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SELECTION OF SUITABLE FORMULA FOR MANUFACTURING MEAT ANALOGUE SUPPLEMENTED WITH WHITE KIDNEY BEAN FLOUR AND JERUSALEM ARTICHOKE FLOUR

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ABSTRACT

This research aimed to study: 1) the suitable formula of meat analogue supplemented with white kidney bean flour and Jerusalem artichoke flour, 2) the chemical and physical properties of the supplemented meat analogue, and 3) the consumer acceptance. The experiment was designed by a mixture design approach and the following three parameters were included: 30–45% of white kidney bean flour, 20–30% of Jerusalem artichoke flour and 35–40% of soybean flour, resulting in 9 formulas. K-Mean cluster analysis of the 9 formulas showed that formula 1, 3, 5 and 6 produced high cutting force and shear force. Among these four, the most suitable formula was the 6th which contained 40% of white kidney bean, 22.5% of Jerusalem artichoke flour and 37.5% of soybean flour, while the cutting force, shear force, a_w and moisture content of the supplemented meat analogue from this formula were at 5.98 ± 0.71, 19.26 ± 0.50, 0.52 ± 0.01 and 3.53% ± 0.20, respectively. Most consumers' overall liking parameter of the supplemented meat analogue was at the very like level.

Key words: Bean flour, Jerusalem artichoke flour, meat analogue, mixture design, soybean flour, white kidney bean flour

INTRODUCTION

Meat analogue is a well-known product among Thai people. It is usually consumed during the vegetarian festival or is a kind of vegetarian food for health-conscious consumers and those who do not want to consume real meat (Kuawiriyapan, 2014). Meat analogue is usually made from extracted protein from soybean flour that provides beneficial nutrition. It contains plant-based protein at the level of 50% and it is around 3 – 4 times (Charunuch *et al*., 2017) cheaper source of protein when compared to real meat. Currently, meat analogue contains high carbohydrate because of the high carbohydrate content in soy flour. Protein content is 49.76 g per 100g meat analogue, while carbohydrate content is 40.86 g per 100 g meat analogue (Chantraporncha *et al*., 1994). For this nutritional value, the soybean-supplemented meat analogue can be categorized as having high carbohydrate content. Consuming too much of this supplemented meat analogue with excessive carbohydrate results in a lot of energy remains which will be transformed into fat and accumulated in the body. This can be the cause of obesity which may lead to many diseases, such as diabetes, kidney failure, cardiovascular and related diseases (Chantraporncha *et al*.,1994).

White kidney bean contains an important chemical called "Phaseolamin". It can inhibit activity of alpha-amylase which delays starch digestion to sugar (Oonsivilai & Oonmetta-aree, 2016). So, the body intake of energy from starch is low, and the accumulation of fat from sugar is reduced. When the body intake of energy is lower than its daily energy expenditure, the body weight will accordingly be lowered. The starch that cannot be digested in the stomach can also prolong satiety

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feeling and suppress hunger. Moreover, white kidney bean promotes the excretory system because of its high fiber content (Chongcharoenyanon, 2016).

Jerusalem artichoke is a beneficial herb for reducing risk of diabetes, heart disease, high blood pressure and vascular disease because it is low in calories and it does not increase blood sugar level due to its content of Inulin. Inulin is insoluble carbohydrate in the digestive system. As a result, it does not provide calories and is not absorbed into the blood stream (Changlek, 2012). Inulin contains high fiber and is categorized as health beneficial prebiotic that can help prevent colon cancer, promote digestion and absorption systems, calcium absorption, and vitamin synthesis. It remains in the digestion system for a long period of time and this helps prolong satiety feeling and suppress hunger (Schaafsma & Slavin, 2015).

This research was aimed to study the suitable formula for manufacturing meat analogue supplemented with white kidney bean flour and Jerusalem artichoke flour, and the physical and chemical properties, along with consumers' acceptance of the supplemented meat analogue.

MATERIALS AND METHODS

In finding the suitable formula for meat analogue supplemented with white kidney bean flour and Jerusalem artichoke flour, the experiment design was undertaken by means of a Mixture design approach. Three parameters in this study were: 30–45% of white kidney bean flour, 20–30% of Jerusalem artichoke flour and 35–40% of soybean flour, resulting in nine formulas. The nine formulas were shown in Table 1 and the manufacturing process of meat analogue supplemented with white kidney beans flour and Jerusalem artichoke flour was shown in Figure 1.

Table 1. Experimental design by Mixture design approach

Formulas	White kidney bean flour (%)	Jerusalem artichoke flour (%)	Soybean flour (%)
1	45	20	35
2	30	30	40
3	40	20	40
4	35	30	35
5	38.75	25	36.35
6	40	22.5	37.5
7	37.5	25	37.5
8	36.25	25	38.75
9	35	27.5	37.5

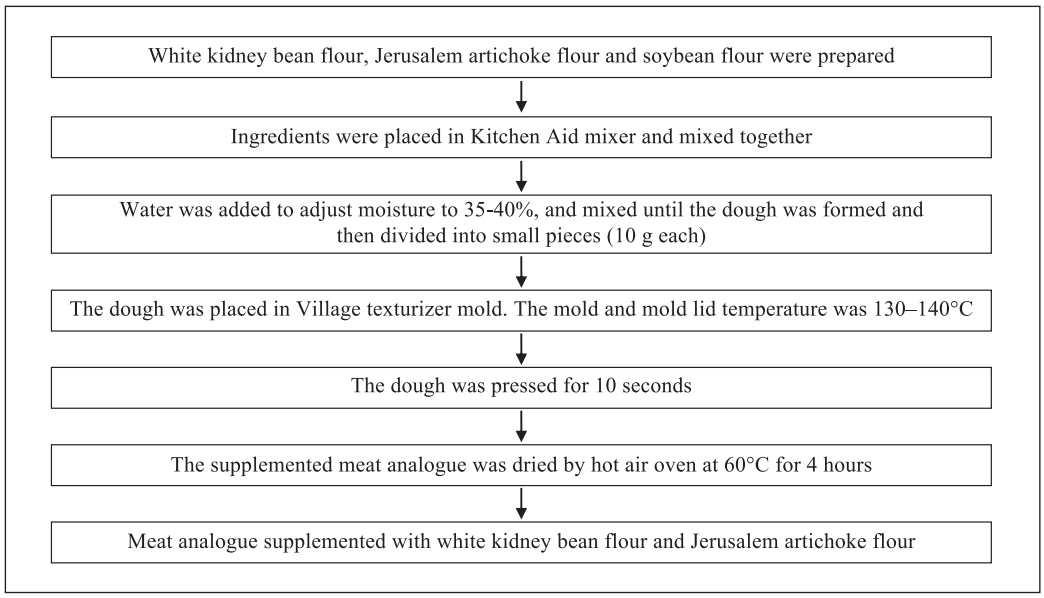

Fig. 1. Manufacturing process of meat analogue supplemented with white kidney bean flour and Jerusalem artichoke flour.

The supplemented meat analogue, manufactured in accord with the 9 formulas as shown in Figure 1, was analyzed in terms of the chemical properties, the moisture contents by means of AOAC (2016), and the physical properties the cutting force and shear force by means of Texture analyzer.

The suitable formula was then selected by consideration of moisture content, cutting force and shear force. The cutting force and shear force of the 9-formula meat analogue were categorized by cluster analysis in K-Mean cluster in order to find the samples with high cutting force and shear force. The supplemented meat analogue from the formula selected was then analyzed for chemical properties, the moisture contents, and for physical properties: the cutting force (N), shear force (N), and Water activity (a_w). The properties of the supplemented meat analogue were also studied by Scanning Electron Microscope while the survey of the consumer acceptance of the meat analogue was included.

RESULTS AND DISCUSSION

From the manufacturing process of the nine formulas of the supplemented meat analogue in Figure 1, the chemical properties of the supplemented meat analogue were analyzed as shown in Table 2.

Chemical properties analysis

The chemical properties, the moisture contents, were analyzed by means of analysis of variance (ANOVA). Duncan's New Multiple Range Test (DMRT) was used to compare statistical differences at 95% confidence level as shown in Table 2. It was found that moisture contents of all supplemented meat analogue from the nine formulas were not significantly different ($p > 0.05$) which met the dried food standard stating that the moisture content should be below 8% to inhibit and control food microbial such as mold, yeast and bacteria (Pongsawatmanit, 2002).

Physical properties analysis

The physical properties: the cutting force and the shear force of the supplemented meat analogue from the nine formulas were analyzed by means of cluster analysis in K-Mean cluster method. From this, the selected formula is the sample with high cutting force and shear force as shown in Figure 2.

Among the 3 different groups, the focus was on the group from formulas 1, 3, 5 and 6 of which the cutting force, the shear force and the protein content were found to be high. The high protein content was from the soybean and white kidney bean flour. This was in corresponding with (Rareunrom, 2005). experiment. The findings were that high content of soybean flour affected high expansion of the supplemented meat analogue. The molecules of soybean flour provided springiness to the supplemented meat analogue structure, and the protein in soybean flour also transformed the internal structure of the supplemented meat analogue to be fibrous, resulting in the meat analogue with cohesiveness,

Table 2. Chemical properties analysis

Formulas	Moisture content ^{ns}
1	3.45 ± 0.07
2	3.60 ± 0.16
3	3.64 ± 0.39
4	3.73 ± 0.74
5	3.49 ± 0.13
6	3.53 ± 0.20
7	3.69 ± 0.14
8	3.17 ± 0.15
9	3.13 ± 0.06

Remark: ^{NS} is not statistically significant different ($p>0.05$), ^{a,b,c} are mean values in the same column followed by different letters are significantly different ($p \leq 0.05$), ± is Standard Deviation.

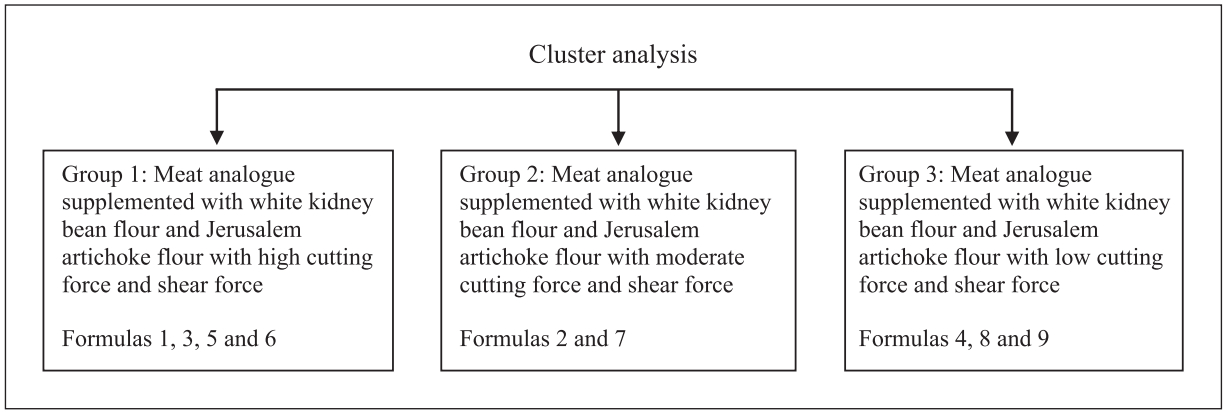

Fig. 2. Cluster analysis of the supplemented meat analogue from 9 formulas by evaluating the cutting force and shear force of the supplemented meat analogue groups.

good texture and increasing cutting force and shear force.

From chemical property analysis in terms of moisture content, it was found that the moisture content of the supplemented meat analogue from all nine formulas were not significantly different ($p > 0.05$); and from the physical properties analysis, it was found that the supplemented meat analogue with high cutting force and shear force was from the following four formulas: formulas 1, 3, 5 and 6. The supplemented meat analogue from these four formulas was then analyzed for chemical and physical properties, along with the consumer acceptance.

Selection of the suitable formula

To select the suitable formula, meat analogue from the following four formulas: 1, 3, 5 and 6. was analyzed for chemical properties, physical properties and consumer acceptance by sensory evaluation as shown in Tables 3 and 4.

Chemical properties analysis

The chemical properties analysis in terms of moisture content was shown in Table 3. It was found that the moisture contents of the supplemented meat analogue from all four formulas were not significantly different ($p > 0.05$) which met the dried food standard, stating that the moisture content should be below 8% to inhibit and control food microbial such as mold, yeast and bacteria (Pongsawatmanit, 2002).

Physical properties analysis

The physical properties such as cutting force, shear force, water activity (a_w) and structure of the supplemented meat analogue were analyzed by means of Scanning Electron Microscope. The result was shown in Table 4 and Figure 3.

It was found that the cutting force and shear force of the supplemented meat analogue from the 4 formulas (1, 3, 5 and 6) were significantly different ($p \leq 0.05$). The sixth formula resulted in the highest cutting force and shear force which agreed with (Rareunrom, 2005). experiment. The findings were that high content of soybean flour brought about high expansion of the supplemented meat analogue. The molecule of soybean flour provided springiness to the supplemented meat analogue, and the protein in soybean flour also transformed the internal structure of the supplemented meat analogue to be fibrous and made it more cohesive with good texture and increasing cutting force and shear force.

The water activity (a_w) of the supplemented meat analogue from the four formulas (1, 3, 5 and 6) were not significantly different ($p > 0.05$). The water activity was the main factor to control and prevent deterioration of food products. It directly affected the food product shelf life because a_w was an indicator of the minimum water level for microbial growth and chemical reaction. If a_w of food product was low, the shelf life of the product would be longer (Pongsawatmanit, 2002).

The structures of the supplemented meat analogue from the four formulas were studied by means of scanning electron microscope at 15 X magnification as shown in Figure 3. In Figure 3A, the structure of the supplemented meat analogue from Formula 1 illustrated the heterogeneous porous network, thick crust and dense structure rearrangement. In Figure 3B, the structure of the supplemented meat analogue from formula 3 illustrated large porous, thin crust and a fibrous network forming. In Figure 3C, the structure of the supplemented meat analogue from formula 5 illustrated fine porous, dense porous structure and a homogenous structure forming. In Figure 3D, the structure of the supplemented meat analogue from formula 6 displayed large porous disperse in sample, thick crust and a fibrous network forming. In the

Table 3. Chemical properties analysis

Formulas	Moisture content ^{ns}
1	3.45 ± 0.07
3	3.64 ± 0.39
5	3.49 ± 0.13
6	3.53 ± 0.20

Remark: ^{NS} is not statistically significant different (p>0.05), ^{a,b,c} are mean values in same column followed by different letters are significantly different (p d" 0.05), ± is Standard Deviation.

Table 4. Physical properties analysis

Formulas	Cutting force (N)	Shear force (N)	Water activity (a_w) ^{ns}
1	17.88 ± 1.27^{b}	5.09 ± 0.01^{b}	0.52 ± 0.01
3	18.88 ± 0.40^{ab}	5.88 ± 0.64^{ab}	0.53 ± 0.01
5	18.72 ± 0.22 ^{ab}	5.74 ± 0.59^{ab}	0.51 ± 0.00
6	19.26 ± 0.50^{a}	5.98 ± 0.71^{a}	0.52 ± 0.01

Remark: ^{NS} is not statistically significant different (p>0.05), ^{a,b,c} are mean values in same column followed by different letters are significantly different ($p \leq 0.05$), ± is Standard Deviation.

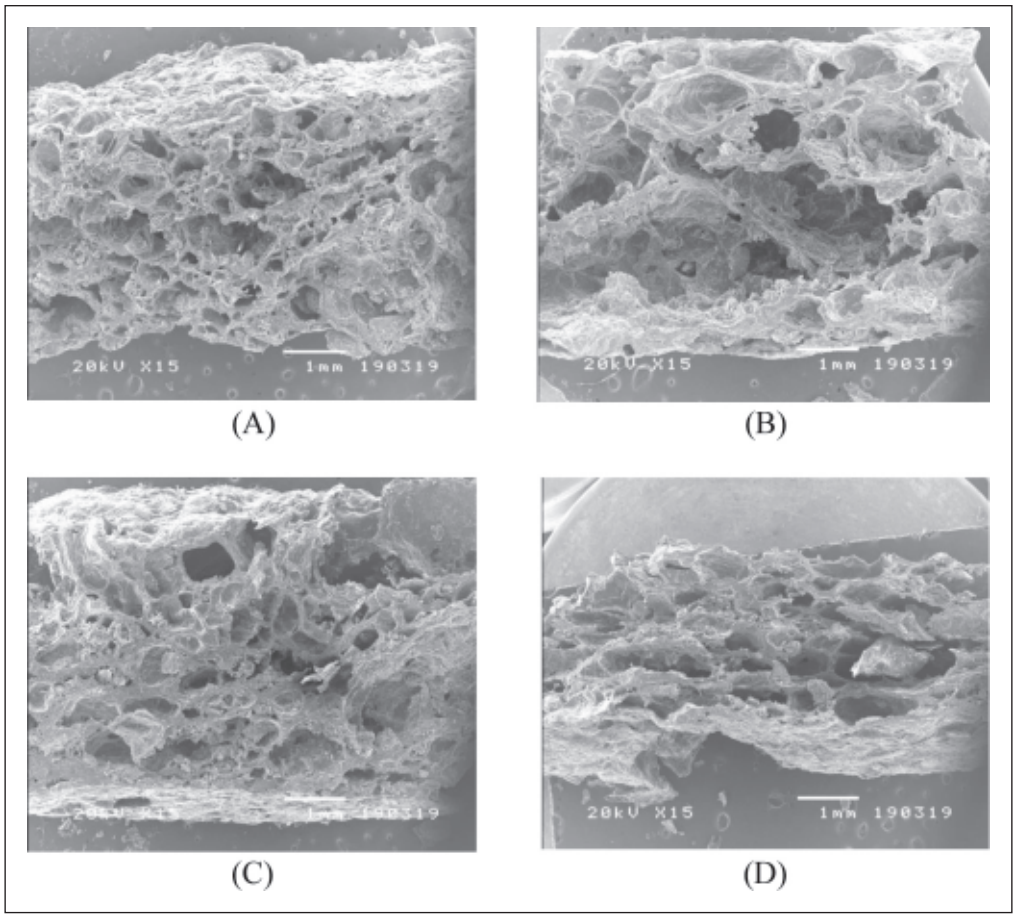

Fig. 3. The study of the supplemented meat analogue structures by scanning electron microscope.

6th formula meat analogue, high protein and carbohydrate content was from white kidney bean flour and soybean flour while Jerusalem artichoke flour caused a larger porous among other formulas. White kidney bean flour had water absorption properties which held ingredients together, formed homogeneous mixture, and provided cohesiveness and springiness to the product (Chongcharoenyanon, 2016). Soybean flour provided a fibrous structure formation and cohesiveness to the supplemented meat analogue (Pongsawatmanit, 2002). The higher amount of Jerusalem artichoke flour was related to looser formation and less cohesiveness due to loose starch arrangement in the flour molecule. This was correspondent with (Sheard *et al*., 1984) experiment; the findings were that protein and carbohydrate contents in raw materials affected the fibrous structure and texture of the supplemented meat analogue product because they were the main structure for forming meat fibrous texture. The process of producing supplemented meat analogue by extruder needed high temperature and high pressure in short time which affected the denaturation of soybean protein to be elongated and rearranged into a new fiber formation structure (Sheard *et al*., 1984).

The study of the consumer acceptance of the supplemented meat analogue

The study of consumer acceptance of the supplemented meat analogue was undertaken by means of 9-Point hedonic scale and Central Location Test (CLT) with focuses on the following factors: appearance, color, overall flavor, cohesiveness, overall taste and overall liking. The subjects were 100 normal and vegetarian consumers of the age range of 20 – over 60 years old, in Pathum Thani Province. The sample food, fried supplemented meat analogue in curry paste was served, together with a questionnaire. The finding was shown in Table 5.

It was found that the average sensory evaluation scores of the supplemented meat analogue from the four formulas were significantly different ($p < 0.05$) in terms of appearance, color, overall flavor, cohesiveness, overall taste and overall liking. Most consumers accepted the supplemented meat analogue from formula 6 because the meat provided high cohesiveness as it was the main parameter for consumers' acceptance. The high cohesiveness was related to the cutting force and shear force of the supplemented meat analogue from formula 6, of which the cutting force and shear force were the highest among other formulas. The cutting force

Table 5. The average sensory evaluation scores of the supplemented meat analogue from the four formulas

Formulas	Sensory evaluation					
	Appearance	Color	Overall Flavor	Cohesiveness	Overall taste	Overall liking
1	6.24 ± 0.91^{c}	6.24 ± 0.91^{c}	6.24 ± 0.91^{c}	6.24 ± 0.91^{c}	6.24 ± 0.91^{c}	6.24 ± 0.91^{c}
3	6.84 ± 1.21^{b}	6.74 ± 1.18^{b}	6.64 ± 1.08^{bc}	6.52 ± 1.08^{b}	6.68 ± 0.97^{bc}	6.80 ± 1.10^{b}
5	6.94 ± 1.31^{b}	6.74 ± 1.15^{b}	6.80 ± 0.92^{b}	6.64 ± 1.18^{b}	6.78 ± 0.90^{b}	6.90 ± 0.99^{b}
6	7.82 ± 0.99^{a}	7.58 ± 1.05^{a}	7.62 ± 1.09^{a}	7.64 ± 1.06^{a}	7.60 ± 1.08^{a}	7.84 ± 0.99^{a}

Remark: ^{a,b,c} are mean values in same column followed by different letters are significantly different ($p \leq 0.05$), ± is Standard Deviation.

and shear force were indicators of the product's cohesiveness texture. If the cutting force and shear force were high, the product texture would be high in terms of cohesiveness and springiness (Charunuch *et al*., 2017). The desired supplemented meat analogue texture was high cohesiveness and springiness. Therefore (Charunuch *et al*., 2017), the suitable formula for manufacturing meat analogue supplemented with white kidney bean flour and Jerusalem artichoke flour was formula 6.

From the study of suitable formula for manufacturing meat analogue supplemented with white kidney bean flour and Jerusalem artichoke flour, it was found that the most suitable formula was the 6th formula which contained 40% of white kidney bean, 22.5% of Jerusalem artichoke flour and 37.5% of soybean flour. From the physical and chemical analysis in terms of cutting force, shear force, water activity (a_w) and moisture content, it was found that the supplemented meat analogue from the 6th formula displayed the cutting force at 5.98 ± 0.71, the shear force at 19.26 ± 0.50, a_w at 0.52 ± 0.01 and the moisture content at 3.53% ± 0.20. Most consumers gave very like score in the overall liking parameter of the supplemented meat analogue at 7.84 ± 0.99. Accordingly, formula 6 was suitable for manu-facturing meat analogue supplemented with white kidney bean flour and Jerusalem artichoke flour.

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