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Optimization of Rice, Soybean, and Yellow Sweet Potato Flour Concentrations for Improved Nutritional and Sensory Quality of Infant Food

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Complementary food is important in the first two years of an infant's life for optimum growth and development. In the Philippines, especially in areas without access to adequate food sources, infants are fed with complementary foods of low nutrient density. To improve the nutrition in areas where malnutrition among 0–2-yr-old children is highly prevalent, this study developed a plant-based complementary food premix from rice, soybean, and yellow sweet potato for infants aged 6–23 mo. Ten (10) complementary food premixes were formulated and optimized using D-optimal mixture design. Results showed that different proportions of flour blends had significant ($p < 0.05$) effects on protein, ash, fat, carbohydrates, water absorption index, swelling power, and consistency. The optimized complementary food formulation was with the ratio of 50% rice, 35% soybean, and 15% yellow sweet potato flours. A 100-g serving of the complementary food provides 408.77 kcal and 15.68 g of protein.

Keywords: complementary food, D-optimal design, nutrition, optimization, rice

INTRODUCTION

Complementary foods (in liquids, semisolids, and solids form) are nourishment other than breast milk or infant formula that are introduced to infants to provide supplemental nutrients for normal growth and development (Laryea *et al*. 2018). These foods sustain protein and fat requirements for normal growth and development in children. Formulating and developing nutritious complementary foods that can supply the appropriate nutrients from underutilized local and readily available raw materials has received a lot of attention in developing countries, including the Philippines (Perlas 2013).

Homemade complementary foods in the Philippines are primarily plant-based such as rice, which is mostly cooked as thin porridges called *"am"* in the Filipino language. Perlas (2013) reported "*am*" as low-energy and -nutrient infant food, resulting in insufficient intake of nutrients when fed to infants and young children. Thus, there is a need to develop a nutritious complementary food that can easily be prepared or made available at the household level.

Rice and sweet potato had been recognized as a viable complementary food ingredient for supplementing the nutritional needs of babies in developing countries. Rice is rich in carbohydrates but low in micronutrients. Sweet potato has a high energy content, vitamin C, potassium, iron, and zinc (Chipungu *et al.* 2017; Koua *et al*. 2018); however, it is low in protein and fat (Laryea *et al.* 2018). To enhance the nutritional content of rice and sweet potato, Pobee *et al.* (2017) and Amagloh *et al.* (2012) included soybean and dried mango in reported complementary foods. Adding soybean in the product addresses macro and micronutrient deficiencies among infants as it is

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one of the richest and cheapest sources of plant proteins, fats, carbohydrates, vitamins [A, B (thiamine, riboflavin, niacin, pantothenic acid, and folate), and E], phosphorus, magnesium, sulfur, calcium, chloride, and sodium (Lokuruka 2010). Nutrient contents of legumes such as soybean make them excellent ingredients in improving the nutritional quality of the yellow sweet potato and rice as an instant complementary food.

Enhancing a child's nutritional status to prevent the possible occurrence of undernutrition can be achieved through a combination of locally available food crops. These local crops must complement each other to provide the recommended daily nutrient intake of an infant. An optimum combination of ingredients for desirable product attributes can be attained using mixture design (Ayele *et al.* 2017).

This study was designed to develop a nutritionally enriched and palatable complementary food product from rice, soybean, and yellow sweet potato blends tailored for poor households, which usually only rely on rice water or "*am*" as a nutritional food for the infant.

MATERIALS AND METHODS

Materials

Milled NSIC Rc 17 glutinous rice (*Oryza sativa* L.) was provided by the Philippine Rice Research Institute (PhilRice) while soybean (*Glycine max.*) and yellow-fleshed sweet potato (*Ipomoea batatas* L.) were obtained from local farmer's market. Other raw materials such as sugar and skim milk were obtained from a local supermarket in Science City of Muñoz, Nueva Ecija, Philippines.

Sample Preparation

Rice flour. Cleaned milled glutinous rice was soaked in water and refrigerated at 4-7 °C for 24 h. The soaked grains were then steamed at 100 °C for 25 min. The cooked rice was then evenly and thinly spread in an aluminum pan and dried in a hot air oven at 50 °C for 12 h to facilitate uniform drying. Dried grains were powdered into a fine flour using a Cyclotec™ 1093 sample mill, FOSS Tecator. The flour was then passed through a 100-mesh (150 µm) sieve and packed in a resealable polyethylene pouch and stored in the refrigerator until use.

Yellow sweet potato flour. Whole, unpeeled, and average-sized yellow-fleshed sweet potato were rubbed and washed with potable water and placed into a stainless-steel steamer and cooked for 20 min. It was then peeled and cut into thin slices (0.15 mm) using a vegetable slicer, further the slices were dried in a hot-air oven at 60 °C for 24 h. The dried slices of yellow sweet potatoes were powdered using the Cyclotec™ 1093 sample mill – FOSS Tecator, to produce fine flour and then passed through a 100-mesh (150 µm) sieve. The flour was packed in a resealable polyethylene bag and stored in the refrigerator until further use.

Soybean flour. Cleaned soybean seeds were soaked in water (1:3 ratio) overnight at ambient temperature. The steeped water was drained, while the soybean seeds were washed and manually dehulled. Soybean was cooked in a steamer at 100 °C for 3 h or until fully cooked and oven-dried at 50 °C for 24 h, then powdered using Cyclotec™ 1093 sample mill, FOSS Tecator to make flour. Soybean flour was sieved in a 40-mesh (425 µm) sieve, packed in a resealable polyethylene bag, and then stored in a cool place until use.

Experimental Design and Treatment Combinations

The parameters that were subjected to D–optimal mixture design using Design–Expert® Version 11.0 software in formulating complementary food premix is shown in Appendix Table 1. Different concentrations (low and high limit) of flours (rice, soybean, and yellow-fleshed sweet potato) were assigned as generated from the D-optimal mixture design. The tool suggests optimal concentrations of each of the three crops to formulate high desirability based on the pre-defined criteria (*i.e.* proximate composition and functional properties). Treatment combinations of each flour using a conventional 3^3 circumscribed design leading to 10 formulations generated by the two independent factors (types of flour and concentrations of each flour) are summarized in Appendix Table 2.

Formulation of Complementary Food Premix

Ten (10) complementary food premix combinations of rice, soybean, and yellow-sweet potato flours were prepared based on the different flour formulations obtained using Design-Expert Version 11.0 software (Appendix Table 2). The different complementary food premixes were toasted individually and added with sugar and skim milk in very low heat for 10 min. The same amount of sugar (0.75 g) and skim milk (1 g) were added to a 5-g serving of each of the 10 formulations. All flour premixes were packed in a resealable plastic bag and stored in a refrigerated temperature until further use.

Proximate Composition Analysis

The moisture, crude ash, crude protein, and crude fat content of different powdered complementary food premixes containing rice flour, yellow sweet potato, and soybean flours were evaluated using the AOAC (2000) Methods 925.10, 942.05, 984.13, and 2003.05, respectively. The total carbohydrate (Equation 1) was calculated based on the following formula (FAO 2003):

$$\%\,total\ carbohydrates = 100 - \%moisture - \%protein - \%ash - \%fat \quad (1)$$

The total energy content (Equation 2) of the complementary food was obtained by computation and expressed in calories (Nguyen *et al.* 2007). It was calculated from carbohydrate, protein, and fat contents using the Atwater's conversion factors:

$$\frac{1\ kcal}{100g} = [(4 \text{ x } carbohydrate) + (4 \text{ x } protein) + (9 \text{ x } fat) \quad (2)$$

Functional Properties

The water absorption index (WAI), water solubility index (WSI), and swelling power (SP) were determined using the protocol of Bryant *et al.* (2001). A total of 500 mg of each premix was measured into a pre-weighed 15-mL centrifuge tube. The powdered samples were added with 10 mL of distilled water. The solution was mixed and shaken for 30 min using a mechanical shaker and was immediately centrifuged at 2,000 rpm for 30 min. The supernatants were decanted into a pre-weighed evaporating dish and were set aside for WSI and SP measurement.

The WAI (Equation 3) was calculated as follows:

$$\text{WAI} = \frac{wt.\,of\ water\ absorbed\ (g)}{wt.\,of\ flour\ sample\ (g)} \quad (3)$$

The supernatants were dried in the oven at 100 °C for 12 h. The dried samples were weighed and the WSI (Equation 4) and SP (Equation 5) were calculated using the formula:

$$\text{WSI} = \frac{wt.\,of\ dried\ supernatant\ (g)}{wt.\,of\ flour\ sample\ (g)} \quad (4)$$

$$\text{SP} = WAI\ x\left(\frac{[1 - WSI]}{100}\right) \quad (5)$$

Complementary Food Preparation and Consumer Sensory Evaluation

A total of 100 g each complementary food premixes (Appendix Table 2) were added with 600 mL of boiling (100 °C) water and stirred for 5 min with a wire whisk consistently until a paste was formed. A panel of 30 parents or caretakers from PhilRice with experience in complementary feeding were recruited to evaluate the 10 formulations. The samples were served in disposable white gravy cups and randomly presented during the assessment. The sensory evaluation of the complementary food (gruel) was conducted at the Food Science Laboratory of PhilRice's Rice Chemistry and Food Science Division. The panelists were asked to assess the coded reconstituted complementary food samples in terms of color, aroma, taste, mouthfeel, consistency, and overall acceptability using a nine-point hedonic scale scorecard where 9 = like extremely and 1 = dislike extremely. The panelists were also asked to drink water or rinse in between tasting of complementary foods to avoid sample assimilation.

Nutritional Content Analysis

The nutritional composition (total calories, protein, vitamin A, niacin, iron, zinc, calcium, magnesium, and potassium) of the final complementary food product in powdered form was analyzed by using the methods of AOAC (2016) and those described by Kirk and Sawyer (1997).

Statistical Analysis

The responses (moisture content, crude ash, crude fat, and crude protein, carbohydrate, energy, and functional properties, and sensory attributes) of each variable were evaluated to determine the interaction of each flour and its concentrations in formulating the complementary food. Numerical optimization using the desirability function, ranging from 0–100 (least to most), was also done. The regression models fitted for all parameters were generated in three-dimensional surface graphs through Design-Expert software Version 11 for a better projection of flour interaction and results (Zen *et al.* 2015) with a significance level of $p < 0.05$.

RESULTS AND DISCUSSION

Proximate Composition of the Complementary Food Premixes

Moisture, ash, crude protein, carbohydrates, and crude fat content of the 10 formulated complementary foods are presented in Appendix Table 2. The 10 treatments of complementary food were within the range of the recommended moisture content (< 5%) by CODEX CAC/GL 08.1991 (Fikiru *et al.* 2016). Soybean has high mineral contents that enhanced the ash content of the blends. The ash content also increased with the addition of yellow sweet potato flour in the complementary formulation. The treatments were also within the recommended crude ash content (< 5 %) by WHO/FAO (2004) for complementary food.

The highest protein content (18.07%) was found in the blend proportion of 50% rice, 35% soybean, and 15% yellow sweet potato (F7), which was significantly different among other flour blends. As infants require a constant supply of protein for healthy bones and tissues that facilitate growth (Michaelsen and Greer 2014). However, proteins in sweet potato and rice are low; thus, supplementation from soybean is needed. Obinna-Echem *et al.* (2018) and Ezeokeke and Onuoha (2016) reported that high soybean blending proportion enhances the protein quality of the complementary foods made from local composite flours. The protein content of the premixes had satisfied the daily protein requirement of WHO/FAO (2004) in complementary foods, which was ≥ 15%. This implies that complementary food can provide an adequate intake of protein essential for the development of children during the critical stage of infant growth.

Dietary fat is also an important component of an infant's diet because it provides essential nutrients, improves energy density and sensory qualities, and facilitates the absorption of fat-soluble vitamins (Solomon 2005). Although soybean can be a high source of oils and fat, the fat content of the complementary food premixes ranged from 4.30–6.28% only. This may be due to the negligible fat content of rice and yellow sweet potato. The maximum percentage level of soybean added to the formulations was only at 35%. This observation is similar to the findings of Martin *et al*. (2010), wherein the level of fat content in the soybean-based complementary food at 20% soybean level was only 4.71%. The fat content of all the complementary food premixes was below the 10–15% daily recommended fat intake for infants 6–23 mo (WHO/FAO 2004).

Carbohydrates served as the primary source of energy in the body. Results showed that the carbohydrate content (73.10–76.35%) of the complementary food premixes were above the daily recommended value of ≥ 65% carbohydrate of complementary flours (Fikiru *et al.* 2016). In a study conducted by Stephen *et al.* (2012), the carbohydrate proportion of infants aged 1 year or less is around 50% energy. Thus, a 100-g serving of complementary food can provide adequate energy and can fulfill the daily recommended intake of 400 kcal for infants 6–23 mo (WHO/FAO 2004).

The summary of ANOVA for the proximate composition of the 10 formulated complementary food premixes as provided by the D-optimal mixture design is shown in Appendix Table 4. The results of the response analysis are summarized in Appendix Figure 1. ANOVA results showed a significant effect of the types of flour and its concentrations on the protein, ash, fat, and carbohydrate content of the complementary food premix and on its linear term implying a strong dependence on the presence of a high concentration of soybean flour (35%), mid-range of rice flour (50%), and minimum amount (15%) of yellow sweet potato flour.

The contour plot shows the effect of each flour type and its concentrations on each of the evaluated responses. Appendix Figure 1 indicates that the protein, fat, ash, and energy content increased with a higher amount of soybean flour (B = soybean) in the graph. Martin *et al.* (2010) and Aduke (2017) also found a similar result, which showed that increasing the percentage of soybean in a formulation augments the content of protein, fiber, fat, and ash. Soybean has high protein content, fat, vitamins, and minerals (Edema *et al.* 2005), earning its place as a highly effective cheap source of nutrients for the improvement of the nutritional quality of traditionally-processed complementary foods. Soybean is oil-dense and functions as a transport vehicle for fat-soluble vitamins and increases energy density (Solomon 2005).

The moisture content (0.86–2.68%) of the premixes was stable (≤ 5%) at all concentration combinations of the flours. To achieve a higher amount of carbohydrates and energy, concentrations of all rice flour (A = rice), soybean flour (B = soybean), and yellow sweet potato flour (C = sweet potato) – as shown in Appendix Figure 1 – must be optimized at its maximum amount, 55%, 35%, and 20%, respectively.

Functional Properties

Results of the functional properties of the flour combinations for the complementary food premix are presented in Appendix Table 3. Appendix Figure 2 shows the contour plot of the relationship of each variable (flour types and percentages of each flour) on the responses evaluated.

A good quality complementary diet must have high nutrient density, low bulk density, viscosity, and appropriate texture that allows easy consumption (WHO 2003). To achieve this, it is pertinent that the functional properties of complementary foods being formulated be evaluated. Functional properties serve as a determinant for the application and use of certain food materials for various products.

The functional properties of the instant complementary food premixes developed showed that there were no significant differences in WAI, WSI, and SP – as shown in Appendix Table 3. WAI measures the volume occupied by the starch granule after swelling in excess of water. It is also an indicator of the degree of starch conversion during heat processing. High WAI of all samples (3.66–4.67 g/g) implied that the pre-gelatinized complementary flour samples will easily reconstitute once added with hot water, which is desirable for instant products. It was also observed that premixes with greater rice proportions exhibited higher WAI as rice and sweet potato contained high hydrophilic constituents such as starches, which affected gelation and hydrophilicity capacity (Kaur and Singh 2005; Odoemelam 2003). All of the complementary food premixes exhibited low WSI and SP. As such, the formulated complementary food premixes produced less viscous semi-solid food, considering its high WAI and low WSI and SP. Appropriate complementary diet produces a gruel or porridge that is neither too thick (when it is too thick, it will be difficult for the infant to ingest and digest because of limited gastric capacity) for the infant to consume nor so thin that energy and nutrient density is reduced (WHO 2003).

Swelling causes changes in the hydrodynamic properties of the food, hence affecting the characteristics of a product including its thickening and increasing food viscosity. Findings showed that only the WAI and SP were affected by the variables (types of flour and its concentrations), respectively (Appendix Table 4). A higher supplementation of rice flour (55%) and yellow sweet potato flour (20%) contributed to an increased capacity of the complementary premix to absorb and swell in the presence of water (Appendix Figure 2), which was mainly due to the high amount of carbohydrates in sweet potato. Moreover, a higher number of hydroxyl groups found in fiber structure, which tends to allow more water interactions through hydrogen bonding, caused the high-water absorption capacity of fiber-rich flours (Noor *et al.* 2012). As glutinous rice was used in the study, the results can be correlated to the amylose-amylopectin ratio of the starch, in which low amylose content leads to a high SP (Adebowale *et al.* 2005) because the swelling and absorption behavior of cereals has been related to amylopectin fraction (Tester and Morrison 1990). This was also found in the study of Hermansson and Svegmark (1996), which revealed that low to waxy starches has a more open structure allowing rapid water penetration, swelling, and solubility. Relatively, the low SP values of the premixes is a desirable characteristic because infant foods with high swelling index tend to absorb more water and hold fewer solids, resulting in low nutrient density (Fasuan *et al.* 2017).

Sensory Evaluation of 10 Formulated CFP

Results on the organoleptic properties of the 10 formulated CFP are shown in Appendix Table 3. The sensory acceptability of the reconstituted complementary food premixes prepared from rice, soybean, and yellow sweet potato flours was evaluated in terms of color, aroma, taste, mouthfeel, and consistency.

Taste is an integral part of the acceptance of a certain product. A complementary food that contained high energy and is nutrient-rich is only appealing if it tastes good. Sensory results showed that the premixes with 50:35:15 (F7) and 55:30:15 (F4, F9) of rice: soybean: yellow sweet potato flour ratio had a moderately liking on its overall acceptability. The inclusion of soybean and yellow sweet potato showed a significant effect on the overall acceptability of the complementary food with the highest score recorded at 50:35:15 (F7) ratio and rating of 7.93 or moderately like (Appendix Table 3). However, skim milk and sugar did not have a significant effect on the overall taste acceptability of the 10 formulations. Overall sensory acceptance improved as the soybean was increased in the premixes. A similar increasing trend was also reported in fortified porridges from orange-fleshed sweet potato, soybean, and moringa (Gebretsadikan *et al.* 2015).

It was also observed that the aroma of the complementary food premixes was slightly liked, which may be attributed to the perceived natural beany flavor of soybean. Similar findings were reported by Ayele *et al.* (2017), Dingra and Jood (2004), Mashayekh *et al.* (2008), and Ndife *et al.* (2011).

Infants can better swallow a smooth gruel. As such, the mouthfeel is an important attribute in the product as it determines the amount of food an infant would consume. Appendix Figure 3 showed that a higher proportion of soybean adversely affected the mouthfeel acceptance. A similar finding was reported by Mezgebo *et al.* (2018), which showed that complementary porridge with high amounts of malted soybean flours received a low mouthfeel acceptability rating. Soy flour's mouthfeel can be improved by using an appropriate sample miller with finer particle size and using a sieve with a fine mesh screen.

Appendix Table 4 summarizes the sensory characteristics of CFP using D-optimal mixture design. Results revealed that there was no significant interaction among the variables (types of flour and its concentrations) on the color, taste, mouthfeel, and overall acceptability of the CFP except for consistency. Moreover, the results indicated a good fit of the model to the experimental data, as reflected by the insignificant ($p > 0.05$) value.

Appendix Figure 3 showed that all the sensory attributes of the 10 formulated CFP were equally liked by the mothers. However, the graphically optimum amount of each flour (rice, soybean, and yellow sweet potato) should be maintained at its mid-ranged values (Appendix Figure 3). It was also observed that higher color, taste, and overall acceptability were achieved when soybean flour was increased, which is similar to the findings of Taghdir *et al.* (2017) on gluten-free bread with soy flour. Influence on color may be due to the presence of yellow pigment found in soybean flour and Maillard reaction during processing (Banureka and Mahendran 2011; Olatidoye and Sobowale 2011). Improvement of mouthfeel and consistency of the complementary food premixes were mainly influenced by rice flour as shown in the graphical contour plot, which correlates with the good hydration of glutinous rice when reconstituted. The formulated complementary food premix from the combined flours was found to be organoleptically acceptable by the panelists in addition to its nutrient enhancement.

Complementary Food Premix Optimal Mixture Composition

To find the optimized conditions, a numerical optimization technique was used wherein an objective function called desirability (D), having a range from 0–100 representing least to most desirable, is estimated based on individual response optimization goals. The criteria used to assess the optimum formulation was done by maximizing the proximate composition, functional properties, and sensory attributes simultaneously with respect to the user-defined criteria and constraints. The defined characteristics of the responses were superimposed to generate the region of interest wherein an overlay plot was obtained in the optimization of the responses.

It can be assumed that the best point to obtain complementary flour premix with desirable characteristics is located at the central point of the desired area (Appendix Figure 4). As shown in Appendix Table 5, two optimized formulations were attained with the highest desirability of the criterion set. Hence, the optimum values of the complementary flour premixes that produced desirable nutrient compositions, acceptable functional qualities, and sensory profile were in the range of 50–52.50% rice, 32.50–35% soybean, and 15% yellow sweet potato flours. Moreover, the highest desirability (80%) was observed in the non-limiting blending ratio of 50% rice flour, 35% soybean flour, and 15% yellow sweet potato flour, which was selected as the most desired complementary premix.

Nutritional Composition of the Optimized Complementary Food Premix

Based on the Philippine Recommended Energy and Nutrient Intake (RENI) of DOST-FNRI (2015), a 30-g product serving of the optimized complementary food (50% rice flour, 35% soybean flour, and 15% yellow sweet potato flour) provides 123 kcal and 5 g of protein that satisfied 17% and 28% of the daily recommended energy and protein requirement of 6–11-mo-old children, respectively. It can also supply 8% vitamin A, 17% niacin, 12% iron, 22% zinc, 37% magnesium, 5% calcium, and 22% potassium (Appendix Table 6). Hence, it can be implied that the developed complementary food product offers promising nutritional attributes that can significantly contribute to improving the diet quality of older infants. The complementary food product can also combat the ill-effects of stunting and wasting among children in rice-based farming households and low-income communities.

CONCLUSION

Results from this study clearly showed that all the physicochemical and nutritional characteristics of complementary food premixes are within the standard limit required for complementary food for infants. As such, the formulated and optimized complementary food premix in the range of 50–52.50% rice, 32.50–35% soybean, and 15% yellow sweet potato flours can be a practical and healthier food choice, which address the country's malnutrition problems especially for infants in poor households with inadequate access to the food supply. Shelf-life study of the complementary food product will be pursued to improve its quality.

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STATEMENT ON CONFLICT OF INTEREST

The authors declare no conflict of interest.

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APPENDICES

Table 1. Parameters in the optimization of rice-based complementary food.

Code[a]	Parameters	Lower limit (%)	Upper limit (%)
A	Rice flour	50	55
B	Soybean flour	30	35
C	Yellow sweet potato flour	15	20

[a]A + B + C = 100%

Table 2. Mean proximate composition of complementary food premixes.

Formulation	Percentage of flour type			[a]Mean proximate composition					
	Rice flour (%)	Soybean flour (%)	Yellow sweet potato flour (%)	Moisture content (%)	Protein (%)	Ash (%)	Fat (%)	Carbohydrate (%)	Energy (kcal)
F1	51.70	31.60	16.70	2.49[a]	16.50[cd]	1.37[cde]	5.47[a]	73.88[ab]	411.21[bc]
F2	52.60	32.40	15.00	2.68[a]	17.04[bc]	1.39[bcd]	5.84[a]	73.10[b]	413.00[abc]
F3	53.50	30.90	15.60	2.35[ab]	16.67[bcd]	1.41[abc]	4.66[a]	74.84[ab]	419.24[ab]
F4	55.00	30.00	15.00	1.84[bc]	16.17[d]	1.34[de]	5.44[a]	75.07[ab]	413.87[abc]
F5	50.00	32.50	17.50	1.32[cd]	17.18[bc]	1.46[a]	5.93[a]	74.32[ab]	417.98[abc]
F6	50.90	33.30	15.80	1.50[c]	17.27[b]	1.46[a]	5.90[a]	73.65[ab]	411.21[bc]
F7	50.00	35.00	15.00	0.86[d]	18.07[a]	1.44[ab]	6.28[a]	73.28[ab]	422.55[a]
F8	50.00	30.00	20.00	1.32[cd]	16.12[d]	1.44[ab]	6.07[a]	74.83[ab]	418.78[ab]
F9	55.00	30.00	15.00	1.89[bc]	16.19[d]	1.32[e]	4.30[a]	76.35[a]	408.88[c]
F10	52.80	30.00	17.20	1.35[cd]	16.10[d]	1.39[bcd]	5.62[a]	75.48[ab]	417.42[abc]
			[b]WHO/FAO standards	≤ 5%	≥ 15%	≤ 5%	10-15%	≥ 65%	≥ 400 kcal

[a]n = 3
[b]Source: WHO/FAO (2004)

Table 3. Mean functional properties and sensory acceptability result of the different complementary food premixes.

Formulation	Functional properties			Sensory acceptability					
	WAI (g/g)+	WSI (g/g)+	SP (%)+	Aroma[1]	Color[1]	Taste[1]	Mouthfeel[1]	Consistency[1]	Overall acceptability[1]
F1	3.96	0.25	0.03	6.59[a]	6.59[a]	6.45[ab]	6.34[a]	6.14[a]	6.31[b]
F2	3.66	0.27	0.03	6.70[a]	6.97[a]	6.87[ab]	6.73[a]	6.87[a]	6.90[b]
F3	4.08	0.26	0.03	6.59[a]	6.59[a]	6.86[ab]	6.62[a]	6.80[a]	6.59[b]
F4	4.16	0.26	0.03	6.60[a]	6.60[a]	7.07[a]	7.07[a]	7.10[a]	6.27[b]
F5	4.06	0.25	0.03	6.38[a]	6.67[a]	6.87[ab]	6.87[a]	7.03[a]	6.67[b]
F6	4.05	0.27	0.03	6.83[a]	6.72[a]	6.48[ab]	6.21[a]	6.52[a]	6.59[b]
F7	4.17	0.27	0.03	6.70[a]	6.80[a]	7.33[a]	6.67[a]	6.90[a]	7.93[a]
F8	4.67	0.25	0.04	6.97[a]	6.77[a]	6.97[ab]	6.67[a]	6.50[a]	6.67[b]
F9	4.19	0.25	0.03	6.73[a]	6.73[a]	6.67[ab]	6.67[a]	7.27[a]	7.13[b]
F10	4.09	0.26	0.03	6.79[a]	6.55[a]	6.83[ab]	6.97[a]	6.59[a]	6.66[b]

+All treatments were not significantly different at $p < 0.05$.
Means with the same letter within the same column are not significantly different at $p > 0.05$.
[1]Scale: 1 – dislike extremely; 2 – dislike very much; 3 – dislike moderately; 4 – dislike slightly; 5 – neither like nor dislike; 6 – like slightly; 7 – like moderately; 8 – like very much; 9 – like extremely

Table 4. Summary of *p*-value of the analyses of variance conducted on the response parameters of the complementary food premixes.

Source of variance	Proximate composition						Functional properties			Sensory characteristics					
	Moisture content	Ash	Protein	Fat	Carbohydrate	Energy	WAI	WSI	SP	Aroma	Color	Taste	Mouthfeel	Consistency	Overall acceptability
p-value*	0.0537	0.0048	0.0001	0.0257	0.0161	0.7257	0.0080	0.0806	0.0246	0.3184	0.1870	0.4907	0.3578	0.0349	0.2260
Lack of fit	0.0735	0.3768	0.0768	0.9575	0.8225	0.3978	0.2357	0.6547	0.2026	0.4177	0.6039	0.6526	0.7542	0.5861	0.9175
Suggested model	Quadratic	Linear	Linear	Linear	Linear	Special cubic	Special cubic	Linear	Special cubic	Quadratic	Quadratic	Special cubic	Special cubic	Special cubic	Quadratic
Model *R*-squared	0.88	0.78	0.97	0.65	0.69	0.55	0.98	0.51	0.97	0.68	0.77	0.70	0.77	0.96	0.74

*$p =< 0.05$ is significant; $p => 0.05$ is not significant

Table 5. Optimized formulation of CFP generated by D-optimal design.

Optimized formulation	Rice flour	Soybean flour	Yellow sweet potato flour	Desirability
F7	50%	35%	15%	80%
[a]R1	52.50%	32.50%	15%	50%

[a]R – desirable premix values generated by D-optimal numerical optimization

Table 6. Nutritional composition and contribution of CFP with 50% rice flour, 35% soybean flour, and 15% yellow sweet potato flour.

Parameter	Nutritional composition (per 100 g)	Nutritional composition (per 30 g serving)	% RENI[a]
Total calories	408.77 kcal	123 kcal	17%
Protein	15.68 g	5 g	28%
Vitamin A	ND	31 μg/RE	8%
Niacin	ND	1 mg	17%
Iron	4.05 mg	1 mg	12%
Zinc	3.13 mg	1 mg	22%
Calcium	62.89 mg	19 mg	5%
Magnesium	62.17 mg	19 mg	37%
Potassium	508 mg	152 mg	22%

[a]Percent RENI values are based on 2015 DOST-FNRI reference requirement of 6–11-mo-old infant.

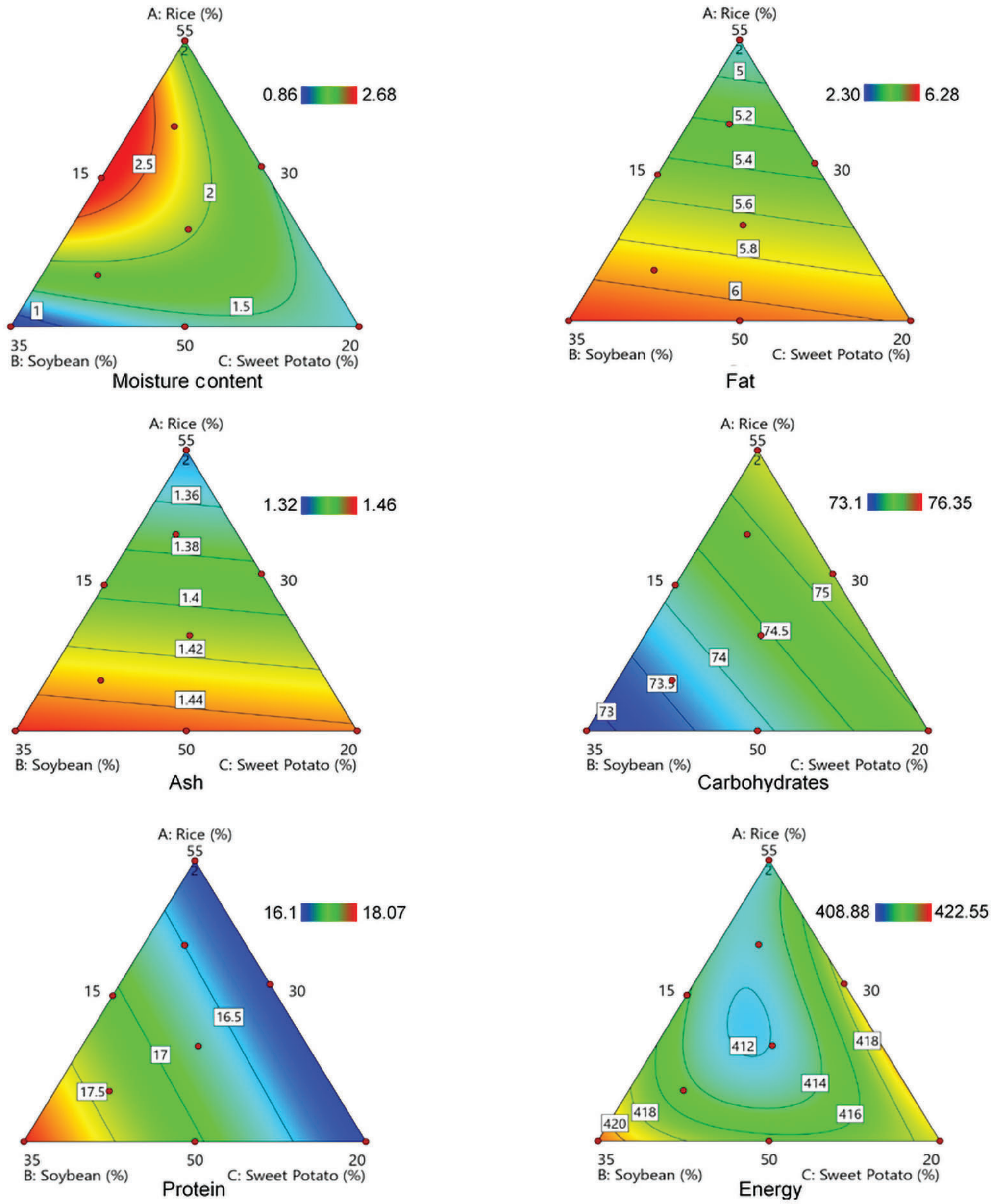

Figure 1. D-optimal mixture design generated contour plots as affected by the set lower and upper limit percentage level of (A) rice flour (50–55%), (B) soybean flour (30–35%), and (C) yellow sweet potato flour (15–20%) in moisture content, ash, protein, fat, carbohydrates, and energy. Moving from blue to red color indicates increasing values of proximate composition.

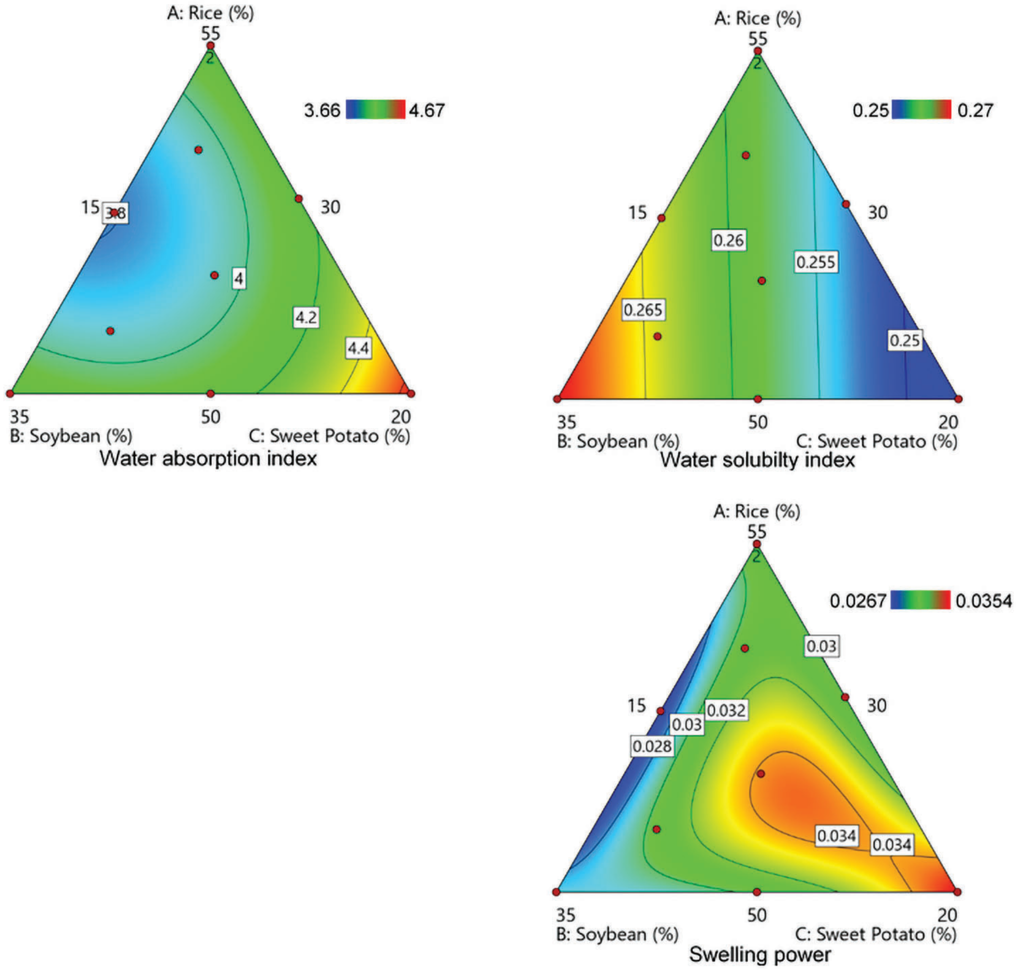

Figure 2. D-optimal mixture design generated contour plots as affected by the set lower and upper limit percentage level of (A) rice flour (50–55%), (B) soybean flour (30–35%), and (C) yellow sweet potato flour (15–20%) in WAI, WSI, and SP. Moving from blue to red color indicates increasing values of functional properties.

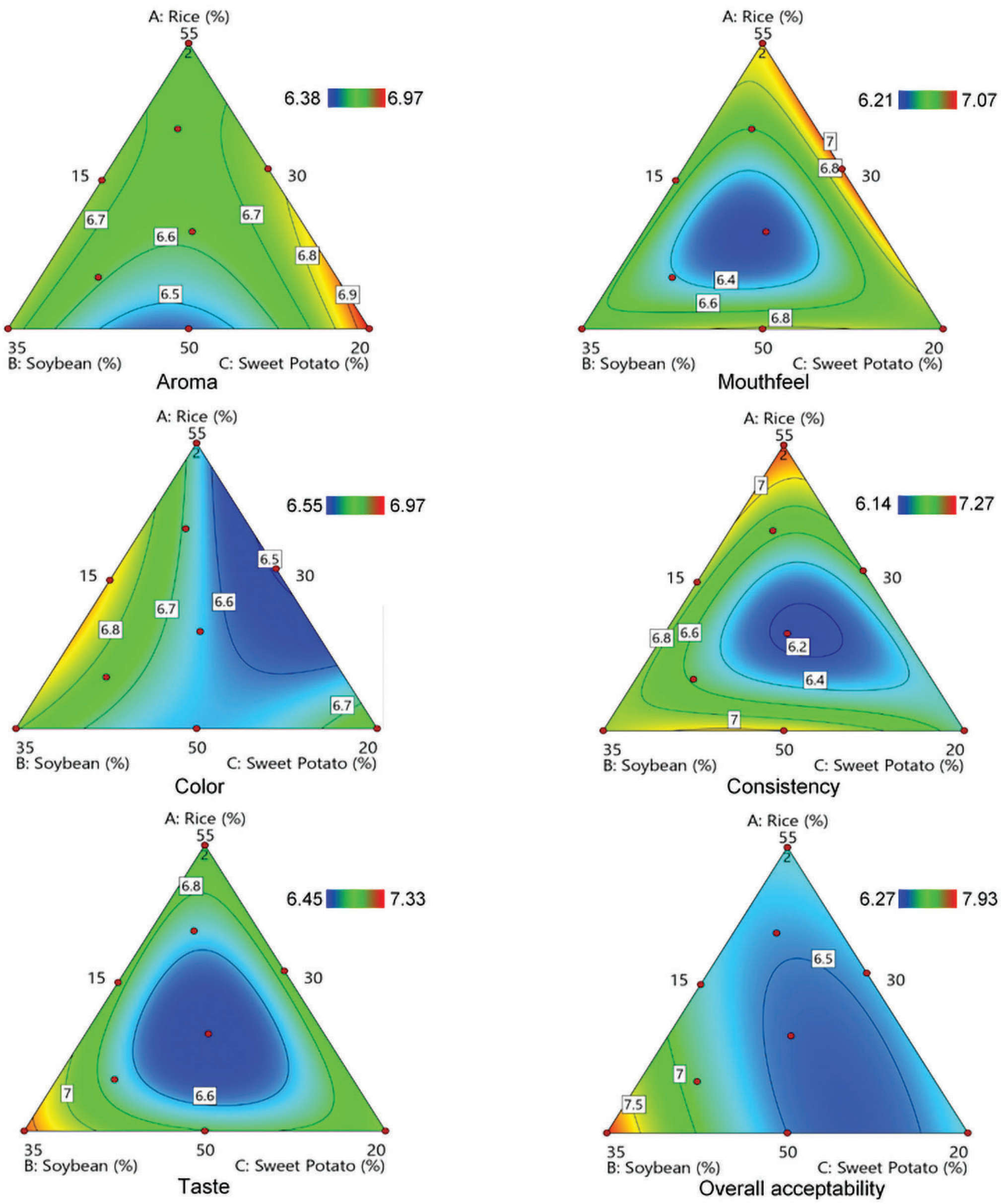

Figure 3. Contour plot of relationship between three variables, percentage of (A) rice flour (50–55%), (B) soybean flour (30–35%), and (C) yellow sweet potato flour (15–20%) in aroma, color, taste, mouthfeel, consistency, and overall acceptability.

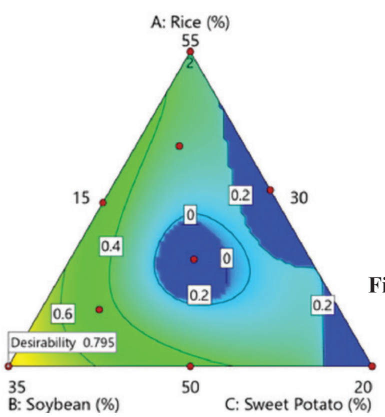

Figure 4. Overlaid contour plot showing the area of desirability based on individual response optimization goals. Moving from blue to red color indicates increasing values of desirability.