Science & Technology Development Journal – Engineering and Technology 2022, 6(3):1622-1632

Open Access Full Text Article

Research articles

Investigating the effects of ingredient proportions on the texture of Vietnamese sausage using mixture experiment design

Nguyen Thi Hien*, Pham Huu Thinh, Nguyen Hoang Dzung

ABSTRACT

In this study, the effect of different ingredient proportions on the textural and hedonic characteristics of Vietnamese sausage was investigated. Vietnamese sausage is a widely popular traditional food of Vietnam, yet its characteristics are rarely investigated, especially the texture and hedonic properties. Vietnamese sausage's texture was heavily influenced by three main ingredients: lean meat, lard and starch. In order to study the interactive effects of these three ingredients on texture as well as liking, eight samples with different proportions of these three main ingredients were prepared based on the mixture design approach. The textural characteristics (including hardness, cohesiveness, springiness, chewiness and gumminess) were determined using the texture profile analysis method, while a consumer panel (N = 70) evaluated their texture liking score. Surprisingly, all the texture characteristics were statistically significant difference. However, cohesiveness had a small variance between samples, signalling that this attribute is not important in describing the texture of Vietnamese sausage. To model the effect of ingredients, response surface regression with mixture model was carried out. The results showed that Scheffe's special cubic model had a good fit for hardness (R^2 = 0.946), chewiness (R^2 = 0.902) while Scheffe's quadratic model had a good fit for liking score (R^2 = 0.967). The lean meat was found to be the ingredient with the largest effect on increasing the textural charactertistics as well as the liking score. Interestingly, upon inspecting the correlation between texture and liking score, the PCA map of both showed a similar structure. Finally, optimal values of the main ingredients for Vietnamese sausage formulations based on hedonic (> 6.5 liking score) were 4% - 8% starch, 70% - 76% lean meat and 18% - 26% lard. The analysis of consumers' liking scores suggested that springiness is the main driver of liking for Vietnamese sausage products.

Key words: Vietnamese sausage, texture, hedonic, mixture design

Department of Food Technology, Faculty of Chemical Engineering, Ho Chi Minh City University of Technology, VNU-HCM, Vietnam

Correspondence

Nguyen Thi Hien, Department of Food Technology, Faculty of Chemical Engineering, Ho Chi Minh City University of Technology, VNU-HCM, Vietnam

Email: nthien@hcmut.edu.vn

History

- Received: 19-5-2022
- Accepted: 18-8-2022
- Published: 30-11-2022

DOI : 10.32508/stdjet.v5i2.1007

INTRODUCTION

Vietnamese sausage, a Vietnamese traditional food classified as a type of sausage, is mainly composed of lean meat, lard and starch. Vietnamese sausage is usually prepared by first grinding and mixing the above ingredients to create a homogenous and gelatinous mixture, then cooked in extended hours to create a dense, firm and chewy texture. Various spices and additives can be added when mixing to diversify the flavour and texture of the final products. However, despite its popularity in Vietnamese cuisines, limited researches had been conducted on the effect of ingredients on the sensory, as well as consumers' acceptance, of Vietnamese sausage.

Of all the sensory modalities for food products, texture is one of the main sensory modalities that drives consumer acceptance. Texture is often not a focus like flavour, however, texture is often appreciated latently. If consumers'expectations of texture are not met, texture becomes the main point for criticism and rejection of the food. Texture is even more important for sausage products, since firm, elastic texture with good bite is characteristics for this type of food [1].

Many studies utilized mixture design experiments for studying the effect of various ingredients simultaneously as well as optimization [2,3]. Mixture experiments involve blending two or more ingredients to form a product. In these types of experiments, the variables represent proportion amount in the mixture, rather than unrestrained amounts. Ingredients (factors) of the product are combined in various proportions according to an experimental design to determine the effects of interaction between ingredients.

Response surface methodology (RSM) can be used to statistically determine the effects of multiple variables on response variables (such as quality attributes) while minimizing the number of experiments that needed to be conducted [4]. RSM is a designed regression analysis used to predict the value of a response or dependent variable based on controlled values of the experimental factors. This study was therefore utilizing mixture design and response surface methodol-

Cite this article : Hien N T, Thinh P H, Dzung N H. **Investigating the effects of ingredient proportions on the texture of Vietnamese sausage using mixture experiment design**. *Sci. Tech. Dev. J. – Engineering and Technology; 2022,* 6(3):1622-1632.

ogy to study the effects on the texture and optimizing formulation based on consumers' acceptance of Vietnamese sausage using different proportions of the three main ingredients: lean meat, lard and starch.

MATERIAL AND METHODS

Material

The meat and lard were first minced separately, then ground and mixed at 10^0C for 3 minutes, using a bowl cutter, to create the meat emulsion. Starch was added to the mixture at 1.5 minutes and other ingredients (spices and additives) were added to the mixture at 2 minutes. The other ingredients, which were fixed between different formulations, included 10.8g fish sauce, 11.4g sugar, 5.1g monosodium glutamate, 2.5g polyphosphate, 7.6g salt and 100g ice per 1kg mixture of lean meat, lard and starch. After mixing, the mixture was filled into a polyethylen bag for shaping, then sealed and cooked at 120^0C in 30 minutes to create the final product.

Experiment design

Mixture experiment design was used to investigate the efffect of lean meat, lard and starch ratio on the texture of Vietnamese sausage. A three-component constrained simplex lattice mixture design as described by *Cornell (2002)* was utilized[5]. Component proportions were expressed as percentages of the mixture with a sum of 100%. Initially, a formulation recommended in Vietnamse sausage manufacturing was used as the basis for varying the levels of the ingredients (lean meat 80%, lard 15% and starch 5%). From this formulation, Vietnamese sausage samples with the highest and lowest proportions of the ingredients that would result in an acceptable texture were prepared. These proportions were used as constraints in the mixture experiment where the highest and lowest levels were identified as the extreme vertices in the constrained region (the constrained values are listed below; x_1 was lean meat proportion, x_2 was lard proportion and x_3 was starch proportion).

$$\begin{aligned} 70\% &\leq x_1 \leq 90\% \\ 10\% &\leq x_2 \leq 30\% \\ 0 &\leq x_3 \leq 10\% \end{aligned} \tag{1}$$

For constrained region, *McLean and Anderson (1966)* suggested to first finding the extreme vertices, where the value for the components falls within its lower and upper constraints[6]. Once the extreme vectices are found, the edge centroids can be calculated by locating the vertices with a constant value for one component and then average the other components. Similarly, the centroids of facets can be found by first finding the vertices where two components are constant then average the remaining.

After using R software to calculate the experiment points using the *McLean and Anderson (1966)* design, the experimental regions consisted of the following 8 points: four points representing the four extreme vertices (outlining the constrained region) and four midpoints (Figure 1). The proportions of lean meat, lard and starch for each experimental points (samples) are presented in Table 1.

Texture analysis

The texture profile analysis (TPA) procedure was modified from the research by *A.M. Herrero (2007)*[7]. First, the sausage product was taken from the refrigerator and allowed to warm naturally to 25°C. The sausage product was then cut off the two heads (1cm), placed in a fixed frame to cut into slices with a thickness of 2cm, then cut by a cylindrical steel mold with a diameter of 2.5cm. Samples were then preserved by sealed packaging, avoiding contact with the environment before measuring.

Instron machine model 5543 was used for the determination of the textural characteristics (hardness, cohesiveness, springiness, chewiness, gumminess) of Vietnamese sausage samples. The samples were pressed to 50% deformation with a speed of 2 mm/s. Each measurement was repeated three times at the same experimental conditions and the average values were calculated.

Sensory evaluation

Seventy consumers, from 18 to 26 years old, consisting of undergraduate and graduated students at Ho Chi Minh University of Technology (HCMUT) were randomly recruited to participate in the consumer test. All participants consumed Vietnamese sausage at least once a week and had interest in this study.

Each participant received a fan-shaped slice of Vietnamese sausage sample with thickness of 1 cm. The participants were asked to eat the samples and then scored their liking on a 9-point hedonic scale for each sample. Samples were labelled with 3-digit code and the presentation order for each participant was determined using the Latin William square. The participants drank water to clean the palate between samples.

Statistical analysis

The textural characteristics were first analyzed by one-factor ANOVA and post hoc test to find statistical differences between formulations. The consumers' liking score was analyzed by two-factor ANOVA, with

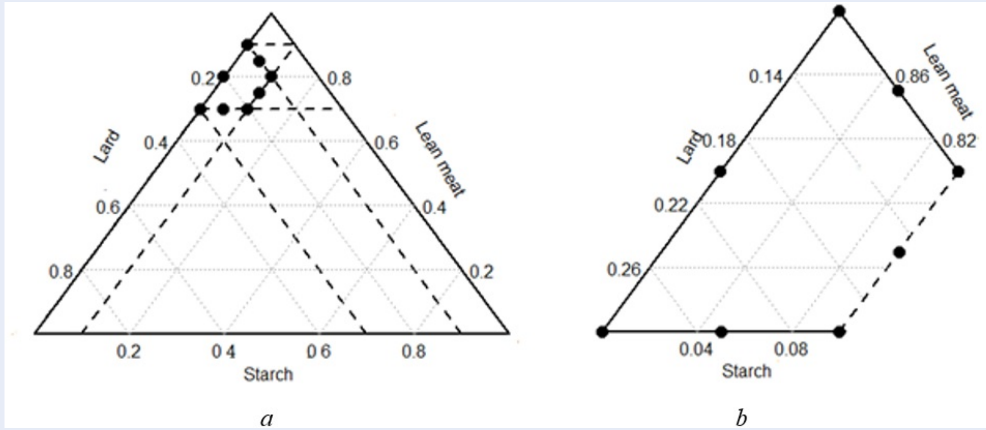

Figure 1: Experimental points in the simplex coordinate system (a) and in the constraint region (b)

Table 1: Ingredient proportions for the Vietnamese sausage samples

Formulation	Lean meat (x_1)	Lard (x_2)	Starch (x_3)
F1	70%	30%	0%
F2	90%	10%	0%
F3	70%	20%	10%
F4	80%	10%	10%
F5	80%	20%	0%
F6	70%	25%	5%
F7	85%	10%	5%
F8	75%	15%	10%

samples as fixed factor and consumers as random factor. Then, Principal Component Analysis (PCA) was applied to visualize the differences in texture between samples in a smaller number of dimension. The PCA method is well documented in the literature on food quality and acceptability[8].

In response surface modeling with independent factors, the experimental region can be restricted so that the quadratic model can approximate well the nonlinear response surface. However, in a mixture experiment, the experimental region consists of the full constrained region and cannot be restricted. Therefore, higher order polynomial equations are sometimes necessary to approximate the true model. In this study, the following Scheffe's special cubic model was used to fit for each textural characteristics and consumers' liking score:

$$y = \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_{12} x_1 x_2 + \beta_{23} x_2 x_3 + \beta_{31} x_3 x_1 + \beta_{123} x_1 x_2 x_3 + \varepsilon \quad (2)$$

Where y is the estimated response; x_1 is lean meat proportion, x_2 is lard proportion and x_3 is starch proportion. β_1, β_2, β_3, β_{12}, β_{23}, β_{31}, β_{123} are constant coefficients for linear and non-linear interaction terms. The model is then used to evaluate the effects of ingredients on the response variables.

The relationship between liking score and the textural properties was analysed using the technique of projection of supplementary variables on the PCA space. Firstly, an analysis of principal component was run on the hedonic data, which results in a multidimensional space of which the first two components are typically focused on. The space represents products as points and consumers as vectors. The vectors indicate liking directions for each consumer, in other words, the further away a product is located in that direction, the more a given consumer like it[9]. To explain the differences in preferences between samples, the textural characteristics were then projected as supplementary variables within the hedonic space. This projection allows the examination of the linear relationships between the main dimension of preferences and the textural characteristics. In addition, this technique also allows the segmentation of consumers, which can be done visually by considering groups of vectors pointing in the same directions.

The computational work was performed using R 4.1.0 software, with the help of *mixexp* package for mixture experiment analysis and *FactoMineR* and *SensoMineR* package for PCA analysis [10].

RESULTS

Textural characteristics of Vietnamese sausage samples

The mean values and standard deviations of textural characteristics (hardness, cohesiveness, springiness, chewiness and gumminess) of different Vietnamese sausage samples are shown in Table 2. Hardness had a large variance between formulations. All the formulations with low hardness (F1, F3, F6 and F9) all had low proportions of lean meat and high proportions of lard, while the formulations with high proportions of lean meat and low proportions of lard (F2, F5 and F7) had high hardness. Springiness also showed a significant difference between formulations (5.21 mm to 6.84 mm). In general, samples with lard proportion greater than 15% and added starch (F6 and F9) had high values for springiness, while samples with lard proportion less than 15% (F2, F3 and F7) had low values for springiness. In contrast to hardness, springiness was negatively correlated with lean meat proportions. However, formulations with lard proportions higher than 20% (such as sample F1) also had low springiness. This showed that when the fat content was too high (> 20%), the sausages had a soft structure, which made it difficult for the sausages to recover their height after compression. Finally, for chewiness and gumminess, the results showed that formulation F1 and F3 with high proportions of lard (> 15%) had the lowest values for chewiness and gumminess, while sample F2 with the highest proportion of lean meat (90%) had the highest values.

Figure 2 shows the results of PCA for the textural characteristics. Figure 2a shows that the Dim 1 axis represents 56.49% of the difference and the Dim 2 axis represents 35.92% of the difference. The difference expressed by the remaining axes (F3, F4, F5, ...) only 7.59%, so the plane of Dim 1 and Dim 2 is sufficient to represent the difference between Vietnamese sausage samples. Figure 2a shows the Dim 1 axis has a good correlation with hardness, chewiness and gumminess while the Dim 2 axis correlates with springiness and cohesiveness. Figure 2b shows that there are two trends in the differences between Vietnamese sausauge samples. The first trend is highlighted by Dim 1, where there is a large difference between sample F1 (very low hardness, chewiness and gumminess) and the other samples. The Dim 2 represents the second trend in differences, which divide the samples into two groups, sample F6 with high springiness and cohesiveness, while other samples had closer values for springiness and cohesiveness.

In general, the PCA analysis showed that when the ratio of ingredients changed, the texture of Vietnamese sausage samples varied, but some ingredients had more profounding impact on the textural characteristics. The non-starch samples (F1, F2, F5) had large differences in texture, because of the large difference in proportions of lean meat and fat. In contrast, the samples, F4, F8) located closely on the Dim 1 & Dim 2 plane, suggesting small texture differences, because of the smaller variation of the ratio of lean meat and lard than the group without added starch.

Response surface modeling for textural characteristics

Table 3 showed the results of the special cubic regression model evaluation for hardness. The model showed a good fit for experimental data ($R^2 = 0.946$). All of the single effects were statistically significant, while only the interaction effect of meat-lard had meaningful p-value ($p < 0.05$). Of the three ingredients (lean meat, lard and starch), only lean meat had a positive impact ($p < 0.05$) on hardness, while lard and starch both had negative impacts on hardness.

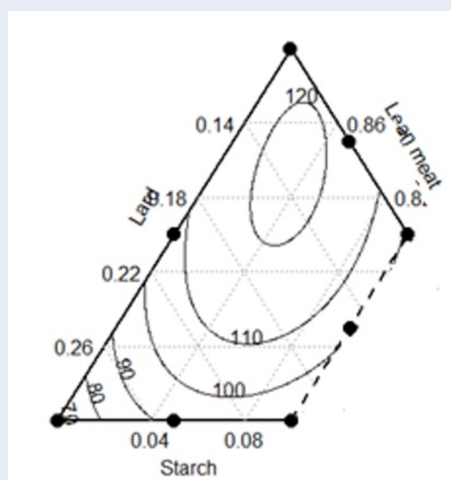

Figure 3: Contour plot in the experimental region for hardness

Table 2: Mean and standard deviation of textural characteristics for Vietnamese sausage samples

Sample	Hardness (N)	Cohesiveness	Springiness (mm)	Chewiness (N)	Gumminess (N*mm)
F1	66.33±3.48^{f}	0.56±0.01^{c}	6.17±0.15^{b}	36.92±1.87^{d}	227.53±8.37^{e}
F2	117.92±3.05^{a}	0.57±0.02^{bc}	5.42±0.18^{ef}	66.81±1.65^{a}	361.89±3.34^{b}
F3	86.87±3.55^{e}	0.57±0.02^{bc}	5.21±0.22^{f}	49.86±3.81^{c}	259.27±16.62^{d}
F4	101.17±3.59^{cd}	0.59±0.02^{ab}	6.08±0.17^{bc}	59.35±2.50^{b}	361.02±17.35^{b}
F5	107.07±3.28^{b}	0.55±0.02^{c}	5.84±0.25^{cd}	59.23±2.36^{b}	345.56±9.04^{bc}
F6	95.67±2.38^{d}	0.60±0.01^{a}	7.21±0.14^{a}	57.71±0.90^{b}	416.39±14.36^{a}
F7	113.64±3.97^{a}	0.57±0.01^{bc}	5.13±0.17^{f}	65.15±2.16^{a}	334.20±14.46^{c}
F8	101.71±3.59^{bc}	0.58±0.01^{bc}	5.66±0.17^{de}	58.66±2.61^{b}	332.13±24.54^{c}

ANOVA results for all the textural characteristics were significant at α = 0.05
In a column, means with no common letters were significantly different at α = 0.05

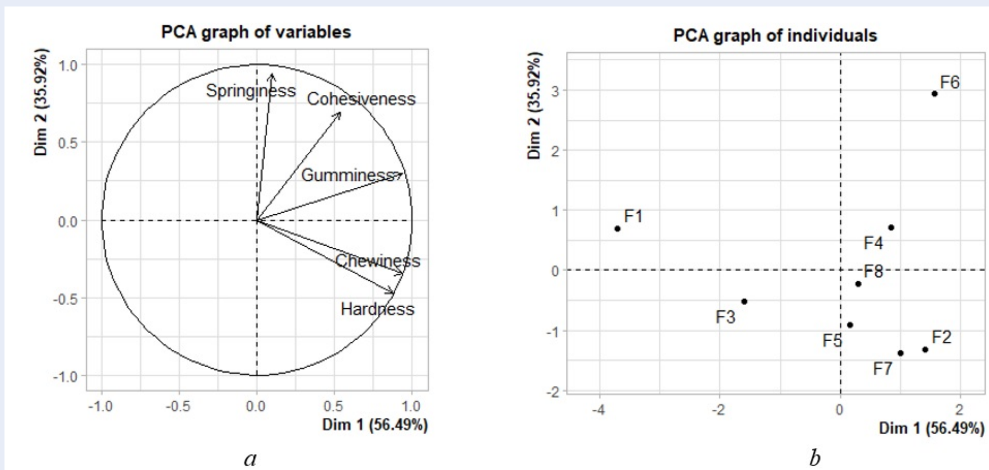

Figure 2: Correlation between textural characteristics (a) and representation of samples on Dim 1 and Dim 2 (b) of PCA

Table 3: Special cubic model evaluation for hardness

Factor	β	Value	p
Lean meat	β_1	96.225	< 0.001
Lard	β_2	-1045.018	< 0.001
Starch	β_3	-2457.581	0.032
Meat-lard	β_{12}	1494.333	< 0.001
Meat-starch	β_{13}	2279.642	0.122
Lard-starch	β_{23}	-5644.976	0.523
Meat-lard-starch	β_{123}	15790	0.224
R^2 = 0.946			

The model evaluation for chewiness (Table 4) showed that the binary interaction of lard – starch and the tertiary interaction between lean meat, lard and starch were not significant with a large p-value ($p > 0.3$). The R^2 ($R^2 = 0.902$) for the model was high, indicating that the special cubic model was sufficient to describe the trend in the experimental data. The lean meat was also the only factor that had a positive impact ($p < 0.05$), while adding lard and starch reduced the chewiness of the Vietnamese sausage.

For cohesiveness, springiness and gumminess, the special cubic model was found to be unsuccessful in describing the effects of ingredients on these particular texture characteristics. The R^2, which explains the variance explained by the model, was not high ($R^2 = 0.437$ for cohesiveness, $R^2 = 0.587$ for springiness and $R^2 = 0.450$ for gumminess). This result implied an even higher model than special cubic model to sufficiently describe the response surface for cohesiveness, springiness and gumminess.

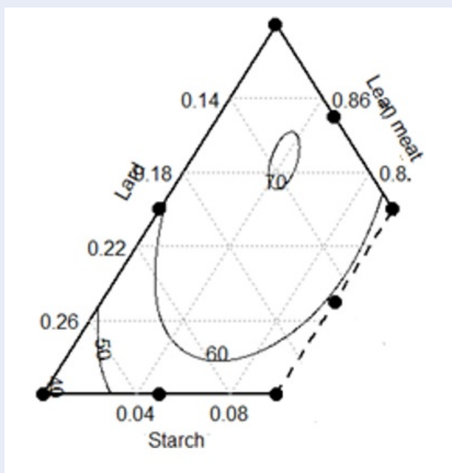

Figure 4: Contour plot in the experimental region for chewiness

Response surface modeling for liking scores

The ANOVA results showed that there was a significant difference in preference scores between the samples at $\alpha = 0.05$. Subsequently, a post-hoc multiple comparision test (Fisher's Least Significant Difference) was performed and the results is presented in Table 5. Sample F6 has significantly higher texture liking score compared to other samples, suggesting the texture of this sample to be very favored by the consumers. In contrast, sample F2 had the lowest texture liking score, indicating that there might be many defect which the consumers disliked. In general, the liking scores indicating that the samples were significantly different in terms of consumer preferences.

The results for the special cubic model evaluation for liking score showed a high R^2 ($R^2 = 0.973$), however, all the factor were not statistically significant ($p > 0.05$) (Table 6). *J.Lawson (2016)* suggested this implied a justification for a less complicated model[11]. Therefore, the following Scheffe's quadratic model (3) was fitted for the average liking score:

$$y = \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_{12} x_1 x_2 + \beta_{23} x_2 x_3 + \beta_{31} x_3 x_1 + \varepsilon \quad (3)$$

The quadratic model analysis (Table 7) had a slightly lower R^2 ($R^2 = 0.967$) than the R^2 of the special cubic model, however only lard and the interaction between lean meat – lard were not statistically significant.

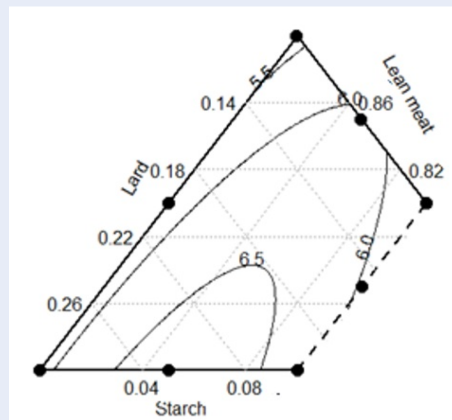

Figure 5: Contour plot in the experimental region for consumers' liking score

DISCUSSION

Textural characteristics of Vietnamese sausage samples

Interestingly, cohesiveness showed a significant difference between formulations ($p < 0.05$). The study of *M.Rahman* on fish sausage (prepared from fish fillet) and the study of *P.Santana* on fish sausage (prepared from surimi) showed that cohesiveness usually was not significantly different between sausage samples[12,13]. In this study, the cohesiveness showed a significant difference because the sausage samples were prepared with a wide range of different proportions of ingredients. However, the cohesiveness only varied within a small range (0.56 – 0.61) compared to other textural characteristics, which implied changes

Table 4: Special cubic model evaluation for chewiness

Factor	β	Value	
Lean meat	β_1	57.263	< 0.001
Lard	β_2	-521.919	0.003
Starch	β_3	-1969.444	0.029
Meat-lard	β_{12}	736.24	0.007
Meat-starch	β_{13}	1939.777	0.097
Lard-starch	β_{23}	-2482.03	0.72
Meat-lard-starch	β_{123}	8877.2	0.38
$R^2 = 0.902$			

Table 5: Mean and standard deviation of liking scores for Vietnamese sausage samples

Sample	Liking score
F1	5.81 ± 0.22^{bcd}
F2	5.38 ± 0.18^{d}
F3	6.19 ± 0.15^{b}
F4	5.71 ± 0.17^{cd}
F5	5.76 ± 0.19^{bcd}
F6	6.79 ± 0.17^{a}
F7	5.94 ± 0.15^{bc}
F8	5.88 ± 0.16^{bc}

In a column, means with no common letters are significantly different at $\alpha = 0.05$

Table 6: Special cubic model evaluation for consumers' liking score

Factor	β	Value	p
Lean meat	β_1	4.589	0.106
Lard	β_2	-3.063	0.862
Starch	β_3	-222.3	0.209
Meat:lard	β_{12}	16.912	0.58
Meat:starch	β_{13}	262.581	0.234
Lard:starch	β_{23}	560.948	0.533
Meat:lard:starch	β_{123}	-433.824	0.714
$R^2 = 0.973$			

Table 7: Quadratic model evaluation for consumers' liking score

Factor	β	Value	p
Lean meat	β_1	4.674	0.016
Lard	β_2	-1.447	0.904
Starch	β_3	-197.121	0.044
Meat:lard	β_{12}	14.36	0.479
Meat:starch	β_{13}	224.302	0.044
Lard:starch	β_{23}	262.376	0.033
R^2 = 0.967			

in proportions of lean meat, lard and starch only had a small effect on cohesiveness.

Chewiness and gumminess are secondary parameters, which are calculated from hardness, cohesiveness and springiness. Therefore, chewiness and gumminess had complicated changes because of many interactions between lean meat, lard and starch. The results still showed a high influence of lean meat on chewiness and gumminess, indicating the importance of protein. However, the interaction between fat, starch and protein contributed significantly to the chewiness and gumminess of the Vietnamese sausage.

In general, these results showed the important role of lean meat in creating the structure for the Vietnamese sausage product. Other studies on sausage products also showed that the lower the fat content, the higher the hardness of the final product [14]. This is caused by the fact that the fat molecules interfere with the formation of the protein network, therefore lowering the force resistance of sausage products. Moreover, the study of *Z. Pietrasik* investigating the firmness of Frankfurters sausage showed that the resistance to forces of sausage samples had a proportional relationship with protein content [15].

Response surface modeling for textural characteristics

For hardness, which is defined as the peak resistant force of a sample when subjected to deformation, the model fit particularly well. Hardness is an important textural attribute for sausage products, since this characteristic signify a good bite for sausage products. The contour plot (Figure 3) shows hardness quickly drop for formulations with a high proportion of lard, implying the significant impact on the structure of Vietnamese sausage products upon increasing the lard proportions. Usually, lard is used as a substitute for lean meat to reduce the production cost, but this can result in a softer texture, which is highly unpreferred by consumers.

Low chewiness of sausage products usually had a negative influence on Vietnamese consumer's appreciation since it implied a high crumbling and easy to break down during mastication. However, since the binary interaction of lean meat – starch and lard – starch was positive, reducing lean meat proportion did not have a large negative impact on chewiness. From the contour plot in Figure 4, the formulation with 4% starch proportion and 12% lard proportion was predicted to have chewiness around 65N, which was not very far from the highest value for chewiness of formulation F2 (66.81N).

Response surface modeling for liking scores

Interestingly, starch had a very high negative impact on the liking score for Vietnamese sausage formulations, indicating a perceivable texture defect for formulations with high proportions of starch. Despite having a positive impact, increasing lean meat proportions did not necessarily increase the liking score, with samples that had lean meat proportion higher than 86% were predicted to have lower than 6.0 liking score. This implied that despite being the most important ingredient in creating the structure for sausage products, high meat content formulations can negatively impact consumer acceptance. The binary interaction between meat-starch and lard-starch had positive effects, indicating an optimum region for product optimization. It is clear from Figure 5 that highly appreciated Vietnamese sausage samples could be prepared from mixtures containing 4% - 8% starch, 70% - 76% lean meat and 18% - 26% lard (mean liking score > 6.5).

Relationship between texture and consumer's liking

Figure 6 shows the principal component analysis of the texture liking scores for Vietnamese sausage samples. Surprisingly, the preference map had a strikingly similar distribution with the PCA map of textural characteristics (see Figure 2), where sample F1 and sample F6 both located far from other samples. This result implied that Vietnamese consumers can perceive and evaluate the differences in texture and the differences in texture had a high impact on the preference of Vietnamese consumers.

For consumer segmentation, Figure 6 shows two different preference trends. The first trend is highlighted by F1 axis, where the majority of consumers tend to prefers sample F6 over other samples. The second trend is highlighted by the F2 axis, where two group of consumers seemingly had opposite preference: one group preferred sample F4 and F8 while the other group preferred sample F1. To explain these difference trends, the textural characteristics were projected on the preference mapping as supplement variables (Figure 6a). The results showed that the majority of consumers preferred Vietnamese sausage samples with high springiness and low hardness (sample F6). For the two opposite group along the F2 axis, one group preferred samples with high chewiness and cohesiveness (good bite texture) while the other group liked samples with low chewiness and cohesiveness (tender texture).

CONCLUSIONS

The three ingredients (lean meat, lard and starch) were found to have significant impacts on the textural characteristics as well as consumers' liking score for the Vietnamese sausage products. Changes in the proportions of these three ingredients, even within a small range, can lead to profound differences in hardness, springiness, chewiness and gumminess. Mixture response surface methodology was used to determine the effects of varying proportions of lean meat, lard and starch on the texture of Vietnamese sausage. The results showed that lean meat played the most important role, however many interactions between these three ingredients were also found to be significantly affected the textural characteristics.

Liking score results suggested using the parameters of sample F6 as a Vietnamese sausage reference, with hardness = 95.67 N, cohesiveness = 0.60, springiness = 7.21 mm, gumminess = 57.71 N and chewiness = 416.39 N*mm. Surprisingly, the preference mapping had a similar distribution as the PCA map for textural characteristics, suggesting texture had a big impact on liking score. The projection of texture characteristics on the preference mapping shows that most consumers liked samples with high springiness. Optimization based on the consumers' liking score suggested formulations with 4% - 8% starch, 70% - 76% lean meat and 18% - 26% lard was highly preferred (mean liking score > 6.5). These results can be applied widely in Vietnamese sausage manufacturing, as well as serve as a preliminary step in studying the effect of mixtures of different additives on the texture of Vietnamse sausage.

ACKNOWLEDGEMENT

This research is funded by Vietnam National University Ho Chi Minh City (VNU-HCM) under grant number C2020-20-37.

LIST OF ABBREVIATIONS USED

ANOVA: Analysis of variances

PCA: Principal component analysis

TPA: Texture profile analysis

COMPETING INTERESTS

The authors declare that they have no competing interests

AUTHORS' CONTRIBUTION

Nguyen Hoang Dung, Nguyen Thi Hien designed the ideas for the study and design the experiments.

Pham Huu Thinh conducted the experiments, analyzed the data and wrote the manuscript.

All authors provided critical feedback, discussion, and helped finishing the manuscript.

REFERENCES

1. Cardoso CML, Mendes R, Nunes ML. Instrumental texture and sensory characteristics of cod frankfurter sausages. Int J Food Prop. 2009;12(3):625-43;Available from: https://doi.org/10.1080/10942910801992959.
2. Masmoudi M, Besbes S, Bouaziz MA, Khlifi M, Yahyaoui D, Attia H. Optimization of acorn (Quercus suber L.) muffin formulations: Effect of using hydrocolloids by a mixture design approach. Food Chem [Internet]. 2020;328(May):127082;Available from: https://doi.org/10.1016/j.foodchem.2020.127082.
3. Ammar I, Gharsallah H, Ben Brahim A, Attia H, Ayadi MA, Hadrich B, et al. Optimization of gluten-free sponge cake fortified with whey protein concentrate using mixture design methodology. Food Chem [Internet]. 2021;343:128457;Available from: https://doi.org/10.1016/j.foodchem.2020.128457.
4. San Juan EM, Edra E V., Sales JM, Lustre AO, Resurreccion AVA. Utilization of peanut fines in the optimization of peanut polvoron using mixture response surface methodology. Int J Food Sci Technol. 2006;41(7):768-74;Available from: https://doi.org/10.1111/j.1365-2621.2005.01065.x.
5. A.Cornell J. Experiments with Mixtures: Designs, models and the analysis of mixture data. 2002;Available from: https://doi.org/10.1002/9781118204221.

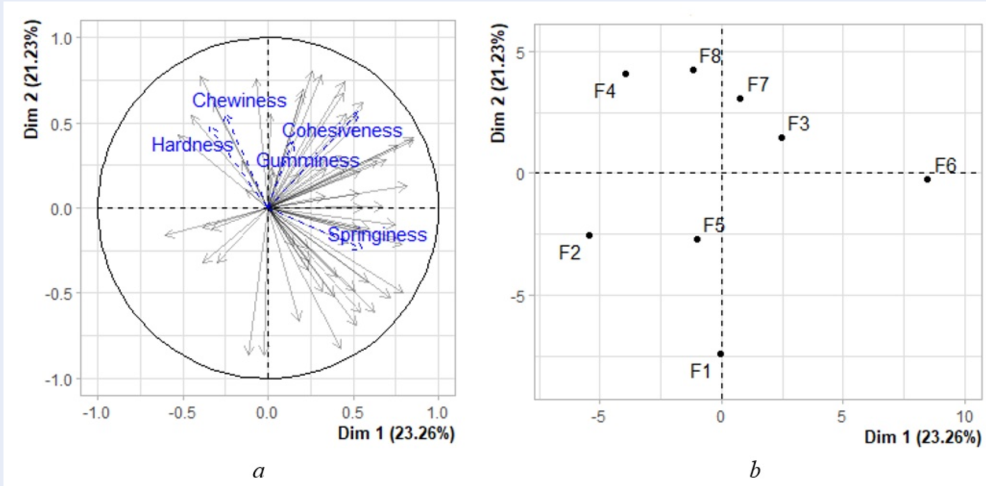

Figure 6: Correlation between textural characteristics and consumer preference (a) and representation of samples according to consumer preference (b)

6. McLean R. A. AVL. Extreme vertices designs of mixture experiments. Technometrics. 1966;8:447-54;Available from: https://doi.org/10.1080/00401706.1966.10490377.
7. Herrero AM, Ordo JA, Avila R De, Herranz B, Cambero MI. MEAT Breaking strength of dry fermented sausages and their correlation with texture profile analysis (TPA) and physico-chemical characteristics. 2007;77:331-8;PMID: 22061785. Available from: https://doi.org/10.1016/j.meatsci.2007.03.022.
8. Resano H, Sanjuán AI, Cilla I, Roncalés P, Albisu LM. Sensory attributes that drive consumer acceptability of dry-cured ham and convergence with trained sensory data. Meat Sci [Internet]. 2010;84(3):344-51;Available from: http://dx.doi.org/10.1016/j.meatsci.2009.08.052.
9. Rousseau B, Ennis DM, Rossi F. Internal preference mapping and the issue of satiety. 2012;24:67-74;Available from: https://doi.org/10.1016/j.foodqual.2011.09.003.
10. Team RC. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria;.
11. Lawson J, Willden C, Gore WL. Mixture Experiments in R Using mixexp. 2016;72(August);Available from: https://doi.org/10.18637/jss.v072.c02.
12. Rahman MS, Al-Waili H, Guizani N, Kasapis S. Instrumental-sensory evaluation of texture for fish sausage and its storage stability. Fish Sci. 2007;73(5):1166-76;Available from: https://doi.org/10.1111/j.1444-2906.2007.01449.x.
13. Jin S-K, Kim C-W, Chung K-H, Jo K-K, Jeong J-Y, Hur I-C, et al. Physicochemical and sensory properties of irradiated dry-cured ham. Radiat Phys Chem [Internet]. 2012;81(2):208-15;Available from: http://linkinghub.elsevier.com/retrieve/pii/S0969806X11003343.
14. Olivares A, Navarro JL, Salvador A, Flores M. Sensory acceptability of slow fermented sausages based on fat content and ripening time. Meat Sci [Internet]. 2010;86(2):251-7;Available from: http://dx.doi.org/10.1016/j.meatsci.2010.04.005.
15. Pietrasik Z. Effect of content of protein , fat and modifed starch on binding textural characteristics , and colour of comminuted scalded sausages. Meat Sci. 1999;51:17-25;Available from: https://doi.org/10.1016/S0309-1740(98)00068-0.

Tạp chí Phát triển Khoa học và Công nghệ – Kĩ thuật và Công nghệ 2022, 6(3):1622-1632

Open Access Full Text Article

Bài nghiên cứu

Khảo sát sự ảnh hưởng của tỷ lệ nguyên liệu đến cấu trúc của chả lụa theo phương pháp thực nghiệm hỗn hợp

Nguyễn Thị Hiền*, **Phạm Hữu Thịnh, Nguyễn Hoàng Dũng**

TÓM TẮT

Trong nghiên cứu này, chúng tôi khảo sát sự ảnh hưởng của tỷ lệ thành phần nguyên liệu lên tính chất cấu trúc và thị hiếu của người tiêu dùng đối với sản phẩm chả lụa. Chả lụa là một sản phẩm thực phẩm truyền thống vô cùng phổ biến ở Việt Nam, tuy nhiên, các tính chất cấu trúc và thị hiếu của nó chưa được quan tâm nghiên cứu nhiều. Cấu trúc của chả lụa chịu ảnh hưởng lớn của ba loại nguyên liệu chính: thịt nạc, mỡ và tinh bột. Nhằm nghiên cứu sâu về tương tác giữa các thành phần nguyên liệu này lên cấu trúc cũng như thị hiếu, tám mẫu chả lụa thí nghiệm được tạo ra với tỷ lệ thịt nạc, mỡ và tinh bột khác nhau dựa trên thiết kế thực nghiệm hỗn hợp. Nhóm tính chất cấu trúc (bao gồm độ cứng, độ cố kết, độ đàn hồi, độ dẻo và độ dai) được xác định bằng phương pháp phân tích profile cấu trúc (texture profile analysis), còn thị hiếu được đánh giá bằng một hội đồng người tiêu dùng 70 người. Kết quả cho thấy tất cả các tính chất cấu trúc đều có sự khác biệt có ý nghĩa thống kê. Tuy nhiên, độ cố kết có phương sai giữa các mẫu không lớn, cho thấy tính chất này không quan trọng trong công tác mô tả cấu trúc của sản phẩm chả lụa. Để xây dựng mô hình thể hiện ảnh hưởng của nguyên liệu, chúng tôi sử dụng phương pháp hồi qui bề mặt đáp ứng với mô hình dành cho hệ hỗn hợp. Kết quả cho thấy mô hình bậc ba đặc biệt của Scheffe có độ phù hợp cao với độ cứng (R^2 = 0.946), độ dẻo (R^2 = 0.902); mô hình bậc hai của Scheffe có độ phù hợp cao cho điểm ưa thích thị hiếu (R^2 = 0.967). Thịt nạc là thành phần nguyên liệu có ảnh hưởng tích cực nhất đến tính chất cấu trúc cũng như điểm ưa thích thị hiếu cho chả lụa. Kết quả còn cho thấy sự giống nhau rất thú vị giữa mặt phẳng PCA của tính chất cấu trúc và mặt phẳng PCA của điểm ưa thích thị hiếu. Cuối cùng, giá trị tối ưu cho các thành phần nguyên liệu của chả lụa để cho ra mẫu có điểm ưa thích cao (> 6.5) được xác định là 4% - 8% tinh bột, 70% - 76% thịt nạc và 18% - 26% mỡ. Kết quả phân tích điểm ưa thích của người tiêu dùng cho thấy tính chất độ đàn hồi là yếu tố thu hút người tiêu dùng (drivers of liking) cho sản phẩm chả lụa.

Từ khoá: chả lụa, cấu trúc, thị hiếu, thực nghiệm hỗn hợp

Bộ môn Công nghệ Thực phẩm, Khoa Kỹ thuật Hóa học, Trường Đại học Bách Khoa - ĐHQG-HCM, Việt Nam

Liên hệ

Nguyễn Thị Hiền, Bộ môn Công nghệ Thực phẩm, Khoa Kỹ thuật Hóa học, Trường Đại học Bách Khoa - ĐHQG-HCM, Việt Nam

Email: nthien@hcmut.edu.vn

Lịch sử

- Ngày nhận: 19-5-2022
- Ngày chấp nhận: 18-8-2022
- Ngày đăng: 30-11-2022

DOI : 10.32508/stdjet.v5i2.1007

Trích dẫn bài báo này: Hiền N T, Thịnh P H, Dũng N H. **Khảo sát sự ảnh hưởng của tỷ lệ nguyên liệu đến cấu trúc của chả lụa theo phương pháp thực nghiệm hỗn hợp**. *Sci. Tech. Dev. J. - Eng. Tech.;* 2022, 6(3):1622-1632.