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Effect of Formula Variation in the Properties of Fish Feed Pellet

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Abstract: Most of fish feed pellet in market is low in terms of water stability and easily swell when it is immersed in water. Thus, the soluble vitamins and minerals will be easily leached out from the pellet. These will lead to the nutrient deficiency and environmental problems in fish tanks or ponds. Therefore, a study was conducted to minimise the degree of swelling and mineral leaching while the floating time is maximised. For these purpose several formulations of fish feed were made and tested. The formulation was based on common resources such as corn flour, soy flour and tapioca flour. To get water stability which is better floating time and lower leach ability, palm oil stearin was added as a main subject compound for this study. Statistical method, D-optimal crossed design of response surface methodology was used for the analysis and optimisation of the properties of fish feed pellet produced. In the statistical analysis, the physical properties such as degree of swelling, leaching and floating ability were chosen as the responses whereas pellets composition and processing temperature as the independent factors. The result shows there is a relationship between fish feed formulation and properties of fish feed pellet produced. The optimum of the floating time, leach ability and stability of fish feed pellet also can be obtained.

Key words: Fish pellet, degree of swelling, mineral leaching, floating ability

INTRODUCTION

In modern times, aquaculture has sustained a global growth, continue to grow and is expected to increasingly fill the shortfall in aquatic food products resulting from static or declining capture fisheries and population increase well into the year 2025 (De Silva, 2000). Fish contributes a high proportion of animal protein in human diets in most Asian countries and most countries are trying to increase fish production through aquaculture. In Malaysia, production of aquaculture has increased drastically from 15,000 tonnes in 1990 to 90,000 in 2003. Aquaculture production in Malaysia is targeted to reach 600, 000 tonnes annually by the year 2010 (Musa and Nuruddin, 2005).

Currently, production of fish in Malaysia mainly depends on trash feed, formulated feed, waste from poultry industry and other agriculture by-product. However, production of marine-cultured fish is totally relying on trash fish, as the supply is readily available. Direct use of trash fish will exploit marine fish resources. Several ways to improve feeds for aquaculture include invest in feed research for inland/marine species and promote adoption and change over to pellet feeds. However, nutritious feed is the most expensive component in incentive aquaculture industry. Fish feed represents about 50% of the production cost in the Atlantic salmon cage-culture industry (Vielma *et al*., 2000). The price competitive nature of fish farming is now more like other livestock requiring an increased precision in diet formulation to minimize input costs while maintaining maximum performance (Barrows *et al*., 2008).

As reported, the conversion efficiency of feed to aquaculture product was only around 20% at best, so 80% of the inputs are wasted (Devenport, 2003). Therefore, many nutritional scientists have now struggle to formulate a fish feed with the highest nutritional value (Barrows *et al*., 2008; Paus *et al*., 1998) and maximum digestibility (Hansen and Storebakken, 2007; Booth *et al*., 2000; Bahurmiz and Ng, 2007). Maximum nutrient utilization allows fish to utilize almost all of the food they have eaten and this provides another benefit such as less waste as a by-product in the tank and a healthier environment for fish. Currently, starch is required to bind the ingredients in order to form a durable pellet. At the same time, starch is a requirement for expansion and floating of pellet. Unfortunately, expansion can result in pellets with a weaker overall structure, even at high degree of gelatinization (Aarseth *et al*., 2006). Water soluble and hygroscopic ingredients weaken pellet

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structure in water, allowing components to separate and making the feed only partially accepted. Commercial feeds for fish culture normally float for a few minutes and started to sink and breakdown at the bottom of the tank. Previous study reported that the sinking pellets were very moist and unattractive for halibut (Kristiansen and Ferno, 2007). Decomposition of uneaten feed together with fish wastes and other organic matter in the tank can increase levels of nitrogen wastes, which is toxic to fish. In other cases, there is a danger of over-feeding fish with hard pellets, causing swelling and rupture of the stomach. Therefore, a little attention needed to find an alternative way to minimise the degree of swelling and mineral leaching while the floating time is maximised

In this study, formulated fish feed were produced with inclusion of palm fat since palm oil is abundant. Malaysia is world's larger producer and exporter of palm oil and produce about 47% world's palm oil supply (Sumathi *et al*., 2008). Beside that, palm oil is the cheapest vegetable oil in the market. Therefore, the cost for fish feed can be relatively low. Previous research suggest that palm oil product, such as crude palm oil, refined, bleached, deodorized palm olein, palm fatty acid distillate can be added in fish feed formulation to replace fish oil in fish meal-based diets for red hybrid tilapia without negative effects on growth performance, feed utilization efficiency or body-organ indices (Bahurmiz and Ng, 2007). Therefore, the current research aim to improve water stability of the pelleted fish feed. Inclusion of palm fat promote longer floating time of the pellet since fat is less dense than water.

On the other hand, degree of swelling was minimised as the fat will reduce absorption of water in the pellet. Since most of vitamin soluble in oil, vitamin and mineral leaching from pellet were minimised.

MATERIALS AND METHODS

Raw materials: Pam oil stearin was purchased from IOI Edible Oils Sdn. Bhd. Sodium chloride used as a salt. Tapioca flour, soy bean flour and dried corn grain were purchased from local market.

Experimental design: The experimental design was conducted using Design Expert (version 6.10, Stat-Easy Inc., Minneapolis, USA). Formulation of fish feed is based on four components, which are corn flour, soy bean powder, tapioca flour and stearin. This components mixture comprises 99.5% of the constraints which are four components factor and one process factor, as shown in Table 1. There are restrictions on the component.

Table 1: Formulations of Fish Feed

Formulation	Corn flour	Soy flour	Stearin	Tapioca flour	Salt	Drying temperature
1	40.50	14.00	7.00	38.00	0.50	100.00
2	40.50	15.80	5.20	38.00	0.50	100.00
3	40.50	15.80	5.20	38.00	0.50	80.00
4	37.90	16.00	7.60	38.00	0.50	80.00
5	38.08	15.18	9.12	37.12	0.50	80.00
6	35.50	16.00	10.00	38.00	0.50	100.00
7	35.50	16.00	10.00	38.00	0.50	90.00
8	40.50	15.80	10.00	33.20	0.50	80.00
9	40.50	14.00	7.00	38.00	0.50	80.00
10	37.90	16.00	7.60	38.00	0.50	90.00
11	37.50	14.00	10.00	38.00	0.50	90.00
12	37.90	16.00	10.00	35.60	0.50	80.00
13	40.50	16.00	9.80	33.20	0.50	90.00
14	40.50	16.00	7.50	35.50	0.50	100.00
15	40.50	16.00	7.50	35.50	0.50	80.00
16	37.90	16.00	10.00	35.60	0.50	100.00
17	40.50	15.80	10.00	33.20	0.50	100.00
18	40.50	14.00	10.00	35.00	0.50	80.00
19	37.50	14.00	10.00	38.00	0.50	80.00
20	40.50	15.80	5.20	38.00	0.50	90.00
21	40.50	14.00	7.00	38.00	0.50	90.00
22	35.50	16.00	10.00	38.00	0.50	80.00
23	38.08	15.18	9.12	37.12	0.50	100.00
24	37.90	16.00	10.00	35.60	0.50	90.00
25	37.90	16.00	7.60	38.00	0.50	100.00
26	40.50	14.00	10.00	35.00	0.50	90.00
27	37.50	14.00	10.00	38.00	0.50	100.00
28	40.50	16.00	7.50	35.50	0.50	90.00
29	40.08	15.13	9.12	35.17	0.50	90.00
30	40.50	14.00	10.00	35.00	0.50	100.00

Table 2: The Constraint of Component Proportion

Component	Units	Low limit (L_j)	High limit (U_j)
Corn flour (X_1)	%	35.50	40.50
Soy flour (X_2)	%	14.00	16.00
Stearin (X_3)	%	5.20	10.00
Tapioca flour (X_4)	%	33.20	38.00
Drying temperature (X_5)	°C	80.00	100.00

Proportions X_j that take the form of lower L_i and Upper U_j constraint. Table 2 shows the suggested formulation for fish feed according to process factor.

Preparations of feeds pellet: The soy beans were dried at 65°C for 72 h in the oven. Dried soy beans and corn grains were grounded and sieved to get the powder with size about 425 μm. All ingredients were mixed in a domestic mixer according to the formulation in Table 2. The mixture was slowly mixed with hot water (80°C) in proportion 1:2 (v/w) mixing to accomplish agglutination. The dough was passed through extruder to obtained 2 mm diameter pellets. The pellet were cut around 2 to 3 mm length and dried for 1 h. The dried pallets were stored in plastic bags at refrigeration temperature approximately 5°C (Cavalheiro *et al*., 2007).

Physical characterisation

Swelling test: Swelling test of the feed pellets was performed with water at room temperature for 1 h. The photograph of pellet before and after the test was taken and analysed using Able Image Analyzer version 3.1b. The percentage of swelling for each pellet was calculated using Eq. 1.

$$\text{Swelling (\%)} = [(d_1 - d_0)/ d_0]\times 100 \quad (1)$$

where, d_0 is diameter of dry pellet and d_1 is diameter of swollen pellet.

Leaching test: Pellet was immersed in 20 mL of distilled water for 1 h and the water sample was analyzed by AA Spectrophotometer (AAS) to determine the amount of sodium leached out from pellet.

Floating ability test: Floating ability test was conducted to determine the time of pellet retain on water surface before sinking. The pellet was put in 100 mL water and floating time of pellet was recorded.

RESULTS AND DISCUSSION

Effect of composition variations and process factor on degree of swelling of fish feed pellet

The calculations and graphs were performed using Design-Expert version 6.10 software, Stat-East, Inc., Minneapolis. For swelling response, crossed linear x linear model was chosen. Final equation in terms of actual components was performed as Eq. 2.

$$Y_1 = 34.565X_1-11.479X_2-19.351X_3-26.488X_4-0.391X_1X_5+0.111X_2X_5+0.236X_3X_5+0.312X_4X_5 \quad (2)$$

Where:
Y_1 = Swelling
X_1 = Corn flour
X_2 = Soy flour
X_3 = Stearin
X_4 = Tapioca flour
X_5 = Drying temperature

Figure 1 shows the normal probability plot for swelling data. The plots are satisfactory and this suggest that the crossed linear x linear model was adequate to describe the response surface for swelling test.

In order to understand the effects of each component to the swelling, Figure 2 shows the trace response plot. The reference mixture is shown at the point of 0.000 on the horizontal axis. The composition of A (Corn flour), B (Soy flour), C (Stearin) and D (Tapioca) is the main factor to influence the swelling properties. Figure 2a-c show the linear effect of all the four components on the swelling at temperature 80, 90 and 100°C.

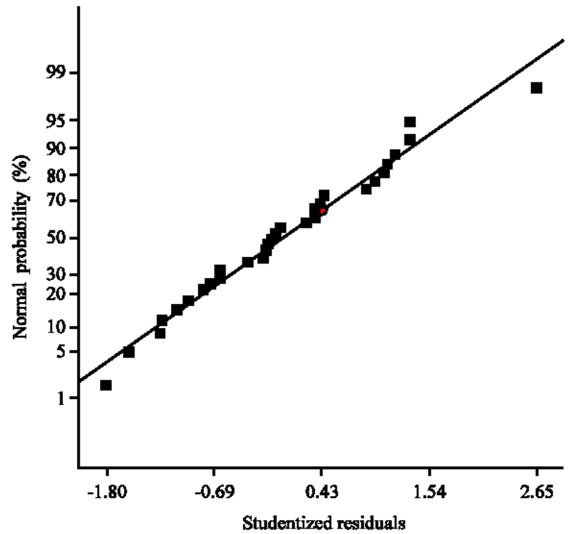

Fig. 1: Normal plot of residuals of swelling response

At temperature 80°C, corn component give significant effect on swelling. Swelling increases as corn component increases. However, swelling decreases as composition of tapioca flour and stearin increases in the formulation. In contrast, increasing corn component lowered the swelling at temperature 90 and 100°C. On the other hand, swelling increases as stearin and tapioca flour increase in the formulation for both temperatures. Soy component does not give a significant effect on swelling at drying temperature ranging from 80 to 100°C. Soy generally improved the physical properties of fish feed in terms of breaking force and bulk density, thus reduced the radial expansion (Sorensen *et al*., 2009).

Effect of composition variations and process factor on mineral leaching of fish feed pellet: Crossed quadratic x mean model was chosen which has been analysed using Design-Expert. Final equation in terms of actual components was performed as Eq. 3.

$$Y_2 = 0.588X_1-3.727X_2-0.855X_3+0.480X_4+0.0271X_1X_2+0.028X_1X_3-0.028X_1X_4+0.047X_2X_3+0.068X_2X_4-0.020X_3X_4 \quad (3)$$

Where:
Y_2 = Leaching
X_1 = Corn flour
X_2 = Soy flour
X_3 = Stearin
X_4 = Tapioca flour

Figure 3 demonstrates the normal probability plot of studentized residuals versus predicted values.

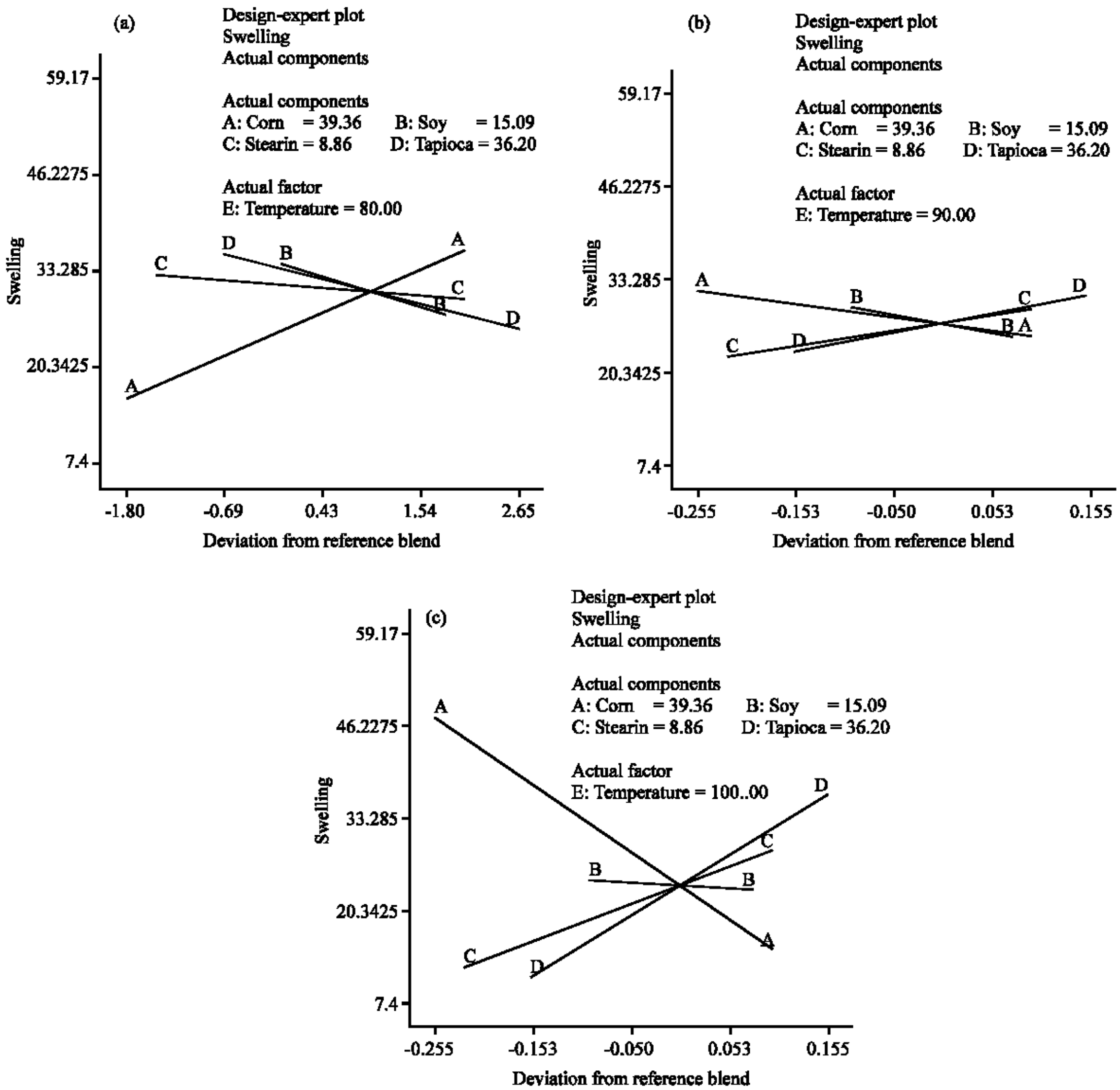

Fig. 2: Trace plot of swelling response at temperature (a) 80°C, (b) 90°C and 100 °C

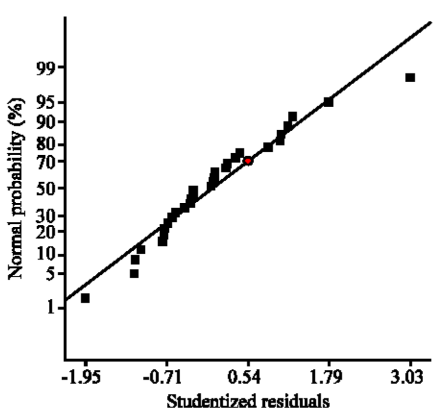

Fig. 3: Normal plot of residuals of leaching response

The plots are satisfactory and suggest that the crossed quadratic x mean model was adequate to describe the response surface for the leaching of formulated fish feed pellets. Trace plot in Fig. 4 shows the effect of leaching response while each of component changing along imaginary line from the reference blend to the original vertex x_i = 1. The trends show that leaching was mainly controls by tapioca flour.

Mineral leaching from pellets increases as composition of tapioca flour increases. Stearin and corn flour gives a less effect to the mineral leaching from pellet as compared to other components. It was also shown that drying temperature did not give noticeable effect to the plot.

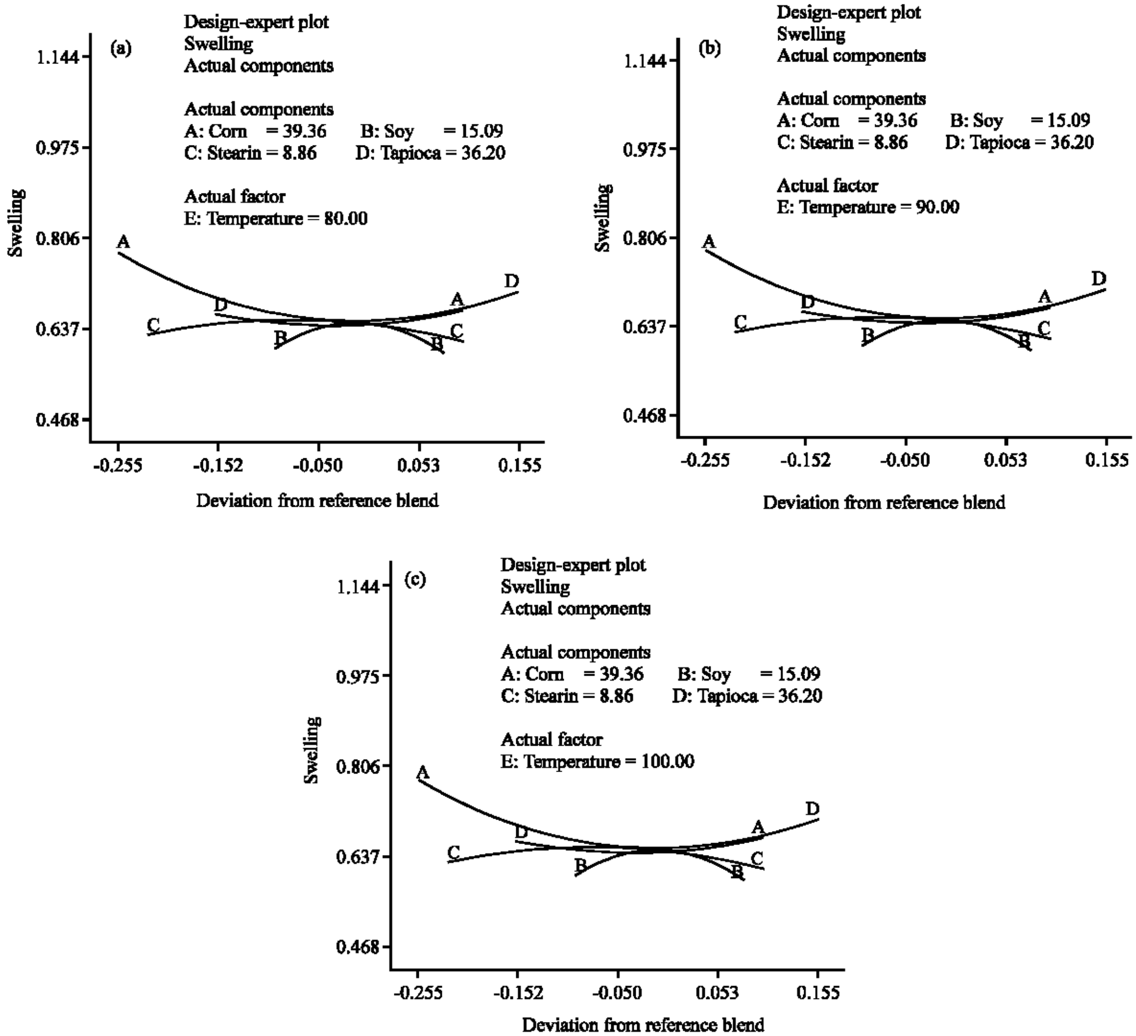

Fig. 4: Trace plot of leaching response for drying temperature (a) 80°C , (b) 90°C and (c) 100°C

Effect of composition variations and process factor on floating ability of fish feed pellet: Crossed quadratic x mean model has been chosen for floating response after analysed in Design-Expert computer program. Final equation in terms of actual components was performed as Eq. 4:

$$Y_3 = -829.89-544.60X_2+358.09X_3+176.22X_4+21.64X_2^2 -4.49X_3^2-0.82X_4^2+0.11X_2X_3-2.77X_2X_4-7.75X_3X_4 \quad (4)$$

Where:
Y_3 = Floating
X_2 = Soy flour
X_3 = Stearin
X_4 = Tapioca flour

It is found that corn and temperature were not influence the floating response.

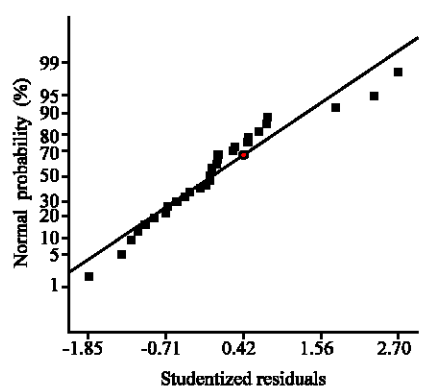

Fig. 5: Normal plot of residuals of floating response

Figure 5 presented the normal probability plot of studentized residuals versus predicted values. The plots in Fig. 5 are satisfactory and can be concluded that the

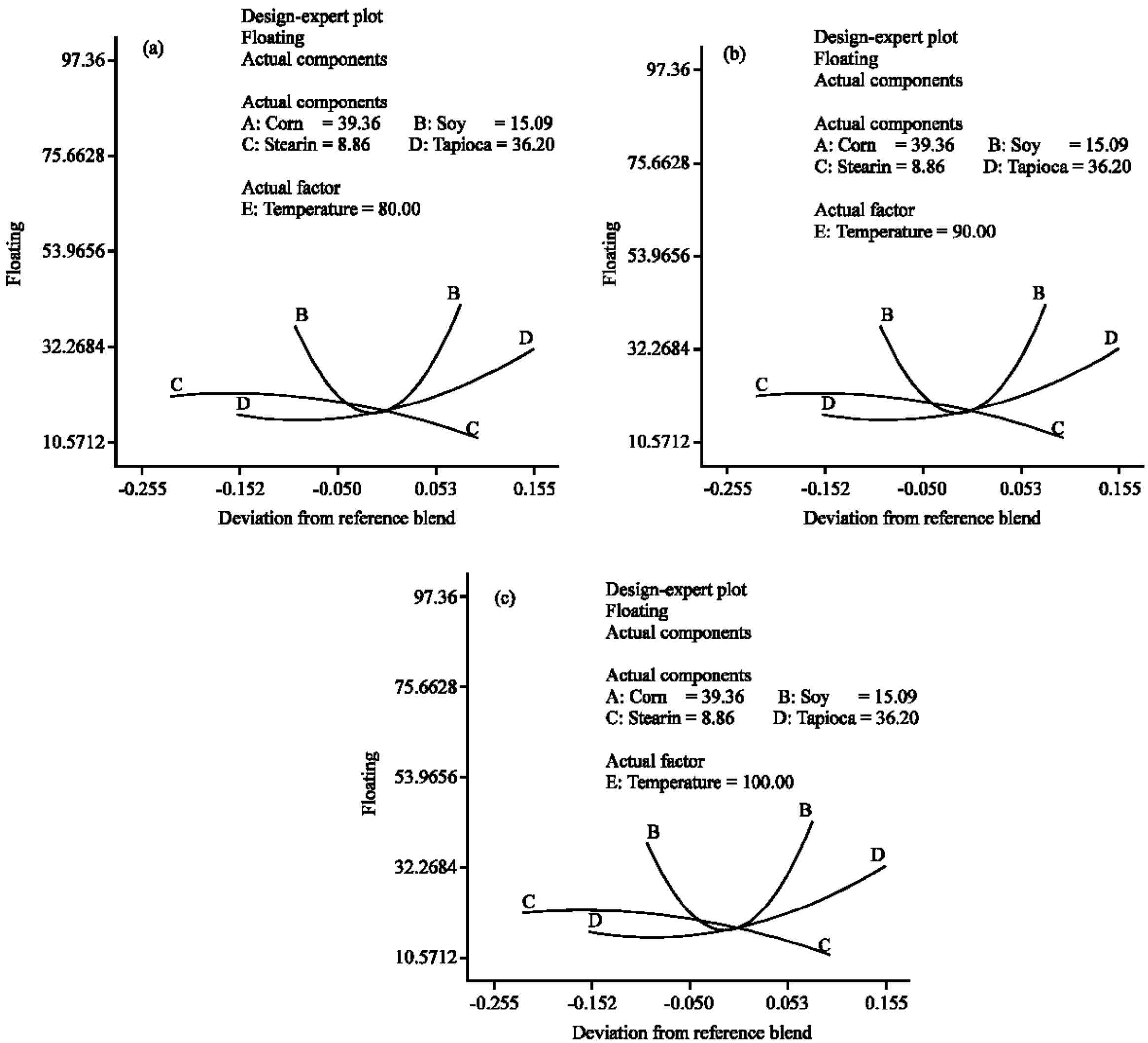

Fig. 6: Trace plot of floating response for drying temperature (a) 80°C, (b) 90°C and (c) 100°C

crossed quadratic x mean model was adequate to describe the response surface for floating of this formulated fish feed. Figure 6 presented trace plot for floating response. Floating significantly as the composition of soy and tapioca flour increases. Theoretically, stearin was added to the formulation to give a good characteristic in floating. In fact, experimental result shows that floating was less influenced by stearin. This may due to the processing condition of the feed pellet which is conducted in temperature between 80 to 100°C.

The fat may be melted and leached out easily from the pellet during high drying temperature. By comparing trace plot in Fig. 6a-c, it is clearly seen that the trend in floating properties does not influenced by temperature change from 80 to 100°C.

Table 3: Optimization goal for the response

Response	Goal
Swelling	Minimum
Leaching	Minimum
Floating	Maximum

Optimisation of fish feed formulation: Numerical optimisation of fish feed formulation was performed to obtain the formulation with desired characteristics. The goals of physical characterisation in this formulation are to achieve minimum swelling and leaching but maximum floating. The goal of each response was summarized in Table 3.

The optimum formulation selected consist 40.50% corn, 14.00% soy, 7.00% stearin, 38.00% tapioca with cooking temperature 90.39°C. Table 4 shows the optimisation of fish feed formulation based on objectives of this research.

Table 4: The Result from Suggested Formulation

Response	Result
Swelling	27.20%
Leaching	0.584 ppm
Floating	58.49 h

CONCLUSION

Thirty formulations of fish feed were prepared from corn flour, soy flour, tapioca flour and stearin with drying temperature 80 to 100°C. It was found that the change in drying temperature only influence the swelling properties of fish feed pellet. Swelling decreases as composition of tapioca and stearin increases at drying temperature of 80°C. Corn was the component that significantly increases swelling. As drying temperature increases up to 100°C, the opposite trend was found for the effect of composition towards swelling. Mineral leaching from the feed pellet was mainly controls by tapioca flour. Mineral leaching from pellets increases as composition of tapioca flour increases. Stearin and corn flour gives a less effect to the mineral leaching from pellet as compared to other components. Floating ability of feed pellet was mainly influenced by tapioca and soy, while stearin gives the least. This may due to the high processing temperature. Stearin might be melted and leached out from the pellet. Numerical optimisation was conducted using RSM and found the optimum formulation consist of 40.50% corn, 14.00% soy, 7.00% stearin and 38.00% tapioca with 90.39°C drying temperature.

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