Development of tilapia frankfurters using response surface methodology  
(Pembangunan frankfurter tilapia menggunakan kaedah permukaan gerak balas)

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Key words: fishery product, tilapia, frankfurter, response surface methodology, central composite design

Abstract
The effect of oil, water and starch levels on the texture and eating quality of tilapia frankfurters was studied using central composite rotatable design (CCRD) of response surface methodology (RSM). The appropriate level of spice mix in the formulation was determined by randomised complete block design (RCBD). Regression models indicated that water and starch levels greatly influenced the textural characteristics and overall acceptance of the product. Increase in water should be accompanied by an appropriate increase in starch level. Oil had little influence on the acceptability of the frankfurters. Optimum spice level was in the range of 0.1 – 0.2%. Potato and waxy cornstarch gave better gel-strengthening effect to the product ($p < 0.01$) compared to tapioca starch, wheat flour and a mixture or cornstarch and modified cornstarch. However the overall acceptability of the product containing tapioca starch was not significantly different from the samples containing potato starch or waxy cornstarch.

Introduction
Cooked sausage products like frankfurters are primarily processed from red meat. Consumer demand for low-fat products creates increased demand for research in the development of low-fat sausages. Many researchers reported that fat reduction in these products affect the stability of the meat system and reduce the quality of the products especially the texture of the product (Hand et al. 1987; Claus et al. 1990; Hensley and Hand 1995). The use of leaner meats in the formulation will increase the cost. Attempts to utilise freshwater fishes in the processing of fish sausage and salted fish cake had been reported by Gelman and Benjamin (1989) and Akande (1989) who worked on silver carp and black tilapia, respectively. The silver carp sausage was found to have achieved the level of acceptance similar to those of the beef-containing products.

Tilapia is a freshwater species that has great potential for product development. It has white and fine textured meat with a sweet, tuber-like taste, which makes it suitable for the production of value-added products. It is a lean fish species with fat content of less than 5% (Che Rohani et al. 1995). Large fish of 500 g to 1 000 g is recommended for the production of frozen fillet, battered and breaded fillet cutlets, and
smoked fillets (Che Rohani and Mat Arup 1997). Smaller fish may be used for surimi, surimi products and fish crackers (Che Rohani et al. 1995). Local tilapia farmers reported that 20–30% of their harvest consisted of undersized fish of 200–300 g. Such undersized fish fetches a very low price in the market, hence it is normally converted into fish or animal feed.

This study was carried out to develop a reduced fat fish frankfurter from tilapia hence increasing its utilization especially the low-value undersized tilapia. Thus the specific objectives of the study were to evaluate the effect of various levels of water, oil and starch on the chemical composition, texture and overall acceptability of fish frankfurters prepared from minced tilapia, to determine the most acceptable level of spice mix to be incorporated into the formulation to optimise its acceptability, and finally to determine the effect of different types of starch on the texture of the product.

Materials and methods
Red tilapia obtained from experimental ponds was bled, cleaned and mechanically deboned to obtain the meat. Cornstarch and modified starch (Firmtex) were purchased from National Starch and Chemical (M) Sdn. Bhd. Shah Alam. Tapioca starch, wheat flour, cooking oil, spices, salt, sugar and other ingredients were purchased locally. The polyvinylidene chloride wiener casings, potato starch, waxy cornstarch and texturized vegetable protein were purchased from Mark Aids Sdn. Bhd. Petaling Jaya.

Sample preparation
Fish meat was mixed with salt, starch, spices and other ingredients to form a smooth and viscous paste using an ice jacketed pestle grinder, keeping the temperature of the mix below 15 °C. The final batter was stuffed into casings using a sausage stuffer (Dick’s, Germany). They were hand-linked, smoked at 40 °C for 60 min, showered and then cooked to reach the core temperature of 90 °C using a Kerres Smoke Kiln (Germany). The samples were then cooled in ice water for 5 min before they were reimmersed in boiling water for about 1 min to obtain a tight pack. Samples were packed into plastic bags and kept at 0–2 °C for evaluation.

Sample evaluation
The sensory responses of samples were evaluated by a trained panel (n = 15) using a 5 inch horizontal line labelled at both ends and panellists indicated their perception by marking a slash on the line provided for each attribute (Stone et al.1974; Che Rohani et al. 2000). The attributes evaluated were hardness and springiness intensities (0 = none, 5 = very hard or very springy), textural acceptability and overall acceptability (0 = dislike very much, 5 = like very much).

In the second experiment to determine the optimum spice level, only responses for texture, spicy flavour and overall acceptance were evaluated. The instrumental hardness (maximum load on cycle 1), cohesiveness (total positive work on cycle 2 divided by total work done on cycle 1) and gumminess (cohesiveness multiplied by hardness) values of the samples in the third experiment were measured using a Stevens Quality and Test system, model QTS25 (UK) fitted with a 5 mm round probe (TA5 assembly). The speed used was 50 mm/min. The moisture, protein and fat contents of all samples were analysed using AOAC methods (1990).

Experimental design
Samples were prepared according to the formulations developed using a three-mixture components namely oil (X1), water (X2) and starch (X3) each at five levels (X1 = 0, 3.75, 7.5, 11.25 and 15%; X2 = 10, 15, 20, 25 and 30%; X3 = 3, 6, 9, 12 and 15%) using a central composite design (CCD) of the response surface methodology (RSM). The design was composed of a 2³ factorial, 6 axial points and 3 centre points. The formulations were developed by placing the standard preparation of the fish
frankfurters as the centre point (0). The extreme samples were chosen to represent concentrations of variables, which were assumed to be on the fringe of acceptability. These were given the values of ±2, and the less extreme samples were formulated at ±1 in relation to the standard at 0. These coded units (0, ±1, ±2) were used to define levels of X1, X2 and X3 (5 levels across each of 3 ingredients factors where the centre point was set as the standard, 0). Other ingredients namely fish meat, texturized vegetable protein, salt, sugar and flavour enhancer were kept at constant levels.

The second experiment was conducted as a randomised complete block design (RCBD) with two factors, namely, 3 levels of oil (0, 2.5 and 5%) and 5 levels of spice mix (0, 0.05, 0.1, 0.15 and 0.2%). The third experiment was conducted using the optimum formulation developed in the first experiment to test the effect of different types of starch, namely potato starch, waxy cornstarch, tapioca starch, wheat flour and a mixture of corn and modified cornstarch, on the texture of the product. Each stage of the experiments was replicated twice. Data were analysed using SAS program (SAS 1985).

Results and discussion

The average sensory intensity scores for hardness and springiness of the 17 formulated tilapia frankfurters ranged from 1.88–3.69 and 2.33–3.97, respectively. The average scores for texture and overall acceptance ranged from 2.80–4.06 and 3.00–4.25, respectively. The coefficient of multiple determination ($R^2$) for each of the best-fitting model equations relating independent and dependent variables were high for hardness intensity ($R^2 = 0.93$), textural acceptance ($R^2 = 0.83$) and overall acceptance ($R^2 = 0.82$). This indicated that the variation of the data for those 3 variables were well explained by the regression models (Table 1). Springiness intensity gave rather low $R^2 (R^2= 0.59)$.

The model fitting indicated that the added oil had a negative linear effect on hardness ($p < 0.01$). The effect was independent on the other two components studied since there was no interaction effect of oil with these components. Fat reduction in cooked meat sausages including frankfurters and bologna has resulted in firmer and more rubbery texture of the product (Hand et al. 1987; Hensley and Hand 1995). Similar effect of fat on the texture of tilapia frankfurters was observed in this study. The hardness decreased with the increase of added oil in the formulation.

The prediction models in Table 1 showed that starch component had significant positive effects on all the sensory responses ($p < 0.01$) while water component had significant negative linear effect for hardness ($p < 0.01$), springiness ($p < 0.05$), textural acceptance ($p < 0.05$) and overall acceptance ($p < 0.10$). However, the presence of significant positive interaction effects of water and starch for these sensory responses ($p < 0.05$) suggested that the effect of added water was dependent on the amount of added starch. At low starch level, the increase in added water had a significant negative effect on all of these sensory response variables (Table 1) but as starch level increased from its midpoint to maximum range the negative effect diminished gradually. This was the reason for the significant interaction term between starch and water. Thus, increase in water level should be accompanied with appropriate increase in starch level to produce a more acceptable product.

The moisture, protein and fat contents in the 17 formulated tilapia frankfurters ranged from 65.6–74.1%, 8.2–13.4% and 4.6–13.6%, respectively. The analysis of variance of the regression models indicated that the moisture and fat contents were significantly influenced by the levels of oil, water and starch in the formulation (Table 2) with coefficient of determination, $R^2 = 0.97$ and 0.94, respectively. It was observed that there were significant negative and positive linear effects of oil ($p < 0.01$) and water ($p < 0.01$), respectively, on moisture content.
Table 1. Reduce regression models describing the relationship between tilapia frankfurter formulation variables and sensory responses

<table>
<thead>
<tr>
<th>Sensory responses</th>
<th>Predictive models</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardness</td>
<td>3.0033 – 0.1508<em>oil – 0.3398</em>water + 0.4031<em>starch + 0.1406</em>water*starch</td>
<td>0.93**</td>
</tr>
<tr>
<td>Springiness</td>
<td>3.2757 – 0.2250<em>water + 0.3008</em>starch + 0.2203<em>starch</em>water</td>
<td>0.59 ns</td>
</tr>
<tr>
<td>Textural acceptance</td>
<td>3.5201 – 0.1125<em>water + 0.2633</em>starch + 0.0806<em>oil</em>oil – 0.0773<em>starch</em>starch + 0.1859<em>water</em>starch</td>
<td>0.83*</td>
</tr>
<tr>
<td>Overall acceptance</td>
<td>3.7299 – 0.0910<em>oil – 0.0941</em>water + 0.1785<em>starch + 0.0737</em>oil<em>oil – 0.0794</em>starch<em>starch + 0.1539</em>water*starch</td>
<td>0.82*</td>
</tr>
</tbody>
</table>

The models were reduced using the stepwise procedure of SAS. All the variables with a p-value <0.01 were kept in the regression model.

*Significant at 5% level, **Significant at 1% level
ns = Not significant

Table 2. Regression models describing the relationship between the formulation variables and the chemical composition of tilapia frankfurters

<table>
<thead>
<tr>
<th>Chemical composition</th>
<th>Predictive models</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture content</td>
<td>69.9660 – 1.6269<em>oil + 1.2044</em>water – 1.1019<em>starch + 0.2823</em>oil<em>oil + 1.1663</em>oil*water</td>
<td>0.97**</td>
</tr>
<tr>
<td>Protein content</td>
<td>10.5118 – 0.5656<em>oil – 0.7413</em>oil<em>water + 0.5987</em>water*starch</td>
<td>0.45*</td>
</tr>
<tr>
<td>Fat content</td>
<td>9.3806 + 2.4088<em>oil – 0.3575</em>water – 0.5675<em>starch – 0.8250</em>oil*water</td>
<td>0.94**</td>
</tr>
</tbody>
</table>

The models were reduced using the stepwise procedure of SAS. All the variables with a p-value <0.01 were kept in the regression model.

*Significant at 5% level, **Significant at 1% level

while the reverse linear effects were shown by the fat content (p <0.01 and 0.01, respectively).

However, the presence of the interaction effects between oil and water on these response variables (p <0.01) suggested that the effect of added oil was dependent on the amount of water added in the formulation. At low level of added oil, increased water component caused slight change on the moisture content but showed an increase in fat content of the product indicating that more fat is bound to the fish protein during mixing of the low-fat frankfurter mixture. On the other hand, at a higher oil level, the increase in added water gave a significant increase in moisture content while decreasing the fat content indicating less fat is bound to the fish protein during mixing compared to water. These high fat samples were observed to be oily on the surface.

Both the moisture and fat contents of the product increased with the decrease in added starch (p <0.01). Even though added oil had negative effect on protein content (p <0.01), the presence of negative interaction between oil and water components (p <0.01) and positive interaction of water and starch components (p <0.01) showed a decrease in protein content when oil and starch were simultaneously increased or decreased. However, the R² value of the regression model was low i.e. only 0.45.

The results in Table 1 indicated that oil had less influence on the textural characteristic and overall acceptance of the
product compared to water and starch interactions. The result suggested that an acceptable low fat frankfurter may be formulated using tilapia mince even though Hand et al. (1987) reported that reduced fat beef frankfurters has a tougher texture resulting in lower quality. Fish proteins contain actomyosin that is responsible for the formation of a firm and elastic textures in comminuted fish products. These characteristic textures of fish products such as surimi products are well accepted by the consumers (Martin 1986; Sperber 1990). Similar results were obtained with tilapia frankfurters in this study whereby firm samples made from potato starch and waxy cornstarch received higher acceptability scores than those with softer texture (Table 3).

The models in Table 1 suggested that the levels of water and starch had to be adjusted appropriately to produce an acceptable product. Increase in water level should be accompanied with appropriate increase in starch level due to dilution effect of water on other ingredients that will affect the taste and texture of the product. Therefore in the second stage of the study, to determine the optimum level of spice, the water and starch levels were kept at 27.5% and 13.5%, respectively. Spice levels had a significant effect on the spiciness and overall acceptance of the product (Table 4). Optimum responses were obtained at spice levels of 0.1–0.2%. The spice mix used in this study was a blend of coriander, clove, ginger and cinnamon.

Starch is used widely in meat-based products including emulsion-type product like frankfurters for texture improvement. Table 3 showed the sensory responses and instrumental textural values of the tilapia frankfurters made with different types of starch. The mean instrumental hardness values for these samples ranged from 542.5–1035.6 g and the mean sensory scores for hardness ranged from 2.85–3.82. The instrumental hardness showed a significant correlation ($r = 0.7^{**}$) with the sensory response for hardness but no significant correlation was observed with overall acceptance of the products.

The sensory responses for hardness, textural acceptability and overall acceptability were significantly different ($p < 0.05$) among all treatments (Table 3). Potato starch and waxy cornstarch had
significantly higher gel strengthening abilities \((p < 0.01)\) as indicated by the hardness intensity score and instrumental hardness values, followed by tapioca starch and wheat flour. The textural acceptability of these two samples was also significantly higher than other samples except that of tapioca starch.

The control sample, which contained cornstarch and modified cornstarch had the least firm texture and the lowest mean value for textural acceptability. However its textural acceptability was not significantly different from those containing wheat flour and tapioca starch. Modified starch was added to improve the freeze-thaw stability of the fish product even though its addition weakened the gel strength in terms of hardness or firmness (Lee et al. 1992). Similar observation of gel-strengthening effect of potato and waxy cornstarch was reported by Kim and Lee (1987) and Wu et al. (1985) in surimi gel.

Moisture affects the gel-strengthening effect of starch as shown in Table 1. Therefore, the levels of water and oil in the third experiment on the effect of different types of starch or flour were adjusted to be the same in all treatments used in the study. However the moisture and the fat contents in the final product were significantly different at 5% level (Table 5). The moisture content ranged from 73.5–75.1% and the fat content 5.23–6.05%. Some moisture loss might have occurred during smoking as expected when using native starches. The fat content increased slightly with the decrease in moisture when comparing products made using modified starch with those produced using only native starches. The control sample, which contained modified starch, had higher moisture content than other samples made from native starches. Modified starch has better water holding capacity than native starch, hence reduced any moisture loss during smoking. The

<table>
<thead>
<tr>
<th>Spice levels (%)</th>
<th>Mean sensory responses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Texture acceptance</td>
</tr>
<tr>
<td>0</td>
<td>4.22a</td>
</tr>
<tr>
<td>0.05</td>
<td>4.23a</td>
</tr>
<tr>
<td>0.10</td>
<td>4.28a</td>
</tr>
<tr>
<td>0.15</td>
<td>4.29a</td>
</tr>
<tr>
<td>0.20</td>
<td>4.33a</td>
</tr>
</tbody>
</table>

Each value is the mean of 90 readings
Means followed by a common letter within the same column are not significantly different \((p > 0.05)\)

Table 5. Mean of moisture, protein and fat contents of tilapia frankfurter using different types of starch or flour \((n = 30)\)

<table>
<thead>
<tr>
<th>Type of starch</th>
<th>Composition (g/100 g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Moisture</td>
</tr>
<tr>
<td>Corn + modified starch</td>
<td>75.1a</td>
</tr>
<tr>
<td>Wheat flour</td>
<td>74.6ab</td>
</tr>
<tr>
<td>Waxy corn</td>
<td>73.5c</td>
</tr>
<tr>
<td>Potato</td>
<td>74.3b</td>
</tr>
<tr>
<td>Tapioca</td>
<td>73.9bc</td>
</tr>
</tbody>
</table>

Means followed by a common letter within the same column are not significantly different \((p > 0.05)\)
protein content in the final product was not significantly different among treatments because the protein-based components, tilapia meat and texturized vegetable protein, were kept constant.

Conclusion
Undersized tilapia can be used to produce acceptable reduced fat fish frankfurters. The acceptability of this product was greatly influenced by the levels of water and starch, but not the oil, in the formulation. Optimum responses for overall acceptability were obtained at spice levels of 0.1–0.2%

The types of starch used in tilapia frankfurters gave significant effect on its texture. Even though potato and waxy cornstarch had better gel-strengthening effect, local tapioca starch also gave acceptable texture to the product. The use of modified starch is recommended to reduce the moisture loss during smoking especially when the fat level is low.

Acknowledgement
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References
Abstrak
Kesan tahap air, minyak sayuran dan kanji terhadap tekstur dan mutu nilai rasa frankfurter tilapia dikaji menggunakan reka bentuk pusat berputar 3 faktor mengikut kaedah permukaan gerak balas. Tahap yang sesuai bagi rempah campur yang digunakan di dalam formulasi ditentukan menggunakan reka bentuk blok lengkap terawak. Model regresi menunjukkan bahawa ciri-ciri tekstur dan penerimaan keseluruhan produk amat dipengaruhi oleh tahap air dan kanji. Apabila tahap air dinaikkan, tahap kanji juga perlu dinaikkan mengikut kesesuaian. Minyak sayuran tidak begitu mempengaruhi penerimaan produk ini. Tahap optimum bagi rempah campur ialah 0.1 – 0.2%. Kanji ubi kentang dan kanji jagung telah memberi kesan yang lebih baik terhadap kekuatan gel produk (p < 0.01) berbanding dengan kanji ubi kayu, tepung gandum dan campuran kanji jagung dan kanji jagung terubahsuai. Walau bagaimanapun, penerimaan keseluruhan produk yang mengandungi kanji ubi kayu adalah tidak berbeza secara bererti berbanding dengan sampel-sampel yang mengandungi kanji ubi kentang dan kanji jagung.