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Optimization of a fruit juice cocktail containing soursop, pineapple, orange and mango using mixture design

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ABSTRACT

A simplex lattice mixture design was used to optimize the formulation of a juice cocktail containing soursop, pineapple, mango and orange, based on physicochemical and sensory attributes of the cocktail. In this study, juice from soursop, pineapple, mango and orange were the components. Physicochemical and sensory parameters were determined using standard methods. Mixture regression models explained up to 99% of the variability in the experimental data. Cox response trace plots generated from the fitted models indicated that pH of the cocktail (ranging from 4.0 to 4.2) was greatly influenced by orange, pineapple and soursop. Increasing amounts of soursop juice resulted in a reduction in °Brix and b* value, which indicates yellowness. Whereas taste of the cocktail was positively influenced by all the components, only extreme amounts of soursop or high amounts of either pineapple or mango enhanced product likeness. Results of the optimization indicated that high amounts of pineapple juice is required to achieve the best cocktail containing these four fruit components. The study demonstrates the potential of utilizing soursop in a juice cocktail together with popular tropical fruits.

Introduction

Fruits play an important role in human nutrition. They are delicious and serve as valuable sources of vitamins, minerals and dietary fiber. Fruits also contain pigments, phenolic compounds with antioxidant properties and other phytochemicals which contribute to preventing cancers, reducing cholesterol and blood pressure [12]. Despite their importance, fruits are highly perishable and need to be preserved or converted into value added forms in order to enhance their availability. In many parts of the world, high postharvest loss of fruits are recorded one season after another. In Ghana for instance, whereas an overall postharvest loss of 27% is estimated for edible fruits, a range of 36–60% and 25–32% is respectively reported for pineapple and mangoes, depending on season [10].

One of the means of adding value to raw fruits is by processing them into convenient forms such as fruit juice. These juices are obtained from mature and healthy fruits, mostly by mechanical extraction. Fruit juices occupy an eminent place in the beverage industry. They are desired because of their refreshing taste, aroma and flavor and their striking resemblance to natural fruits. In recent years, consumption of fruit juices has seen a sharp increase, because they are perceived to be

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Table 1
Physicochemical and sensorial properties of the fruit cocktail.

Run	Component proportion in mixture Sour sop	Pineapple	Mango	Orange	Responses pH	TTA (mg/g)	Brix	Color (b*)	Taste	Likeness
1	0.30	0.30	0.20	0.20	4.14	3.42	7.8	28.30	5.3	4.6
2	0.20	0.30	0.30	0.20	4.23	3.55	8.0	28.32	6.6	6.4
3	0.26	0.27	0.27	0.20	4.18	3.56	8.0	28.03	5.8	5.4
4	0.20	0.40	0.20	0.20	4.05	3.46	7.8	29.49	6.5	6.4
5	0.20	0.20	0.20	0.40	4.10	3.26	7.4	31.52	6.0	5.6
6	0.27	0.26	0.20	0.27	4.04	3.36	7.8	30.25	5.8	5.8
7	0.20	0.30	0.20	0.30	4.10	3.30	7.2	30.10	6.0	6.5
8	0.20	0.20	0.30	0.30	4.15	3.26	8.0	28.01	6.4	5.0
9	0.25	0.25	0.25	0.25	4.08	3.39	7.8	29.18	5.8	5.1
10	0.20	0.20	0.40	0.20	4.15	3.40	8.0	28.06	6.4	6.8
11	0.20	0.27	0.27	0.26	4.12	3.30	8.0	30.04	6.3	6.0
12	0.30	0.20	0.30	0.20	4.03	3.68	8.6	31.56	5.7	5.8
13	0.27	0.20	0.26	0.27	4.03	3.52	8.0	29.76	6.0	6.0
14	0.30	0.20	0.20	0.30	4.11	3.62	7.6	29.78	5.9	5.8
15	0.40	0.20	0.20	0.20	4.08	3.33	7.2	28.31	5.2	5.6

a natural and healthy product [7]. Even though some concerns have been raised regarding low fiber level of fruit juices, Ruxton et al., [21] suggest that pure fruit juices are potentially beneficial to human health because they retain a majority of nutrients and phytochemicals of the whole fruit.

Fruit juices may be produced from a single fruit or a combination of two or more fruits (cocktail). A major advantage of fruit cocktails is the fact that it provides a wide range of pleasant aromas and flavors and a sum of nutritionally different components [18]. Additionally combination of fruits may result in cheaper end products, as cheaper fruits may be combined expensive fruits. Commonly available fruit juice cocktails are made from tropical fruits such as pineapple, orange and mango. These fruits are generally sweet and colorful with an intense pleasant flavor and are notably rich in vitamins. However, other unpopular fruits including soursop (*Annona muricata*), which is less acidic and has a pleasant aroma and juicy flesh may be used in mixed fruit juices [25].

Soursop has an irregular shape. It is pulpy but mushy when very ripe and has a pleasant mouth feel when eaten as a fruit. It is largely underutilized in many areas where it is grown. However, some previous reports indicate that it has successfully been used in making fruit juice [1], fruit nectar [20] and mixed fruit juice with grapefruit [19]. The present study explores the use of soursop in a fruit cocktail with low acid fruits such as pineapple, mango and orange, using mixture design. This presents a useful means to enhance its potential as an industrial raw material, add more value to the fruit and also increase its availability to many consumers. Combining it with popularly known tropical fruits in a cocktail also provides a good entry point for its acceptance by consumers.

Mixture design is a useful tool for optimizing product formulations and investigating the role of ingredients and their interaction in the final formulation [6]. According to Cornell [8], through this technique, predictive mathematical models relating the mixture factors and their responses are obtained. Mixture design experiments are particularly useful in product development and has been extensively applied to optimize many food formulations by evaluating their sensory or physicochemical attributes [3, 4, 15, 23]. The purpose of this study was to optimize a fruit cocktail formula containing soursop, pineapple, mango and orange using simplex lattice mixture design.

Materials and methods

Fully ripe and healthy soursop (*sweet soursop*), pineapple (*sugarloaf*), mango (*Kent*) and oranges (*Valencia*) showing no signs of damage were obtained from a local fruits market in Accra. Pineapple, mango and orange were used in this study because they are colorful low acid fruits which are by far the most popular tropical fruits used in fruit juice processing. On the other hand soursop was selected largely on the basis that it is underutilized. The fruits were stored in a refrigerator (Samsung 2DR) at 4 °C before juice extraction for the experiments.

Juice extraction and blending

The soursop, pineapple, mango (each weighing 2.5 kg) and oranges (3 kg) were washed in potable water and sanitized in calcium hypochlorite solution (150 ppm chlorine) before peeling manually with a stainless steel knife. After removing the seeds (except pineapple), juice from each fruit was extracted individually using a food processor (Philips, HL1654). Juices from the individual fruits were blended according to a 15 point formulation matrix (Table 1)

Table 2
Predicted models for physicochemical indices and sensorial attributes.

Predictor variable	pH	Brix	Instrumental Color (b*)	Taste	Likeness
Soursop (X_1)	5.93	6.55	49.1	35.2	21.8
Pineapple (X_2)	2.24	25.63	73.6	24.0	22.9
Mango (X_3)	5.02	15.65	49.2	8.0	33.4
Orange (X_4)	2.80	4.11	54.9	−2.7	−1.8
$X_1 \times_2$	2.15	−27.62	−53.6*	−112.7**	−143.1*
$X_1 \times_3$	−5.04	−15.25	−182.3**	−73.6**	−29.6
$X_1 \times_4$	−2.93	21.19	−0.2	13.3	38.3
$X_2 \times_3$	−0.09	−38.94	−28.4	19.2	−27.0
$X_2 \times_4$	6.02	22.49*	−240.3**	−24.0*	50.9
$X_3 \times_4$	1.83	−0.12	62.0*	15.1	−105.7*
R^2	0.839	0.935	0.996	0.984	0.901
Adj R	0.552	0.819	0.989	0.955	0.722

Note:.
* -terms are significant at $p<0.05$,.
** -terms are significant at $p<0.01$.

Analyses

pH, tta and °Brix

pH and TTA of juice were determined according to approved methods of the AOAC [26] and soluble solids, expressed as°brix, was determined using a digital refractometer (Hanna HI96801).

Instrumental color

Color of the juices was determined using a Minolta Chroma meter (CR-310 Minolta, Japan) as previously described by Kumar et al., [17] with slight modifications. The device was calibrated with a reference white porcelain tile ($L_0 = 97.63$, $a_0 = 0.31$ and $b_0 = 4.63$) before use. Readings were taken from a transparent pyrex petri dish containing 100 mL of fruit juice. color (in L* a* b* notation) was described using b*, which defines the extent of yellowness or blueness of a product.

Sensory evaluation

Preference test was conducted for the fruit cocktail. A 35-member panel who had previous experience of sensory assessment of food and who were regular consumers of fruit juices was used. The panel consisted of 17 males and 18 females whose ages ranged between 21 and 50 y. They evaluated the taste and likeness of the fruit cocktail using a 7-point hedonic scale (1-dislike extremely, 7-like extremely). The assessors were instructed to rinse their mouth with water and refresh their palates with an unsalted cracker to reduce residual flavor effect of the previous sample evaluated. The assessment was done in three sessions, in a facility which conforms to the requirements of ISO 8589.

Experimental design and data analysis

A simplex centroid mixture design for mixtures of four components was employed to study the effect of ingredients (components) on the physicochemical properties of the juice. The constraints used for each component (soursop, pineapple, mango and orange) was 20 – 40%. This was used to generate a 15-point design matrix (Table 1). Juice cocktail made from these design points were subjected to physicochemical and sensory analyses. The results were analyzed using mixture regression, to fit the experimental data to Scheffe polynomial models (Minitab 17.1.0, Minitab Inc, USA) of the form $Y = \beta_1 \times_1 + \beta_2 \times_2 + \beta_3 \times_3 + \beta_4 \times_4 + \beta_{12} \times_1 \times_2 + \beta_{13} \times_1 \times_3 + \beta_{14} \times_1 \times_4 + \beta_{23} \times_2 \times_3 + \beta_{24} \times_2 \times_4 + \beta_{34} \times_3 \times_4.$ Where $Y=$ predicted dependent variable (pH, brix, color, taste and likeness), $\beta_1, \beta_2, \beta_3, \beta_4, \beta_{12}, \beta_{13}, \beta_{14}, \beta_{23}, \beta_{24}$ and β_{34} = parameter estimates for each linear and cross product term and X_1, X_2, X_3 and X_4 respectively represent pineapple, mango, orange and soursop juice. The polynomials were used to generate Cox response trace plots for the dependent variables. Optimization was done by superimposing contour plots of the responses measured in the experiment. The goal was to maximize the °Brix, b*-value, taste and overall likeness and minimize pH of the fruit juice cocktail.

Results and discussions

Experimental values for the physicochemical and sensory indices of the 15 formulations evaluated are presented in Table 1. As expected the responses varied widely from one run to another as a result of changes in the proportion of individual components in the fruit juice cocktail. Coefficients and R^2 of regression models fitted to the experimental data are presented in Table 2. The R^2 values indicated that the mixture regression models accounted for between 94 and 99% of the variability in the experimental data. Hence they, were found to be adequate in estimating the attributes examined in the study.

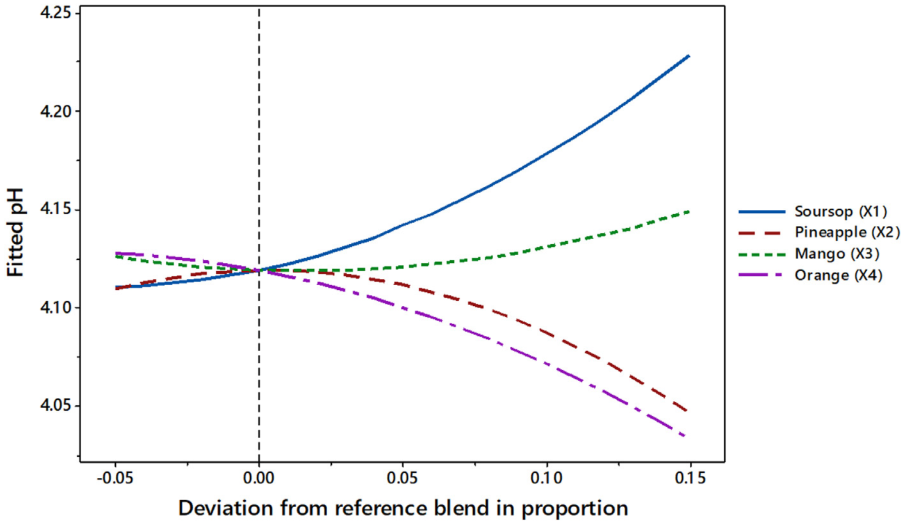

Fig. 1. Cox response trace plot for pH of fruit cocktail as a function of the proportion of soursop, pineapple, mango and orange.

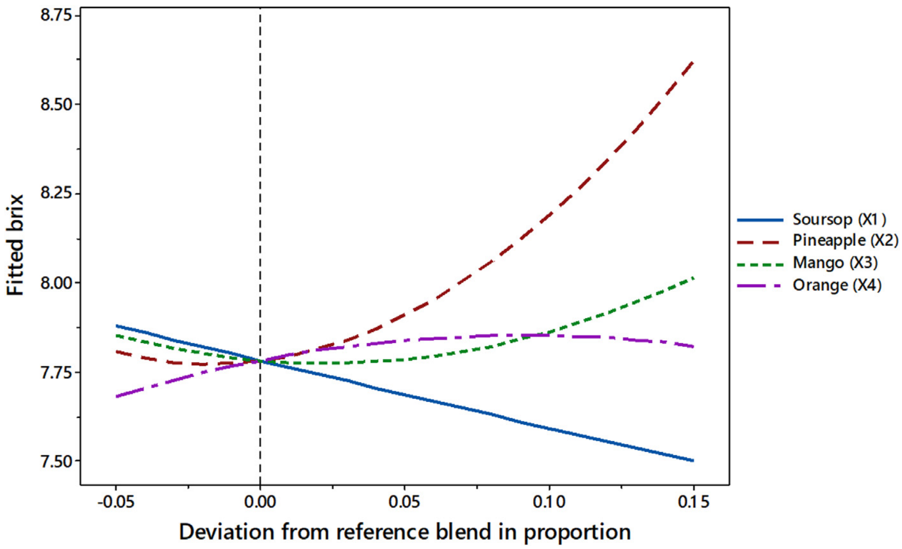

Fig. 2. Cox response trace plot for brix as a function of the proportion of soursop, pineapple, mango and orange.

The pH of the fruit cocktails ranged between 4.0 and 4.2 whilst TTA was between 3.3 to 3.7 mg/100 mL (Table 1). Whereas pH represents acidity or alkalinity, TTA measures the total acid concentration in food [22], and these are important in preservation and maintaining organoleptic properties. Ordinarily, acidity of juices reduces with increasing maturity of fruits [24] but acidity also differs from one fruit to another. As indicated in Fig. 1, orange and pineapple decreased the pH of the cocktail, while increasing levels of mango and soursop, increased pH of the fruit cocktail. This is not surprising since orange and pineapple used had lower pH compared to soursop. The influence of mango on pH, however, was milder compared to the three remaining fruits. The regression model for pH was 84.0% reliable in predicting the pH of the fruit cocktail with an adjusted R^2 of 55%. The pH of the fruit punch fell within the range of low acid foods, which is ideal for most fruit juices and punches. The values obtained in this study were higher than the range (3.5 – 4.0) reported for pineapple-orange juice blend reported by Akusu et al. [5], but lower than 4.3 – 4.5 for pineapple orange juice [13] and 4.8–5.0 for juice cocktail made from pineapple, oranges and carrots [2].

Together with acidity, brix is a major quality indicator of fruit juice quality [24]. It is a reflection of the amount of sugars in food. The cocktails in this study recorded a highest °Brix (soluble sugars) of 8.6 for the formulation containing intermediary amounts of soursop and mango and low amounts of pineapple and orange juice (Table 2). The brix of the juice cocktail was comparable to 7.7 to 8.6 obtained by Islam et al. [13] for mixed fruit juices and also within the range (5.7 – 12.3) reported by Curi et al., [9] for a tropical fruit juice. The Cox response trace plot (Fig. 2) showed that except for soursop, increasing levels of all the fruits in the blend had a positive effect on brix. Pineapple was the most influential on the brix

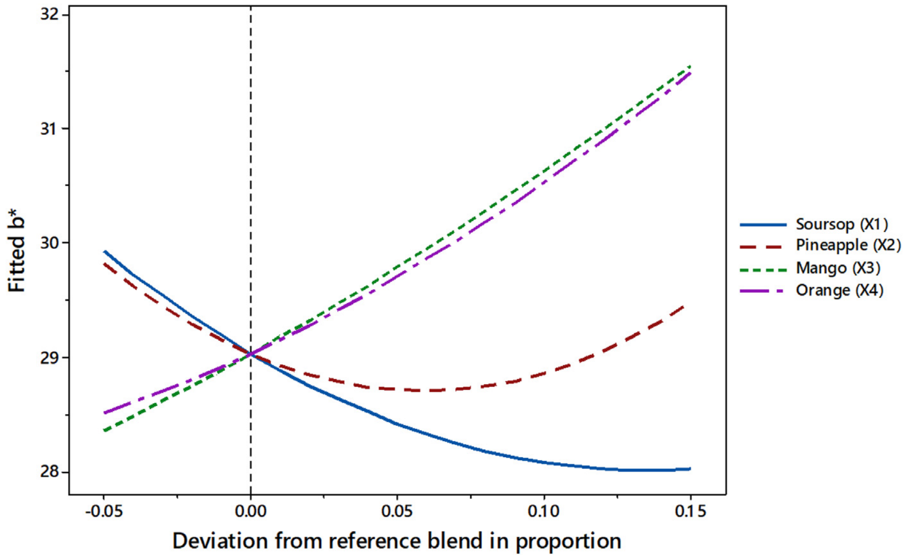

Fig. 3. Cox response trace plot for b* as a function of the proportion of soursop, pineapple, mango and orange.

of the final cocktail, followed by mango. There is no doubt that these two contributed immensely to the brix of the cocktail since the juices from these fruits had highest brix. Increasing levels of soursop caused a slight but consistent reduction in the brix of the cocktail. This may be attributed to the markedly lower brix (6.0) of the raw soursop juice compared to the juice of the other fruits. Obviously, orange had the least influence among the fruits used for the fruit cocktail, and this is reflected in its plot being nearly horizontal (Fig. 2). Binary combination of pineapple and orange was observed to have a positive significant ($p<0.05$) effect on brix of the final juice cocktail, whereas pineapple and mango, followed by soursop and pineapple resulted in the most negative effect.

Color is an important sensory and quality attribute in beverages. Its impact as a factor in selecting food products cannot be discounted. Indeed studies have shown color as a key driver of product acceptability [11]. In this study, juice cocktail resulting from the various formulations had an attractive yellowish hue, and each of the fruits contributed differently to keeping this appearance. The b* values, which ranged between +28 to +32, were reflective of this yellowish appearance. Fig. 3 illustrates the contribution of each fruit juice to the yellowish appearance of the fruit cocktails. Mango and orange had a predictably linear relationship with the yellowish appearance of the cocktail, since their individual juices had the highest b* values (indicating a more yellowish appearance). Increasing levels of these two fruits resulted in a sharp increase in the b*-value of the cocktail. Conversely, increasing levels of soursop reduced the yellowish appearance of the beverage. Binary combinations of the various fruits had significant influence on the yellowness of the juice. For instance, soursop and pineapple; and pineapple and orange significantly ($p<0.01$) reduced yellowness, whereas mango and orange increased it. This observation is in line with Curi et al., [9], and Kumar et al., [16] who respectively reported an improvement in yellowness of fruit punch when the proportion of orange and mango was increased in the mixture. Yellowness of many fruits is ascribed to the high amounts of carotenoids pigments they contain. Soursop, which was observed to reduce yellowness, contains very little amounts of these pigments, and therefore do not appear yellowish.

Generally all the ingredients had a positive influence on the taste of the fruit punch, although the extent of their effects were different, as presented in Fig. 4. While mango caused a dramatic increase in the taste score of the cocktail, extreme (low or high) levels of pineapple or soursop resulted in high sensory scores for taste. Increasing proportion of orange also largely resulted in increasing the sensory score for taste. Although each component affected the final product differently, the taste of each formula must have resulted from a synergy of sweetness and flavor of all the fruits. Taste of fruit juices are influenced by the brix acid ratio and this increases with increasing sugars and decreasing acids [14]. Generally, formulations with higher brix acid ratio (2.3 – 2.4), i.e. samples 2, 4, 8, 10 and 11 had the most preferred taste and these obtained scores ranging between 6.3 and 6.5.

The least liked sample obtained a score of 4.6, whereas the most liked formulation obtained an overall likeness score of 6.8 on the 7-point scale. The most liked formula contained extreme proportions of the various ingredients, i.e. highest amount of mango and lowest of the remaining fruit juices. The model describing overall likeness could explain 90.1% (adj R^2 =72.2%) of the variability in the experimental and predicted scores (Table 2). Cox response trace plot (Fig. 5) generated from the regression model for likeness showed that apart from orange, all the other ingredients affected likeness of the cocktail markedly. For instance, increasing proportions of pineapple or mangoes corresponded to high rating in product likeness. Also, extreme amounts of soursop juice enhanced the acceptability of the final cocktail. The terms pineapple*soursop and

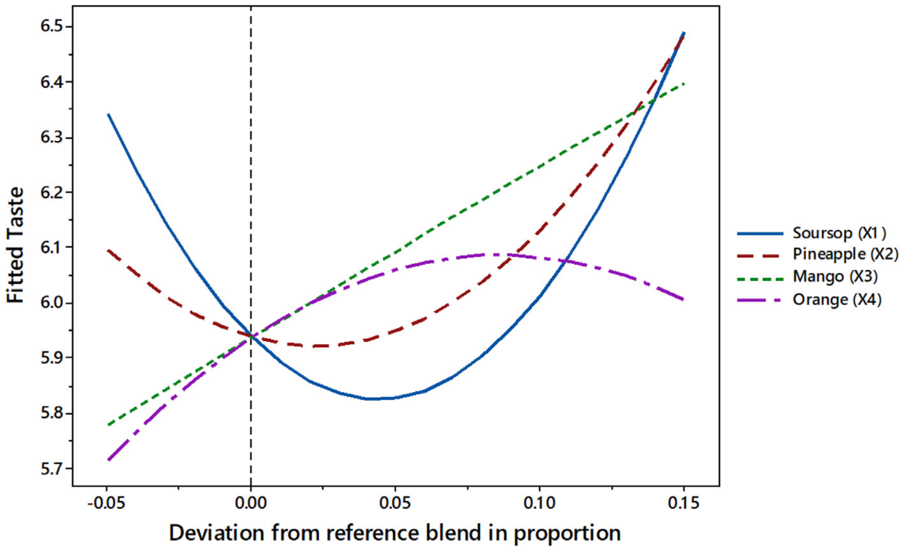

Fig. 4. Cox response trace plot for taste as a function of the proportion of soursop, pineapple, mango and orange.

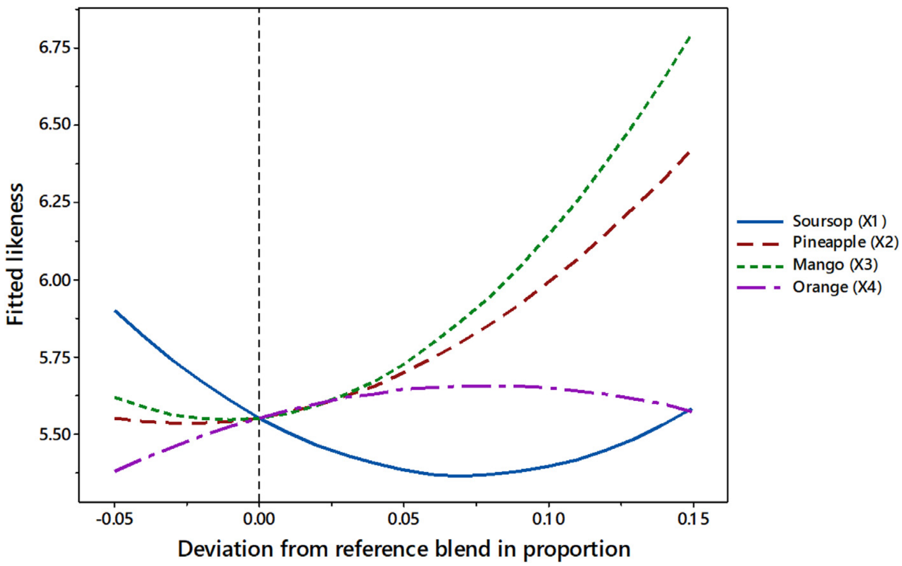

Fig. 5. Cox response trace plot for overall likeness as a function of the proportion of soursop, pineapple, mango and orange.

mango*orange contributed significantly to likeness scores. This indicates the importance of all the fruits in determining the likeness of the fruit juice cocktail.

Optimization of the fruit juice cocktail

To determine the optimum fruit cocktail formula, the physicochemical and sensory responses for all 15 formulations were superimposed in the overlaid contour plots shown in Fig. 6. The optimal region (unshaded area) for the overlaid plots showed that high amounts of pineapple juice is needed to obtain the best fruit juice cocktail containing the four fruits used in the present study. Formulations selected from within this region are likely to present unique physicochemical properties and receive a high score for overall liking. For instance an optimal formulation determined from the feasible region as soursop = 0.21%, pineapple = 0.38%, mango = 0.21%, orange = 0.20%, is predicted to have a pH (4.06), °Brix (8.4), b* (29.45), taste (6.4) and likeness (6.4). Formulations chosen from outside of the feasible region were predicted to have higher pH, lower degree brix and taste and likeness scores (Table 3). The selected formulations were processed and evaluated to validate the predicted models. Even though slight deviations occurred, the results (Table 4) ultimately showed a good fit between the predicted and observed scores.

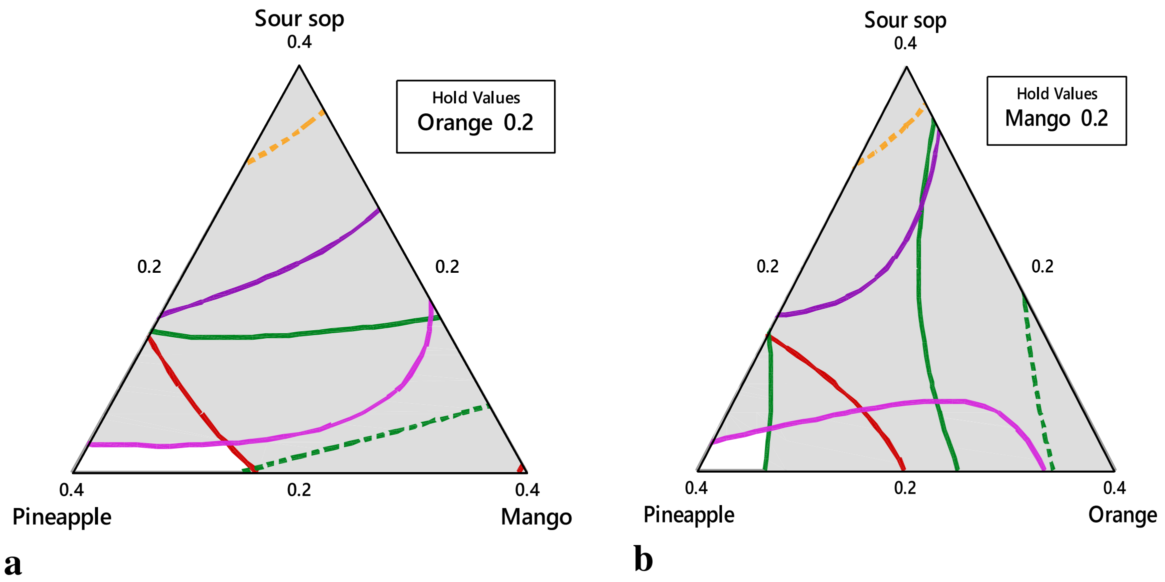

Fig. 6. Overlaid plots of physico-chemical and sensory responses at a minimum orange level of 0.2 **(a)** and a minimum mango level of 0.2 **(b).**

Table 3
Verification of formulations from within and outside of the optimal region.

	Component proportion in mixture				Predicted Responses				
Run	Soursop	Pineapple	Mango	Orange	pH	Brix	Color (b*)	Taste	Likeness
1	0.21	0.37	0.20	0.23	4.07	8.4	28.64	6.2	6.4
2	0.21	0.38	0.22	0.20	4.06	8.4	29.45	6.4	6.2
3†	0.25	0.27	0.27	0.20	4.12	7.7	28.78	5.9	5.5
4†	0.33	0.23	0.20	0.23	4.17	7.7	28.34	5.4	5.3

† These runs were selected from outside of the feasible region.

Table 4
Validated results of samples selected from within and outside of the optimal region.

	Validated responses				
Formula	pH	Brix	Color (b*)	Taste	Likeness
1	4.04	8.6	29.04	6.1	6.5
2	4.05	8.6	29.13	6.3	6.5
3	4.20	6.9	28.28	5.1	5.0
4	4.35	7.0	27.69	5.1	5.0

Conclusions

The study shows the possibility of combining a lesser known fruit with other popular ones in the production of a fruit juice cocktail. The pH of the cocktail ranged between 4.0 and 4.2 and was largely affected by orange, pineapple and soursop, with the latter causing a significant increase in pH. High amounts of soursop juice in the mixture caused a marked reduction in brix but pineapple and orange juice had a positive effect on brix. Taste and likeness of the juice cocktail were greatly influenced by the proportion of pineapple and soursop juice. Extreme amounts of soursop or high amounts of pineapple or mango juice resulted in high likeness score by the sensory panel. Optimization revealed that a juice cocktail with acceptable physicochemical and sensory attributes could be achieved using high amounts of pineapple juice. For example a combination of soursop (21%), pineapple (37%), mango (20%) and orange (23%) was predicted to have a pH (4.07), brix (8.4), b* (28.64), taste (6.2) and overall likeness (6.4). Validated results of the optimized formulation was in agreement with the predicted models.

Declaration of Competing Interest

The Authors declare no conflict of interest in submitting this research manuscript to your journal for publication.

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