PPC2, SPC và 7 mẫu xúc xích khác có trên thị trường được so sánh các tính chất cấu trúc và cảm quan bằng việc áp dụng 3 phương pháp: Phân tích cấu trúc bằng thiết bị (TPA), phân tích mô tả nhanh và pháp phân tích thị hiếu trên thang điểm 9. Kết quả phân tích TPA cho thấy PPC1 và PCC2 không khác biệt đáng kể với mẫu đối chứng và 1 mẫu đang có trên thị trường về độ cứng, độ đàn hồi và độ kết dính, nhưng độ cố kết lại khác nhau. Kết quả phân tích mô tả nhanh cho thấy, PPC1, PPC2, SPC và 2 mẫu đang có trên thị trường có các tính chất cảm quan tương tự nhau vì nằm gần nhau trên mặt phẳng phân bố. Kết quả đánh giá thị hiếu cũng cho thấy 5 mẫu này có mức độ ưa thích của người tiêu dùng tương đương nhau. Kết quả thu được cho thấy rằng có thể sử dụng protein đậu phộng để thay thế protein đậu nành trong sản xuất xúc xích.

***Từ khóa* —** Xúc xích, protein đậu phộng đậm đặc, protein đậu nành, tính chất cấu trúc, bản đồ thị hiếu.