Scientific
Research
Publishing

Development of Saba (*Musa* "BBB" *acuminata x balbisiana*) Peel-Monggo [*Vigna radiata* (L.) R. Wilczek] Flours with Malunggay (*Moringa oleifera* Lam.) Polvoron Bar

Welbert A. Ronquillo[1], Marites Gatchalian-Yee[2], Lotis E. Mopera[3], Aimee Sheree A. Barrion[2]

[1]Department of Nutrition and Dietetics, Adventist Medical Center College, Iligan City, Philippines
[2]Institute of Human Nutrition and Food, College of Human Ecology, University of the Philippines Los Baños, Laguna, Philippines
[3]Institute of Food Science and Technology, College of Agriculture and Food Science, University of the Philippines Los Baños, Laguna, Philippines
Email: aymishe@yahoo.com.ph

Abstract

The study was designed to produce a nutrient-dense polvoron bar from the optimized mixture of Saba-peel, monggo, and malunggay using simplex lattice design (RSM-SLD). Polvoron bar was also evaluated analytically including proximate, iron, total dietary fiber (TDF), and vitamin A content. Shelf stability, consumer acceptability, and microbial assessment of the sample were determined. Results showed that the optimal combination of ingredients was 37%, 52%, and 11% for saba peel flour, monggo flour, and malunggay powder, respectively. Proximate composition revealed that a fresh sample can provide 66% of carbohydrates, 12.17% protein, and 17% of fats. Every 100 g has 1.43 mg Fe content, 1.78 g TDF, and 91.25 mg vitamin A. The optimized product can last up to 111, 98, and 54 days at 30°C, 40°C, and 50°C, respectively, while total aerobic bacteria, yeast and molds, and coliform count are within the acceptable limits of the FDA standards.

Keywords

Malunggay, *Monggo*, Saba-Peel, *Polvoron*

1. Introduction

The Philippines is one of the most prominent countries in Southeast Asia that is susceptible to almost all types of calamities such as war, typhoons, volcanic eruptions, earthquakes, and landslide. On average 20 typhoons hit the country

every year [1] [2]. Properties and assets are destroyed causing destabilization of the country's economy where physical and environmental damages can bring grief and hardship to Filipino people. Survival and safety are the utmost concern when calamities occur. In response, humanitarian agencies of the government and non-government organizations (NGOs) initiate food aid supply among affected communities. High caloric and nutrient wise foods are needed to maintain the integrity of health, reduce the risk for chronic diseases and optimized health [3].

Food and nutrition in emergencies have never been a priority by the government, commonly rationed food during disasters event are considered insufficient in meeting the total physiologic requirement of a person wherein, maintaining health is critical especially among infants, small children, pregnant and lactating mothers [2] [4] [5]. Overwhelming cases of malnourishment, vitamin deficiencies, the epidemic case of morbidity, and the awful rate of mortality among victims of calamities have been associated with food insufficiency [6]. Confronting this issue, and with the advancement of food science and technology, developing a nutrient-dense convenient and affordable product can minimize the increasing incidence of malnutrition and mortality rates among victims of calamities.

Developing an acceptable low-cost emergency food product derived from locally grown crops from saba-peel, monggo, and malunggay was made. The essential nutrition component of the product was evaluated and scrutinized to match with the standard required by World Health Organization (WHO), World Food Program (WFP), and United Nations High Commissioner for Refugees (UNHCR) for emergency food products.

A well-balanced diet requires an intentional amount of nutrients that satisfy the physiologic demand, not only an adequate amount of energy but also in terms of quality and quantity of protein, fats, and micronutrients. Some individuals need special attention particularly the pregnant and lactating women that require an additional amount of nutrients. Emergency food should contain a high-level amount of energy for a relatively small portion, containing intact nutrients in sufficient amounts to support the entire physiologic needs of the individual. It must also be convenient in terms of storage, transport, and consumption with no preparation required as it serves as an immediate food aid. This supplementary feeding is used to bridge the gap during the initial stages of a dilemma, prevent or alleviate protein-energy malnutrition while food basket, access to safe water, cooking fuel and facilities are limited or unavailable.

It is essential to deliver to the affected population within 48 hours since a cause of delay can result in an increasing prevalence of malnourishment and infection. However, as evidence and field experience suggests compact food can be utilized up to 15 days as a main source of food while the transition from the crisis until resilience of food basket can be fully obtained [7]. Studies have shown that food alternatives sources from locally grown products within the regions which are capable of providing sustainable food among consumers with a high-

est possible benefit in terms of energy and essential micronutrients above the set criteria for emergency food products within at least 6 months [6]-[11].

The scoop of the study is limited to the following objectives 1) optimization of ingredients using Response Surface Methodology, Simple-Lattice Design (RSM-SLD), 2) sensory evaluation, 3) vitamin A, Fe, and dietary fiber, and proximate analysis, and 4) accelerated shelf life test.

2. Materials and Methods

2.1. Purchased of Sample and Ingredients

Banana "saba" fruit peel sample "Cardaba", monggo bean seed sample "PAG-ASA 19" and malunggay were obtained from the Institute of Plant Breeding of University of the Philippines Los Baños, Laguna (IPB-UPLB). Other ingredients used to produce the polvoron samples such as whole milk powder (Birch Tree®, Snow Mountain Dairy Corp., Taguig City, Manila), iodized salt (JFM Enterprises Inc., Valenzuela City), refined sugar (NFA, FTIComplex, Taguig City, Manila), and vegetable shortening (Approved®, Tantuco Enterprise Inc., Mandaluyong City) were obtained from Los Baños public market.

2.2. Preparation of Saba Peel Flour

2.2.1. Peeling, Slicing and Treatment

The collected good quality medium-yellow ripe saba samples (no bruise, unwanted cuts, and notable deteriorated portion) were peeled using a stainless sharp knife, horizontally cut into about 5 mm thick, and directly soaked into 1% NaCl water solution for 15 minutes, a sample was drained, and immediately steamed in boiling bath water for 15 minutes and dried.

2.2.2. Drying and Grinding

A mechanical dehydrator at 60°C for 24 hours was applied to facilitate moisture reduction of the sliced saba-peel sample. An imarflex® (12-speed) grinder (Model IM-800B, CJT, Zhejiang, China) was used to ground the dried sample into desirable texture, shifted passing the sieve screen mesh of 0.40 mm.

2.3. Preparation of *Monggo* Bean Flour

2.3.1. Roasting

The roasting process was accomplished using non-stick 10 inches frying pan (Gibson Home, Model 91601.02, Hummington Collection, USA) using the medium to low fire for about 15 - 20 minutes in constant stirring until the light brown color is achieved, thus may help to reduce the available moisture of the *monggo* bean.

2.3.2. Peeling

Roasted *monggo* bean was transferred to stainless steel cooking pan (60 × 40 cm, Tondo, Manila, Philippines), roasted monggo was spread to allow exhaustion of heat moisture for 5 minutes. A wooden rolling pin 30 cm was used to partially

crack the seeds into small particles to remove the skin.

2.3.3. Grinding

Using the electric 220v 3HP in 0.40 mm mesh screen pulverizer (Almedah Food Equipment BNE Food Machineries and Technology Inc., Tondo, Manila, Philippines), peeled monggo was ground in a single batch with control infusion lock applied in moving monggo to grind hole, that allows an efficient technique in producing the 0.40 mm size of the ground product.

2.4. Preparation of *Malunggay* Powder

2.4.1. Harvesting

Fresh malunggay leaves were collected from the stalk of the malunggay tree and washed with tap water to remove dust and other impurities on the leaf surface. To further remove the excess water, stalks were shaken and spread out on the rack for 20 minutes. Leaf-blades were stripped off from the stalk and any infested or discolored leaf were further removed.

2.4.2. Oven Drying

Fresh leaf blades are dried immediately using an electrical oven air dryer (Memmert 220V, 40 - 30's Solution Provider Co., Seyssinet-Pariset, France) using the available plate 40×25 cm at 70°C with 2.5 fresh air infusion for 2 hours based on Alakali and colleagues (2015) [12].

2.4.3. Grinding

Dried malunggay leaves were grounded by rubbing against a fine screen and using electric Imarflex® (Model IM-800B, CJT, Zhejiang, China) 12-speed multi-purpose grinder 220v for 2 - 3 minutes until the very fine texture is achieved, the granules are sifted using 0.40 mm mesh screen to remove unrefined particles of the sample.

2.5. Product Optimization

Response surface methodology (RSM) particular in simplex lattice design model was used to optimize the three major components of the product and identified an acceptable range of measurement 20% - 60% saba-peel, 35% - 75% monggo, and 0.05% - 25% malunggay which was identified during the previous work of this research. Those levels of measurements identified, act as constraints vertices in a triangular model (Figure 1) to locate a specific region for optimization. Given the specified unoptimized location in the triangular plot, the model has now the capability to scrutinize the entire area inside the unoptimized region, and generate 10 different proportions of the three components as X_1, X_2, and X_3 for saba-peel, monggo, and malunggay, respectively, dotted as presented on the triangular plot (Figure 1).

Ten formulations were generated from the model, and each run is considered 100% from the summation of the mixture proportions (X_1, X_2, and X_3) (Table 1),
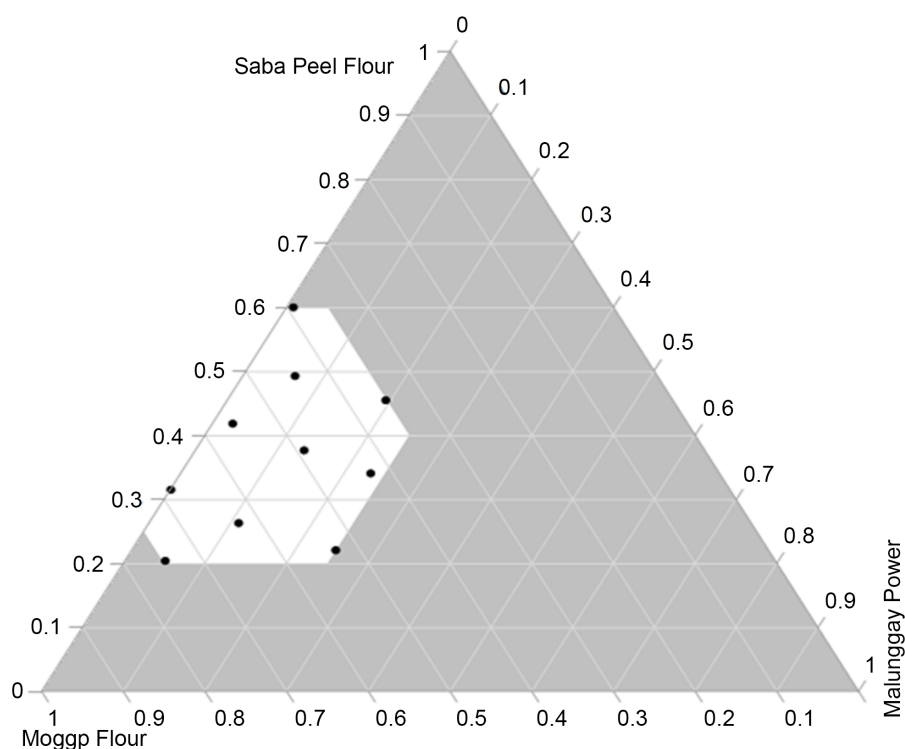
Figure 1. Constrained region in the simplex coordinated defined system.

Table 1. Mean ± standard deviation observed from the sensory evaluation result of the 11 runs of saba peel—monggo with malunggay polvoron blends in three replicates. Significant at 95% confidence level ($p < 0.05$) using one-factorr analysis of variance.

Runs	Factors[b]			Mean Acceptability Rating[a]				
	X_1	X_2	X_3	OA	Color	Aroma	Taste	Texture
1	0.20	0.75	0.05	7.18 ± 1.09	7.28 ± 0.95	6.86 ± 0.97	6.83 ± 1.70	7.13 ± 1.35
2	0.22	0.53	0.25	7.50 ± 0.77	6.77 ± 1.14	6.90 ± 0.78	7.30 ± 0.85	7.58 ± 0.82
3	0.26	0.63	0.11	7.69 ± 0.50	7.04 ± 1.01	6.89 ± 0.94	7.70 ± 0.57	7.49 ± 0.84
4	0.31	0.68	0.00	7.39 ± 0.95	7.50 ± 0.79	7.08 ± 0.85	7.38 ± 0.93	7.42 ± 0.80
5	0.34	0.43	0.23	7.07 ± 0.91	6.84 ± 1.09	6.93 ± 0.96	7.10 ± 0.85	7.41 ± 0.78
6	0.38	0.49	0.13	7.18 ± 0.74	7.19 ± 0.72	7.12 ± 0.55	7.28 ± 0.84	7.28 ± 0.89
7	0.42	0.56	0.02	7.36 ± 0.99	7.59 ± 0.72	7.11 ± 0.83	7.45 ± 1.04	7.27 ± 0.86
8	0.45	0.35	0.19	7.24 ± 0.67	6.73 ± 0.68	6.89 ± 0.76	7.34 ± 0.89	7.03 ± 0.83
9	0.49	0.44	0.06	7.29 ± 1.00	7.34 ± 0.79	6.90 ± 0.93	7.29 ± 0.97	7.27 ± 0.86
10	0.60	0.39	0.01	7.45 ± 0.94	7.66 ± 0.82	7.56 ± 0.72	7.37 ± 0.94	7.27 ± 0.88
Control	-	-	-	5.74 ± 1.38	5.68 ± 1.05	5.49 ± 1.10	5.02 ± 1.48	6.50 ± 1.21
	p-value			3.48E−09*	9.14E−15*	1.27E−07*	1.27E−14*	0.0199

but only 48% of the entire mixture was optimized, 52% was the fixed constant amount the ingredients such as milk powder, sugar, and vegetable fat of which, 17%, 9%, and 26%, respectively.

2.6. Nutritional Analysis

The procedures for securing nutritional analysis of the polvoron sample includes proximate analysis (fat, protein, carbohydrates, moisture, total ash, and fiber), Vitamin A (β-carotene) using spectrophotometer, and total dietary fiber (TDF) which were taken from AOAC (1995) [13].

2.7. Shelf Life Test

Chemical analysis, particularly on the degradation of vitamin A content and organoleptic property of the product using the result of general acceptability (GA) sensory test, from the 10 trained panel members, were used determining shelf stability of the samples. An accelerated shelf life test (ASLT) was applied using proportionality constant (Q_{10}) following 30˚C, 40˚C, and 50˚C storage conditions for six sample periods. Hence, the increase of storage temperature at 10˚C allows the chemical reaction rate to double according to the thermodynamic temperature coefficient of the Arrhenius reaction rate theory [14].

2.8. Color Analysis

The color was analyzed using Pantone CAPSURE® (Model RM200, S/N: 0010049365, x-rite, China) which measured color in a three-dimensional color space (L*, a*, b*) allowing perceived specific color element value to be measured. Color space abbreviated from CIELAB 1976 (CIE, 1986), L* or light channel is the central vertical color axis that consists of white, down to the black color, ranges from black = 0 to white = 100, of which gray (achromatic) color is exactly located at the center of the spectrum model. The two chroma coordinates, a* and b*, that represent red to green and yellow to blue color, respectively. The value for both +a-a' and +b-b' axes represent neutral grey are = 0. However, if the perceived color difference between the two stimuli increases, the distance in the color space between these two points increases accordingly [15].

2.9. Water Activity (a_w) Analysis

Water activity determination of the product was accomplished through Novasina Lab*Swift-aw*® water activity analyzer machine model GRPO: 500200 in triplicates recorded at ±0.01.

2.10. Microbial Analysis

Methods applied in the laboratory procedures for microbiological analyses of the product samples were derived from FDA's Bacteriological Analytical Manual (BAM), which includes Aerobic Plate Count (APC), Yeast and Molds, and Coliforms [16]. Ten grams of the polvoron sample was diluted in 90 ml 0.01% peptone buffered diluent, homogenized, employing 10^{-1}, 10^{-2}, and 10^{-3} plated in triplicates using standard method agar (SMA) for APC, potato dextrose agar (PDA) with 0.1 g chloramphenicol to inhibit the growth of bacteria for yeast and molds analysis, and red-violet bile agar (VRBA) for coliforms analysis. Inocu-

lated media were incubated at 32˚C for 24 hours except for yeast and mold which requires 48 - 120 hours incubation period.

2.11. Statistical Analysis

Linear regression and *t*-test at 5% alpha were used to verify results and the accuracy of the model. Analysis of variance (ANOVA) and post *hoc* at 95% level of confidence, and linear regression for shelf life duration using MegaStat® Add-Ins software of Microsoft Excel 2010 and SAS (JMP) statistical tool.

3. Results and Discussion

3.1. Product Optimization

The optimization of the three major ingredients such as saba-peel, monggo, and malunggay has resulted in high variance of consumer acceptability and other sensory attributes from the 10 formulations. The observed commendable values of sensory parameters from the entire runs were used as the database to create an optimized proportion of the three ingredients and predict a relative consumer acceptance rating.

3.2. Model to Predict the Optimized Value

The mathematical equation is expressed to illustrate the full interaction of each associated factors and the obtained sensory values. The accuracy in formulating optimized ingredients based on sensory desirability is determined by their corresponding R-squared values. These also help to represent the degree of association between the predicted sensory score and actual sensory rating.

In the same manner, the level of intimacy between the model and actual sensory rating is particularly high in color for 98% while low in taste for 62% confidence level, respectively (Figure 2). This indicates that the model has a higher probability to predict the commendable sensory score for color relative to the amount of the optimized ingredients as compared to the taste. Further, the effect of the strong relationship between variables will result in an insignificant amount of variance ($p < 0.05$).

3.3. Deriving the Optimum Formulation

The saba-peel monggo with malunggay polvoron (SPMMP) has the mean consumer acceptance score of ≥7 for overall, color, taste, and texture. Regions of overlap for the optimized formulation were used as a framework for obtaining the optimized value. Thus, 37%, 52%, and 11% for saba peel flour, monggo flour, and malunggay powder, respectively, were considered as the optimal combination since given the percentage predicted scores on the model does not fall below the projected acceptance rating of ≥7 (Figure 3).

The decreasing amount of malunggay content produced a higher desirability rating and a better-predicted score for taste, color, aroma, and overall acceptance, while it decreases the texture rating. This trend of variations has contributed
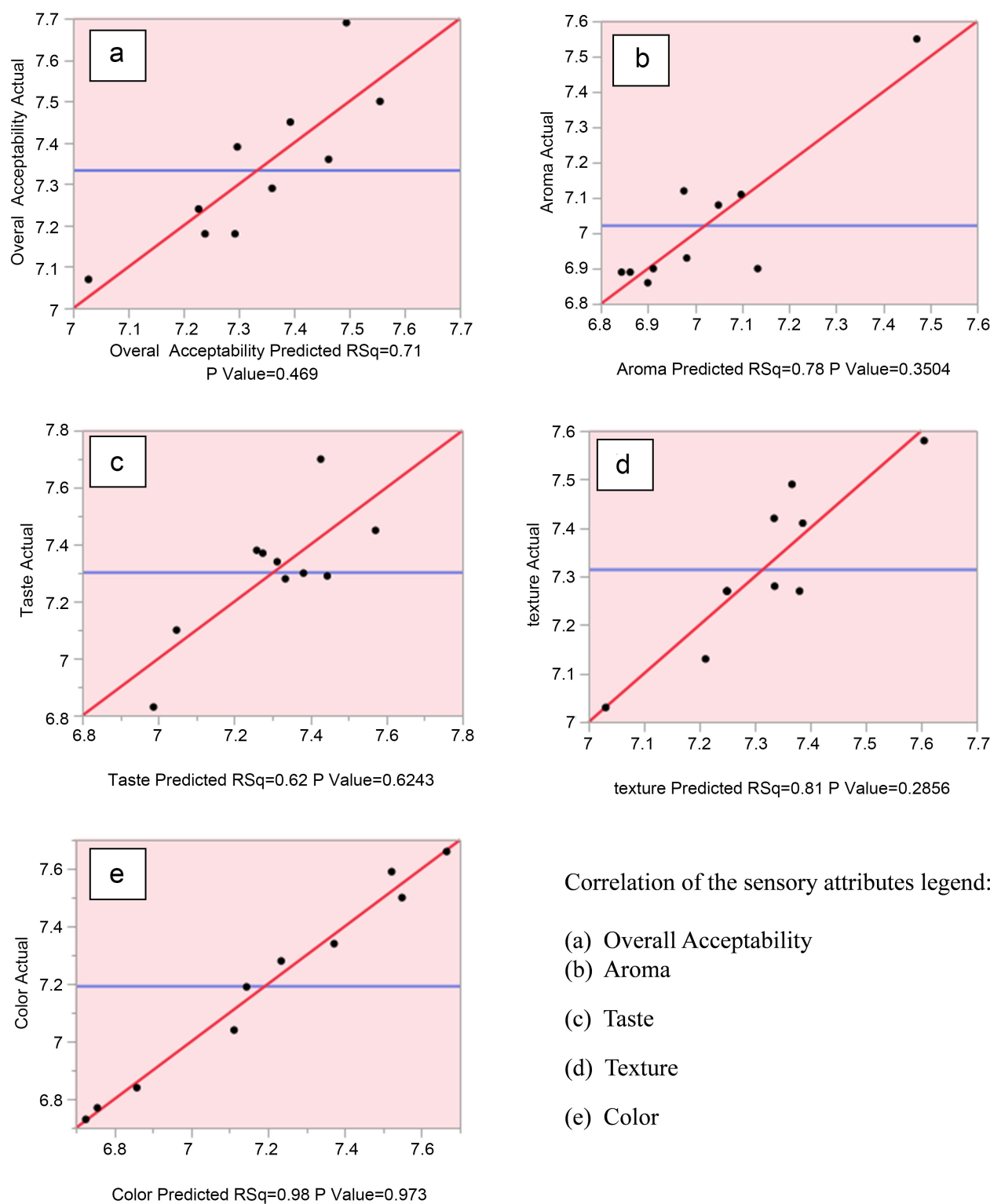
Figure 2. Observed values from sensory evaluation and predicted values upon determination of the R2.

simultaneously to increase the amount of saba-peel and monggo powder content. The desirability of 46% was generated by the model to produce an optimal combination of ingredients having the corresponding proportion of 37%, 52%,
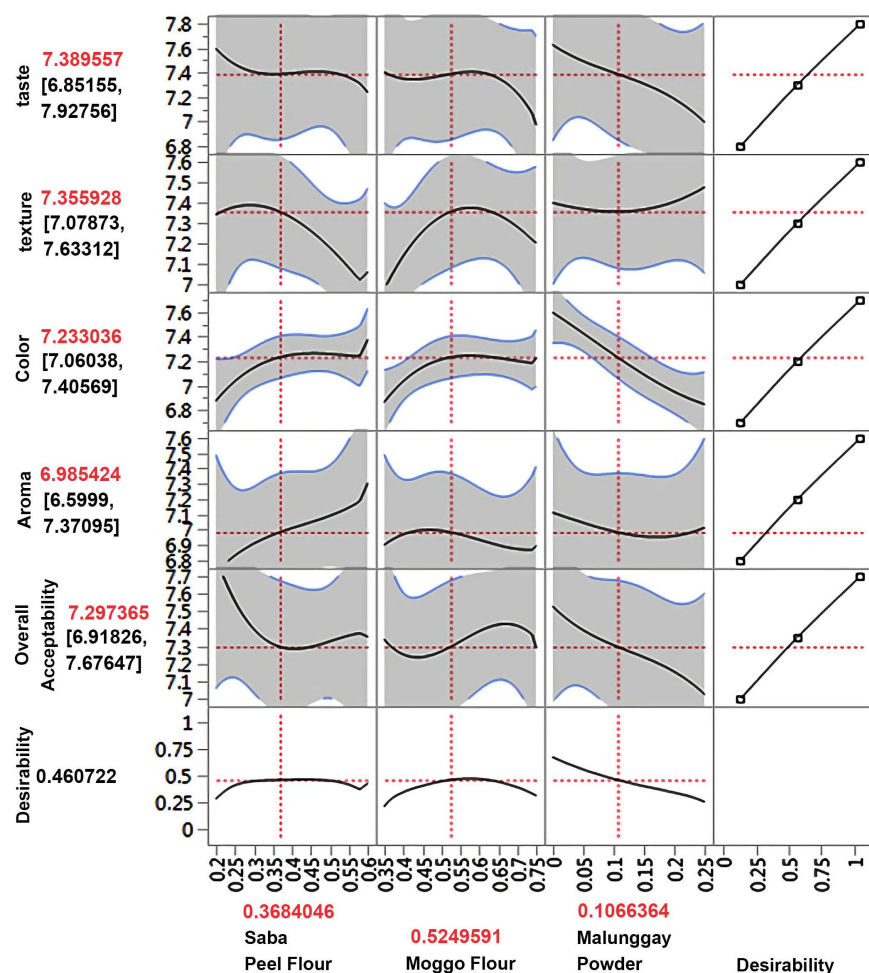
Figure 3. Optimized values of the ingredients and predicted sensory.

and 11% of saba peel flour, monggo flour, and malunggay content, respectively (**Figure 3**). However, the chances to increase desirability rating to obtain the best possible optimal value of ingredients is not possible since the desirability curve is solely dependent on optimal values obtained from the sensory rating score.

The study shows that contour plots of the acceptance rating for taste and texture decrease when the amount of saba-peel and monggo flour was high at 30% - 60% and 55% - 75% respectively. Meanwhile, the increasing amount of saba-peel flour up to 60% has a direct effect to improve the aroma attribute due to the innate banana essence. These results relate to the previous work [17] which they emphasized that when banana peel concentration reaches up to 30% or greater, the level of preference among panelist reduces, while the concentration of banana flavor is more likely dominant. However, if lower concentrations of close to zero amount of banana peel mixture to the product, samples have the high tendency to be well accepted. In contrast, the increase of monggo flour concentration decreases the aroma acceptability, while the score for color improves simultaneously when the amount of monggo and saba-peel ingredients increases.

3.4. Nutritional Analysis

3.4.1. Proximate Composition

It is well-known the fact that lipids or fat is the topmost concentrated source of energy as 9 kcal/g, followed by carbohydrates and protein as 4 kcal/g, respectively. Results show that SPMMP possessed 16.73%, 65.95%, and 12.17% for fats, carbohydrates (Nitrogen-free extract or NFE) and, protein, respectively (**Figure 4**). These data are relatively close to the WHO, WFP, and UNHCR emergency food nutritional requirement of 17% for fat, 10% - 13% for protein and 60% - 70% carbohydrates. Hence, 23.15% per 100 g total caloric contribution based on the caloric requirement of a normal male 70 kg adult requires about 2000 kcal per day [18]. It is important to understand that protein is an essential factor to maintain muscles integrity, immunity, repair, and build body tissues, as well as to prevent the severe case of protein malnutrition (Kwashiorkor) or PEM. The recommended energy and nutrient intake (RENI) [18] suggests 5% - 15%, 6% - 15%, and 10% - 15% source of energy from protein for infants, children, and adults, respectively. However, 30% - 60%, 15% - 35%, and 15% - 30% source of energy from fats for infants, children, and adults, respectively.

3.4.2. Total Dietary Fiber

Dietary fiber has functional properties, a non-nutrient source but able to provide a beneficial effect to health on the gut and prevent long-term diseases such as diabetes hypertension, and obesity [19] [20] [21] [22]. Based on RENI [18] children and adults have at least 6 - 23 g and 20 - 25 g, daily dietary fiber intake,
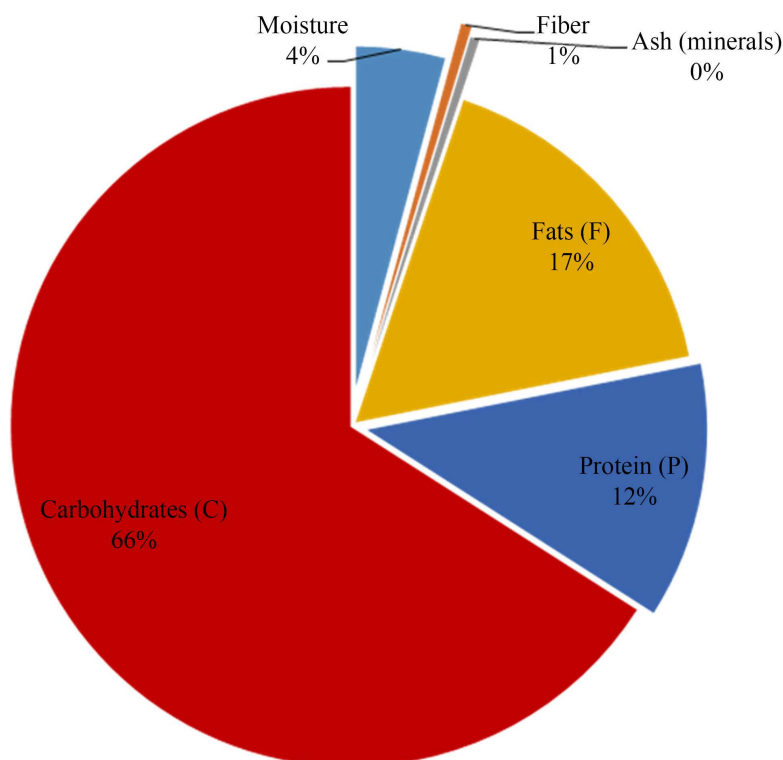

Figure 4. Nutrient composition of the optimized SPMMP.

respectively, thus, 1.78% of TDF from polvoron is considered a negligible amount to support the daily required amount.

3.4.3. Iron

The iron content of the optimized polvoron sample is approximately 1.43 mg/100g. Consuming around 3 - 4 servings (100 g/serving) may contribute one half to one third of iron requirement per day of children and adults, respectively [18].

3.4.4. Vitamin A Analysis

The effect of high-temperature storage contributes to diminishing the vitamin A potency of the SPMMP sample throughout the sampling period having the initial (control) measure of 91.25 mg/100g significantly decrease into 51.26 mg/100g and 20.65 mg/100g for 40°C and 50°C, respectively (**Figure 5**). Further, it has been observed that samples treated at 50°C have much destruction of vitamin A as compared to the 40°C and 30°C. The oxidative losses of vitamin A rapidly increase during storage due to exposure to oxygen (during extrusion), light, moisture, heat, minerals, acid, and fat rancidity, since, vitamin A is unstable to these factors [23]. Even though depletion of vitamin A lost about 25.2% 43.9% and 77.4% for 30°C, 40°C and 50°C, 68.44 mg/100g, 51.26 mg/100g, and 20.65 mg/100g, respectively, it is still considered the significant amount of vitamin A to fight against VAD cases, considering RENI range only 0.4 mg - 0.8 mg of the recommended tolerable allowance of 3.0 g/day of a normal 70 kg male adult [18].
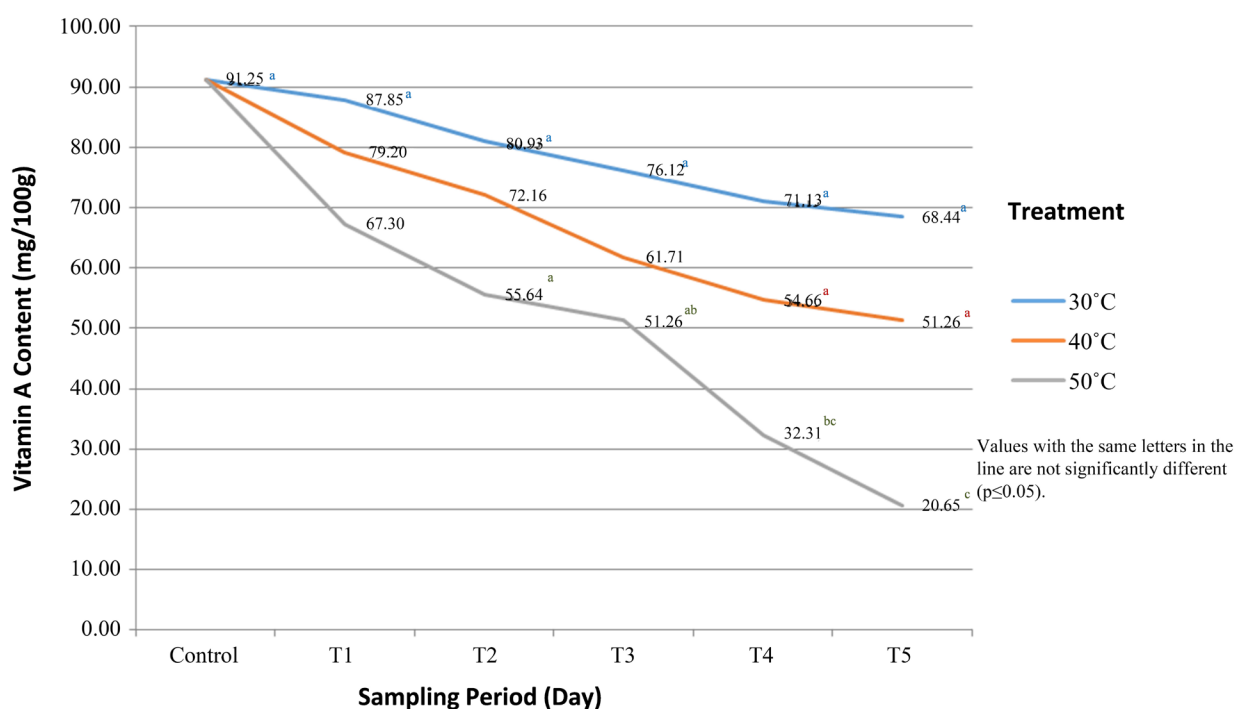

Figure 5. Vitamin A content of the optimized polvoron samples evaluated from the six sampling periods, where control as 0-day and T1 to T5 are tested every 23, 20, and 10 days for 30°C, 40°C, and 50°C, respectively.

3.5. Sensory Evaluation of the Optimized Sample

The data obtained from the sensory parameters results help to quantify and qualify the changes of magnitude or the degree of quality perceived by the trained panelists through which the product remains acceptable or not. Consequently, the color changes from green to brown occurs more rapidly in the samples treated at 50°C as compared with 40°C and 30°C as shown in **Figure 6**. Result suggests that as the duration of storage of the samples prolonged, the original intensity of color faded into a much lighter shade that corresponds to quality loss. Meanwhile, the increase of temperature and time have also contributed to the color changes participated by the non-enzymatic browning effect a Maillard reaction where presents metals such as iron (Fe^{3+}) and copper (Cu^{2+}) and complex amino acids present within the food that further elaborates the browning response [24] [25].

The immediate increase of aroma-rancidity values was also observed especially at 50°C rising to 3.37 (very mild) and 2.2 (just detectable) for 40°C. These results have been associated with the increasing loss of semi-volatile organic compounds and the formation of polycyclic aromatic hydrocarbons (PAHs) occurs upon oxidation of milk lipids and added vegetable fats [26] [27]. A_w stability suggests that when high lipid oxidation occurs when a_w of the samples reaches below 0.2 and above 0.5, since water is bound with metals such as Cu, Fe, Co, and Cd, and during dehydration state, this metals are most active and will serve as a catalyst to form free radicals which can accelerate lipid oxidation [28]. Thus, the optimal condition where minimal, when lipid oxidation occurs is within the range of 0.19 and 0.49.

The immediate increase of bitter taste into 3.67 and 4.75 as described as "very mild" for 40°C and 50°C, respectively, from the initial score of 1.25 (just detectable) relative to increase with time and temperature. Previous studies suggest that the occurrence of Maillard reaction participate in the degradation of reducing

Figure 6. CMYK color model analysis from the six sampling period of optimized SPMMP samples stored at 30°C, 40°C and 50°C. Values obtain from analyzed CEILAB color space model.

carbohydrates and amino acids during heating process can result in multiple breakdowns of sugary compounds, particularly glucose and fructose that can form distinct taste, flavor, and aroma, resulting to low perceived sweet taste and formation of bitter substances [29] [30].

In general, all samples demonstrated a high significant total loss of sensory rating, which means less acceptability over time. In the comparison of all samples, 50°C has the highest tendency to received discriminative score than 30°C and 40°C due to several factors associated with it, such as color, aroma, flavor, taste, and fracturability, since these factors strongly determine the consumer acceptance of the product.

Water Activity (a_w)

Water activity (a_w) determines the amount of water available in the food for chemical reactions, physical changes, microbial proliferation, and enzymatic activity. Thus, this property helps to foresee the safety aspects and shelf life condition of the product relative to their reactions leading to food deterioration [1] [5]. Due to the reduction of available water in the SPMMP sample from the initial aw 0.65 up to 0.62, 0.58 and 0.43, for 30°C, 40°C and 50°C, respectively, the ability to support microbial growth and proliferation has minimized especially on the higher temperature (40°C and 50°C). This result was verified during microbial analysis to the viable counts of microorganisms obtained from aerobic bacterial, yeast, molds, and coliforms.

Although the enzymatic reaction is considered minimal at the given result of the SPMMP samples (0.65 - 0.43) for both treatments 40°C and 50°C because of their significant influence under aw, the occurrence of non-enzymatic browning reaction is more obvious. Literature states that the browning reaction might be due to the interaction of amino acids and reducing sugars available in food substances [31]. This reaction resulted in the loss of protein solubility, darkening of light-colored dried ingredients, and the development of off-flavors or bitter taste. Thus, maintaining the quality of the samples, it is very important to sustain critical a_w levels within 0.2 - 0.4 a_w (**Figure 7**), temperature, and pH to prevent conformational changes by securing packaging material able to withstand environmental abuse.

3.6. Shelf Life Termination

3.6.1. Moisture Content (MC)

The present study shows that the effect of total MC reduction from an initial reading of 6.50 into 5.23 and 3.61, for 40°C and 50°C, respectively, relatively affects the SPMMP quality, especially on texture and color aspects. Hence, foods that are high in relative moisture content can be described as moist, juicy, tender and chewy. When the available moisture of the product is lowered, textural attributes become undesirable, turning into hard, dry, stale and tough. However, SPMMP samples are made from various powders and granules, lowering the amount of moisture can affect into caking and clumping properties of powders and granulations. Thus, these results further explain that the association between
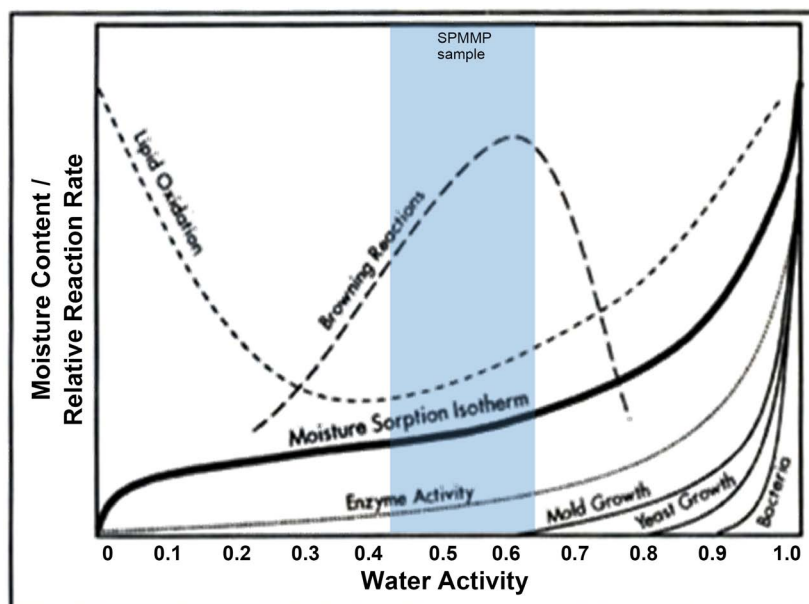
Figure 7. Water activity stability map [32].

the increasing rate of sensual fracturability scores from crumbly (easy to break into small fragment) into brittle (hard, but easy to break) of the samples.

3.6.2. Microbial Analysis

Results showed that the viable microbial count in the SPMMP samples was also reduced relative to the total reduction of a_w, where an initial count of 300 CFU/g for aerobic bacteria 160 CFU/g for yeast and molds in both samples of 40˚C and 50˚C, respectively. Whereas, coliforms test indicates zero total counts throughout the sampling plan. A consistent drop of a_w and moisture at the limit amount of available oxygen in the container used by the product resulted in a total reduction of viable counts both aerobic bacterial, yeast, and molds (**Table 2**) [33].

Although initial results show a huge count for aerobic bacteria, yeast, and molds, these could not be the best indicator to predict product deterioration since the trend for microbial growth was decreasing as affected with the decreasing value of a_w beyond their survival curve for samples treated at 40˚C and 50˚C. However, facultative anaerobic microbes at 30˚C have proliferated in an increasing amount which has a higher tendency in producing toxins present in the SPMMP sample carried during the processing of the product possibly come from contaminated contact surfaces and other ingredients used in the formulations. The relationship of the increasing number of aerobic bacteria while yeast and mold relatively decrease in counts could come up into a possible assumption that the bacteria were able to adopt the present environmental condition upon the gradual utilization of available oxygen within the packaging material of the sample.

3.6.3. Color Analysis

Color data indicated in using accelerated condition (30˚C, 40˚C, and 50˚C) the

Table 2. Viable counts (CFU/g) of aerobic bacteria, yeast, molds, and coliforms from the six sampling period of the SPMMC samples treated at 30˚C, 40˚C, and 50˚C.

Treatments	Viable Microorganism	CFU/g					
		(Control) Day 0	T1	T2	T3	T4	T5
30˚C (Every 23 days)	Aerobic Bacteria[a]	300	3100	4500	5300	7800	28,000
	Yeast and Molds[b]	160	<10	<10	<10	<10	<10
	Coliform[a]	<25	<25	<25	<25	<25	<25
40˚C (Every 20 days)	Aerobic Bacteria[a]	300	<25	<25	<25	<25	<25
	Yeast and Molds[b]	160	<10	<10	<10	<10	<10
	Coliform[a]	<25	<25	<25	<25	<25	<25
50˚C (Every 11 days)	Aerobic Bacteria[a]	300	<25	<25	<25	<25	<25
	Yeast and Molds[b]	160	<10	<10	<10	<10	<10
	Coliform[a]	<25	<25	<25	<25	<25	<25

[a]Acceptable count range 25 - 250; [b]Acceptable count range 10 - 150.

lightness intensity of polvoron samples increased significantly from 41.94 to 50.42, 54.43 and 48.12, respectively, as shown by an increase in L* color value (Table 3). However, there is no significant change of the browning intensity observed in the 40˚C samples except for 50˚C that has a higher rate of browning reaction as shown in a* and b* color values. This could further explain that among the given treatments, 50˚C samples have higher chances of developing brown-red color which was confirmed during sensual evaluation. In the same manner, samples from 30˚C have the minimal reduction of dark pigments, changes to red and yellow hue saturation of granules more or less of 50% compared to 40˚C samples at the T3 sampling period.

3.7. Shelf Life of the Polvor on Samples

Foods are perishable by nature depending on numerous condition that takes place during processing, storage and distribution that influence undesirable qualities trigger by various environmental conditions, chemical, physical, and microbiological changes leading to food deterioration. However, it should be recognized that "quality" involves several characteristics including the consumer expectations from the presence or absence of desirable and undesirable sensory attributes, thus, determine the degree of food quality. This study uses empirical techniques or human subjects and analytical techniques to qualify and quantify changes in constant monitoring and evaluation of quality that determines shelf life duration of the SPMMP samples (Table 4). Since analytical results remain stable during several experiment parameters, the sensory analysis result of general acceptability (GA) was therefore utilized to further assess how far the product remains accepted or rejected providing the occurrence of internal and external changes. Table 4 shows the GA mean sensory evaluation results from the

Table 3. Mean ± standard deviation color analysis (CEILAB) results of the optimized SPMMP sample.

Samples	L*			a*			b*		
	30˚C	40˚C	50˚C	30˚C	40˚C	50˚C	30˚C	40˚C	50˚C
Control	41.94 ± 1.38[cd]	41.94 ± 1.38[c]	41.94 ± 1.38	2.78 ± 0.50[e]	2.78 ± 0.50[a]	2.78 ± 0.50	15.48 ± 0.16[b]	15.48 ± 0.16[a]	15.48 ± 0.16
T1	41.65 ± 0.94[cd]	44.27 ± 0.01[c]	44.27 ± 0.01[d]	3.30 ± 0.24[de]	4.11 ± 1.06[a]	4.14 ± 0.00	16.23 ± 0.13[b]	20.09 ± 2.56[a]	21.45 ± 2.20[d]
T2	44.29 ± 0.90[b]	49.76 ± 2.04[b]	45.41 ± 2.32[cd]	3.60 ± 0.27[cd]	4.39 ± 0.62[a]	6.97 ± 0.53[b]	17.60 ± 0.50[a]	20.17 ± 3.42[a]	22.27 ± 0.00[cd]
T3	45.97 ± 1.86[b]	50.43 ± 2.00[a]	46.75 ± 0.00[bc]	4.10 ± 0.07[bc]	4.60 ± 0.40[a]	7.78 ± 0.64[ab]	18.08 ± 0.93[a]	22.79 ± 0.45[a]	24.02 ± 1.13[bcd]
T4	48.55 ± 0.74[a]	49.76 ± 2.01[ab]	46.85 ± 0.14[abc]	4.25 ± 0.08[ab]	5.18 ± 2.22[a]	8.63 ± 0.86[a]	20.25 ± 0.18	23.05 ± 0.00[a]	24.38 ± 0.00[abc]
T5	50.42 ± 1.99[a]	54.43 ± 2.47	48.12 ± 0.00[ab]	4.6 ± 0.40[ab]	6.26 ± 2.25[a]	10.68 ± 0.24	22.79 ± 0.45	23.29 ± 8.14[a]	25.38 ± 3.39[ab]
n	3	3	3	3	3	3	3	3	3
p-value	2.12E−05	3.00E−05	0.0002	0.0001	0.1477	4.58E−09	3.22E−09	0.1700	0.0001

L* [darkness (−) to lightness (+)], A* [green (−) to red (+)], and *B** [blue (−) to yellow (+)]; Values with the same letters in column are not significantly different (p ≤ 0.05).

Table 4. Shelf life calculation of the optimized SPMMP samples.

Days (Period)	GA Sensory Result (15 cm scale)			Vitamin A (mg/100g)		
	30˚C	40˚C	50˚C	30˚C	40˚C	50˚C
0	12.95	12.95	12.95	91.25	91.25	91.25
11			10.275			67.3
20		12.13			79.2	
22	12.3		9.375	87.85		55.64
33			7.88			51.26
40		11.86			72.16	
44			6.51			32.31
46	11.4			80.93		
55			4.575			20.65
60		11.26			61.71	
69	10.8			76.12		
72						
80		10.43			54.66	
92	10.1			71.13		
90						
100		9.2			51.26	
115	9.7			68.44		
Slope $(k_s)^{-1}$	0.0026	0.0035	0.0193	0.0026	0.0066	0.0278
R^2	0.9948	0.9409	0.9662	0.9907	0.5766	0.9485
Shelf life (Days)	111	98	54	110	87	53

three experimental conditions 30˚C, 40˚C, and 50˚C, results indicate that SPMMP samples will only remain acceptable after 111, 98 and 54 days, respec-

tively. However, SPMMP vitamin A concentration of 68.44 mg/100g, 51.26 mg/100g, and 20.65 mg/100g for 30°C, 40°C, and 50°C, respectively, can last up to 110, 87, and 53 days, respectively. Thus, natural log rate constant [ln(A)] of GA results provides a better understanding to demonstrate product shelf duration, of which, SPMMP sample remain acceptable for 111 days at 30°C, 98 days at 40°C and 54 days at 50°C demonstrating 99%, 94%, and 97% confidence variability fit, respectively.

4. Conclusion

The development of optimized indigenous crops from saba-peel, monggo, and malunggay following 37%, 52%, and 11% respectively, can have a desirability rating of 46% and ≥7 "like moderately" score in the 9-point hedonic rating. The product provides a high nutritional contribution including protein, carbohydrates, fats, and vitamin A with shelf stability at 54 and 53 days at 30°C.

Acknowledgements

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Cruz, G.D. (2016) Typhoons in the Philippines and the 2016 Polls. Rappler Philippines.
https://www.rappler.com/move-ph/issues/disasters/126001-typhoons-enter-philippines-fast-facts

[2] World Food Program (2016) The Philippines.
http://www1.wfp.org/countries/philippines#

[3] Hasler, C.M. (2002) Functional Foods: Benefits, Concerns and Challenges—A Position Paper from the American Council on Science and Health. *The Journal of Nutrition*, **132**, 3772-3781. https://doi.org/10.1093/jn/132.12.3772

[4] National Nutrition Council Governing Board Resolution No. 1, S. (2003) Adopting the National Policy on Nutrition Management in Emergencies and Disasters.
http://www.nnc.gov.ph>nnc-ro9.NNC IX

[5] Rodriguez, F. (2014) On Nutrition and Disasters. Rappler Philippines.
http://www.rappler.com/move-ph/issues/hunger/64349-nutrition-disasters-breastfeeding-lgu

[6] Zahra, S.M., Nadeem, M., Hussain, S., Quereshi, T.M., Din, A. and Rashid, F. (2014) Development and Evaluation of Nutri-Bars for Internally Displaced People in Humanitarian Emergencies. *Journal of Agricultural Research*, **52**, 217-220.

[7] Webb, P. and Rogers, B.L. (2003) Addressing the "In" in Food Insecurity. Food and

Nutrition Technical Assistance Project Academy for Educational Development.

[8] Guardiano, S.A.T. (2016) DOST Prime NegOr in Emergency Food Preparation. The Mindanao Daily Mirror, Davao City.

[9] Silliman University (2016) DOST Partners with Silliman on NegOr Training in Emergency Food Preparation.

[10] Tanner, C.G. (2001) A Study of Emergency Relief Foods for Refugees and Displaced Persons. FANTA, Washington DC.

[11] US Department of Agriculture (2009) Commercial Item Description Emergency Food Products, Ready-to-Eat (Meal Replacements). Metric—Commercial Item Description.

[12] Alakali, J.S., Kucha, C.T. and Rabiu, I.A. (2015) Effect of Drying Temperature on the Nutritional Quality of *Moringa oleifera* Leaves. *African Journal of Food Science*, **9**, 395-399. https://doi.org/10.5897/AJFS2014.1145

[13] AOAC (1995) Official Methods of Analysis. 16th Edition, Association of Official Analytical Chemists, Washington DC.

[14] Reich, R.R., Sharpe, D.C. and Anderson, H.D. (1988) Accelerated Aging of Packaging: Considerations, Suggestions, and Use in Expiration Date Verification. MD&DI.

[15] Liew, O.W., Chong, P.C.J., Li, B. and Asundi, A.K. (2008) Signature Optical Cues: Emerging Technologies for Monitoring Plant Health. *Sensors*, **8**, 3205-3239. https://doi.org/10.3390/s8053205

[16] U.S. Food and drug Administration (USFDA) (2001) Bacteriological Analytical Manual (BAM).

[17] Futeri, R. and Pharmayeni, P. (2014) Substituting Wheat Flour with Banana Skin Flour from Mixture Various Skin Types of Banana on Making Donuts. *International Journal on Advanced Science, Engineering and Information Technology*, **4**, 76-80. https://doi.org/10.18517/ijaseit.4.2.372

[18] Philippine Dietary Reference Intake (PDRI) (2015) Food and Nutrition Research Institute. Department of Science and Technology, Taguig City, Metro Manila.

[19] Burkitt, D.P., Walker, A.R.P. and Painter, N.S. (1972) Effect of Dietary Fibre on Stools and Transit-Times, and Its Role in the Causation of Disease. *The Lancet*, **300**, 1408-1411. https://doi.org/10.1016/S0140-6736(72)92974-1

[20] Grundy, M.M.L., Edwards, C.H., Mackie, A.R., Gidley, M.J., Butterworth, P.J. and Ellis, P.R. (2016) Re-Evaluation of the Mechanisms of Dietary Fibre and Implications for Macronutrient Bioaccessibility, Digestion and Postprandial Metabolism. *British Journal of Nutrition*, **116**, 816-833. https://doi.org/10.1017/S0007114516002610

[21] Jenkins, D.J., Wolever, T.M., Leeds, A.R., Gassull, M.A., Haisman, P., Dilawari, J. and Alberti, K.G. (1978) Dietary Fibres, Fibre Analogues, and Glucose Tolerance: Importance of Viscosity. *British Medical Journal*, **1**, 1392-1394. https://doi.org/10.1136/bmj.1.6124.1392

[22] Kelsay, J.L. (1978) A Review of Research on Effects of Fiber Intake on Man. *The American Journal of Clinical Nutrition*, **31**, 142-159. https://doi.org/10.1093/ajcn/31.1.142

[23] Charlton, S.J. and Ewing, W.N. (2007) The Vitamins Directory. Context Products Ltd., Packington.

[24] Martins, S.I., Jongen, W.M. and Van Boekel, M.A. (2000) A Review of Maillard Reaction in Food and Implications to Kinetic Modelling. *Trends in Food Science & Technology*, **11**, 364-373. https://doi.org/10.1016/S0924-2244(01)00022-X

[25] Namiki, M. (1988) Chemistry of Maillard Reactions: Recent Studies on the Browning Reaction Mechanism and the Development of Antioxidants and Mutagens. *Advances in Food Research*, **32**, 115-184.
https://doi.org/10.1016/S0065-2628(08)60287-6

[26] Aguinaga, N., Campillo, N., Vinas, P. and Hernandez-Cordoba, M. (2007) Determination of 16 Polycyclic Aromatic Hydrocarbons in Milk and Related Products Using Solid-Phase Microextraction Coupled to Gas Chromatography-Mass Spectrometry. *Analytica Chimica Acta*, **596**, 285-290.
https://doi.org/10.1016/j.aca.2007.06.005

[27] Page, B.D. and Lacroix, G. (2000) Analysis of Volatile Contaminants in Vegetable Oils by Headspace Solid-Phase Microextraction with Carboxen-Based Fibres. *Journal of Chromatography A*, **873**, 79-94.
https://doi.org/10.1016/S0021-9673(99)01201-7

[28] Nelson, K.A. and Labuza, T.P. (1992) Relationship between Water and Lipid Oxidation Rates: Water Activity and Glass Transition Theory. In: *Lipid Oxidation in Food*, ACS Symposium Series Vol. 500, American Chemical Society, Washington DC, Chapter 6, 93-103. https://doi.org/10.1021/bk-1992-0500.ch006

[29] Frank, O. and Hofmann, T. (2002) Reinvestigation of the Chemical Structure of Bitter-Tasting Quinizolate and Homoquinizolate and Studies on Their Maillard-Type Formation Pathways Using Suitable 13C-Labeling Experiments. *Journal of Agricultural and Food Chemistry*, **50**, 6027-6036.
https://doi.org/10.1021/jf020473k

[30] Hofmann, T. (2005) Taste-Active Maillard Reaction Products: The "Tasty" World of Nonvolatile Maillard Reaction Products. *Annals of the New York Academy of Sciences*, **1043**, 20-29. https://doi.org/10.1196/annals.1333.003

[31] Singh, R.P. (1994) Scientific Principles of Shelf Life Evaluation. In: *Shelf Life Evaluation of Foods*, Springer, Boston, 3-26.
https://doi.org/10.1007/978-1-4615-2095-5_1

[32] Labuza, T.P. (1971) The Properties of Water in Relationship to Water Binding in Foods: A Review. *Journal of Food Processing and Preservation*, **1**, 167-190.

[33] Grant, W.D. (2004) Life at Low Water Activity. *Philosophical Transactions of the Royal Society B: Biological Sciences*, **359**, 1249-1267.
https://doi.org/10.1098/rstb.2004.1502