Optimization of blending ratios of jam from swazi indigenous fruits tincozi (*syzygium cordatum*), tineyi (*phyllogeiton zeyheri*) and umfomfo (*cephalanthus natalensis oliv.*) using mixture design

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Optimization of blending ratios of jam from swazi indigenous fruits tincozi (Syzygium cordatum), tineyi (Phyllogeiton zeyheri) and umfomfo (Cephalanthus natalensis Oliv.) using mixture design

Nomfundo P. Dlamini1 and Solomon W. K2*

Abstract: This research was conducted to study effect of blending ratios on the physicochemical and sensory attributes and to optimize the blending proportions of jam made by blending three indigenous fruits: Tincozi (Syzygium cordatum), Tineyi (Phyllogeiton zeyheri) and Umfomfo (Cephalanthus natalensis Oliv.). An augmented simplex lattice mixture design was used where a total of seven formulations were generated using Design Expert software. The results indicated that the blending ratio affected the sensory attributes and the physico-chemical properties significantly (p < 0.05). Except for flavor, pH and water activity which were described by special cubic model, a quadratic Scheffer’s model adequately (R² = 0.84–0.99) described the relationship between blend proportions and the quality attributes. A graphical optimization indicated that the optimal ranges of the proportions for the three fruits for an acceptable product were 7–32%, 7.5–32% and 9–15%, for Tineyi, Tincoz and Umfomfo, respectively. The numerical optimization showed the optimal combination for an acceptable quality to be 20%, 18% and 12% for Tineyi, Tincoz and Umfomfo, respectively which had an overall desirability value of 0.914. Based

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PUBLIC INTEREST STATEMENT
The significant contributions that wild-growing indigenous fruits could make to the diets of a good percentage of the African population, especially in the sub-Sahara is increasing. They serve to supplement the nutrients provided by cereals, legumes and root crops and are important sources of carbohydrate, calcium, magnesium, potassium and vitamin C. Tincozi (common name water berry) (Syzygium cordatum), Tineyi (common name red ivory) (Phyllogeiton zeyheri) and Umfomfo (Cephalanthus natalensis Oliv.) are among the wild indigenous fruits grown in Swaziland. The barks, pulps and seeds of these plants and fruits are reported to be beneficial sources of therapeutic compounds against diarrheal infections. These fruits are seasonal and hence their preservation in processed food, such as jams, jellies, and other products is attractive. Based on the results of the study the three fruits could be blended to produce an acceptable jam.
on the results of the study the three fruits could be blended to produce jam of an acceptable quality.

**Subjects:** Food Additives & Ingredients; Food Chemistry; Food Engineering

**Keywords:** indigenous fruits; Tineyi; Tincoz; umfomfo; Jam

1. **Introduction**

The awareness of the significant contributions that wild-growing indigenous fruits could make to the diets of a good percentage of the African population especially in the sub-Sahara is increasing (Ebert, 2014; Williams & Haq, 2002). They serve to supplement the nutrients provided by cereals, legumes and root crops and are important sources of carbohydrate, calcium, magnesium, potassium and vitamin C.

Tincozi (common name water berry) (*Syzygium cordatum*), Tineyi (common name red ivory) (*Phyllogeiton zeyheri*) and Umfomfo (common name bush berry) (*Caphalanthus natalensis Oliv.*) are among the wild indigenous fruits grown in Eswatini (Swaziland). Tincozi is fleshy purple fruit that resembles grapes in that it has plenty of pulp and small seeds. The plant is wide spread throughout most of Eswatini and is commonly available. The fruit is consumed locally and the bark is used for treating bleeding (Loffer & Loffer, 2005). The *S. cordatum* pulp and seed extracts had demonstrated the therapeutic and biological efficacy (antibacterial, antidiarrheal and anti-motility activities). Due to the pharmacodynamic effects revealed by Tincozi (*S. cordatum*) pulp and seed extracts, the pulps and seeds can be viewed as satisfactorily beneficial sources of therapeutic compounds against diarrheal infections (Maliehe et al., 2017; Maliehe Tsolanku Sidney, Siyabonga, & Kotze, 2015). Tineyi is small oval red fruit that has a sweet taste and scent liked by the Swazi people. The plant is wide spread in eastern and central Eswatini and is commonly available. The fruit is consumed locally and the bark is used for treating diarrhoea as a diuretic. Umfomfo is wide spread in the west, with patches in central and southern-central Eswatini. It resembles strawberries in appearance but has a sweet bitter taste and has dry soft compounds that are white tinged with pink color and is widely available when in season and consumed locally. Umfomfo is believed to have an important health benefit (Loffer & Loffer, 2005; Seeram, 2008). These and other indigenous fruits play an important role in the diet as a food source especially during food shortage season. However, due to their perishability, a large portion of the produce is left to decompose (Tiisekwa & Ndlangamandla, 1996)

The availability of these indigenous fruits in the country can provide a cheaper and accessible source of ingredients for developing value added products which can diversify their utilization. These fruits are seasonal and hence their conversion into processed and stable products, such as jams, jellies, and other products is attractive. Despite their potential to contribute to food security, very few reports are available on the value addition of such fruits in the country. The possibility and limitation of selected indigenous fruit of the country to produce jams and gellies (Tiisekwa & Ndlangamandla, 1996) and possibility of producing flavoured yoghurts using indigenous fruit pulps (Dlamini, Mamba, & Silaula, 2009) have been reported. Thus, there is still a need to diversify the utilization of such valuable indigenous products by adding value and developing innovative products. The objectives of the study were to develop jam by blending Tincozi, Tineyi and Umfomfo, study the effect of blending ratios on selected physicochemical properties and consumer acceptability and optimize the blending proportions for an acceptable product quality.

2. **Materials and methods**

2.1. **Raw material preparation**

The three fruits were obtained from local market and were thoroughly washed under running tap water to remove soil, plant and other foreign materials. Undamaged fruits with no symptoms of
visible discoloration were selected and soaked in warm water (80°C) for 2 min to reduce surface microbial load.

2.2. Jam making

The fruits were sliced to an appropriate size, the seeds were removed and pulped. Based on the formulations presented in Table 1, the fruit pulps were poured into a thick heavy-based sauce pan and cooked until the blend softens and pectin was added to the batch while stirring very vigorously and boiled for about 2 min to ensure a complete dissolution. Sugar was added while keeping the batch boiling. The amount of sugar, pectin and acid added was within a range reported in previous studies (Levaj, Bunić, Dragović-Uzelac, & Kovačević, 2010; Ścibisz & Mitek, 2009). The mixture was then boiled to concentrate the soluble solids to the desired brix (about 68-72°Brix) (Abid, Yaich, Hidouri, Attia, & Ayadi, 2018; Hmar, Mishra, & Pradhan, 2017). Soon after the desired °Brix was attained, the jam was hotfilled into cleaned jars and closed.

2.3. Product analysis

2.3.1. Physico-chemical analysis

The pH was measured using a pH meter (pH50, XS, Instruments, PRC) calibrated with buffer solutions pH = 4 and pH = 7. The °Brix was measured using a refractometer (PAL-3 ATAGO, Tokyo-Japan). The sample was placed on the sensor of the refractometer and the readings were taken and recorded. The water activity was measured using a Lab Swift water activity meter (2,600,179, Novasina, Lachen, Switzerland) (Abid et al., 2018; Hmar et al., 2017).

2.3.2. Sensory evaluation

Sensory evaluation was conducted using 48 untrained panellists to determine consumer acceptability of the developed jams. The panellist were simultaneously presented with coded jam samples. The degree of liking of the product were recorded on a seven-point (1 = Dislike extremely, 2 = Dislike Very Much, 3 = Dislike, 4 = Neither like nor dislike, 5 = Like, 6 = Like Very Much 7 = Like extremely) hedonic scale to evaluate attributes of appearance, taste, texture, aroma, flavour and overall acceptability. Panellists were oriented to take a sip of water before tasting and after tasting each sample so to rinse their mouths (Lawless & Heymann, 2010).

2.4. Experimental design and data analysis

An augmented (upgraded) simplex lattice mixture design (SLMD) was used to investigate the effect of blending ratios on the physico-chemical characteristics and sensory attributes of the jam produced by blending the three fruits. A total of seven runs (formulations) were generated using Design-Expert Stat ease version 7.0 (Table 1). Quadratic and special cubic models shown below were fitted to the data and the adequacy of the model was checked by the values of $R^2$ and adjusted-$R^2$.

$$Y = \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_{12} x_1 x_2 + \beta_{13} x_1 x_3 + \beta_{23} x_2 x_3 + \beta_{123} x_1 x_2 x_3$$

where:

- $Y$ = the predicted variable
- $x_{1,2,3}$ = the proportion of the three fruit pulps in the mixture
- $\beta$’s = the coefficients of the linear, quadratic and cubic terms of the model

The significance of the effect of blending on the mean values of the physico-chemical and sensory attributes was ascertained by ANOVA. Multiple comparison was carried out using LSD at 0.05 level of significance.
Table 1. Proportions and actual quantities of the three fruits Tincozi (*syzygium cordatum*), Tineyi (*phyllogeiton zeyheri*) and Umfomfo (*cephalanthus natalensis oliv.*) and the other ingredients used in different treatments

| Treatments | Tineyi (%) | Tincozi (%) | Umfomfo (%) | Sugar (%) | Pectin and acid (%) | Tineyi (g) | Tincozi (g) | Umfomfo (g) | Sugar (g) | Pectin and acid (g) |
|------------|------------|-------------|-------------|-----------|---------------------|------------|-------------|-------------|-----------|---------------------|
| 1          | 0.0        | 0.0         | 50.0        | 49.5      | 0.5                 | 0          | 0           | 800         | 793.0     | 7.0                 |
| 2          | 0.0        | 50.0        | 0.0         | 49.5      | 0.5                 | 800        | 0           | 0           | 793.0     | 7.0                 |
| 3          | 50.0       | 0.0         | 0.0         | 49.5      | 0.5                 | 160        | 160         | 480         | 793.0     | 7.0                 |
| 4          | 30.0       | 10.0        | 10.0        | 49.5      | 0.5                 | 480        | 160         | 160         | 793.0     | 7.0                 |
| 5          | 10.0       | 30.0        | 10.0        | 49.5      | 0.5                 | 160        | 480         | 160         | 793.0     | 7.0                 |
| 6          | 10.0       | 10.0        | 30          | 49.5      | 0.5                 | 160        | 160         | 480         | 793.0     | 7.0                 |
| 7          | 16.7       | 16.7        | 16.7        | 49.5      | 0.5                 | 266.7      | 266.7       | 266.7       | 793.0     | 7.0                 |
2.5. Optimization

Graphical optimization was used to determine region of optimal combination of the proportions of fruits. The contour plots of different attributes were super imposed to come up with an overlay plot that was used to determine the optimal region based on the optimization criteria. Another useful approach to optimize multiple responses is to use simultaneous optimization technique which makes use of desirability function. The general approach is first to convert each response $y_i$ into desirability function $d_i$ that varies over the range 0 to 1 (Montgomery, 2001). If the objective or target $T$ for the response $Y$ is a maximum value, the individual desirability functions are structured as,

$$d = \begin{cases} 0 & Y < L \\ \frac{(Y - L)^r}{(U - L)^r} & L \leq Y \leq U \\ 1 & Y > U \end{cases}$$

If the target $T$ for response $y$ is minimum:

$$d = \begin{cases} 1 & Y > T \\ \frac{(U - Y)^r}{(U - L)^r} & T \leq Y \leq U \\ 0 & Y < U \end{cases}$$

where $r$ is weight, $L$ is lower value and $U$ is upper value.

Then, for $m$ responses, the design variables are chosen to maximize the overall desirability $D$

$$D = (d_1 \times d_2 \times d_3 \cdots d_m)^{1/m}$$

3. Results and discussion

3.1. Physico-chemical properties

3.1.1. pH

The pH values of the different treatments ranged between 3.4 and 3.91 (Table 2) and the blend proportions brought a significant ($p < 0.05$) effect on the pH. The trends in the changes of pH in relation to the blend proportions are presented by the ternary mixture plot (Figure 1(a)). Acidity increased with increase in the proportion of Tincozi. The data indicated that jam sample with 50% Tineyi had the highest pH, followed by the sample with 50% Umfomfo, the sample with equal proportions of the three fruits, and the treatment with 50% Tincozi. The sample with 30:10:10% (Tineyi:Tincozi:Umfomfo) had the lowest pH reading. The pH values observed in this study were comparable with jams made of Tineyi (Dlamini et al., 2009) and other fruits (Abid et al., 2018; Chauhan, Archana, Singh, Raju, & Bawa, 2013; Hmar et al. 2017; Rababah et al., 2012).

The relationship between the proportions and the pH was adequately described by a special cubic model ($R^2 = 0.99$ and $R^2_{adj} = 0.99$). The linear, binary and ternary mixture blends affected the pH significantly ($p < 0.05$). All the binary blends were synergetic whereas the ternary blend was antagonistic as indicated by the negative and positive coefficients, respectively for a minimized target response (Table 4).

3.1.2. °Brix

The total soluble solids (°Brix) were influenced significantly ($p < 0.05$) by the blending ratios (Table 1). Sample with 50% Umfomfo and 10:10:30% (Tineyi:Tincozi:Umfomfo) had the least °Brix. There was no significant difference ($P > 0.05$) between jam samples containing 50% Tincozi, 10:30:10% (Tineyi: Tincozi:Umfomfo) and the treatment with equal proportion of the three fruits. The sample with 50% Tineyi was significantly ($p < 0.05$) different from the other treatments. °Brix increased with increase in Tineyi and Tincozi whereas an increase in the proportion of Umfomfo resulted in a decrease in the °Brix (Figure 1(b)). The soluble solids content of sample containing 50% Tineyi was higher compared to the other samples and was comparable to °Brix of jam made from Tineyi in previous study (Dlamini et al.,
| Properties | TREATMENTS |
|------------|------------|
|            | 1          | 2          | 3          | 4          | 5          | 6          | 7          |
| PH         | 3.91a ± 0.01 | 3.53c ± 0.21 | 3.57b ± 0.01 | 3.40e ± 0.01 | 3.42de ± 0.01 | 3.43d ± 0.27 | 3.55b ± 0.06 |
| °Brix      | 70.53a ± 0.29 | 69.10c ± 0.10 | 68.41d ± 0.01 | 69.81b ± 0.12 | 69.23c ± 0.06 | 68.44d ± 0.12 | 69.23c ± 0.21 |
| Aw         | 0.88a ± 0.02 | 0.74d ± 0.27 | 0.83b ± 0.02 | 0.85ab ± 0.01 | 0.84b ± 0.03 | 0.79c ± 0.01 | 0.75d ± 0.02 |
and jams produced from other fruits (Basu & Shivhare, 2013; Chauhan et al., 2013; Hmar et al., 2018) and recommended by CODEX (CODEX, 2009). This indicates that the jams produced in this study have good texture since the soluble sugars are the largest contributors of the texture (Garrido, Lozano, & Genovese, 2015). The relationship between the proportions of the fruits and °Brix was adequately ($R^2 = 0.99$ and $R^2_{adj} = 0.98$) described by a quadratic model with a non-significant lack of fit. The linear and
Table 3. Sensory evaluation scores of jam made from the indigenous fruits Tincozi (*syzygium cordatum*), Tineyi (*phyllogeiton zeyheri*) and Umfomfo (*cephalanthus natalensis oliv.*)

| Sensory parameters | Treatments |
|--------------------|------------|
|                    | 1          | 2          | 3          | 4          | 5          | 6          | 7          |
| Appearance         | 5.25a ± 1.51 | 4.38b ± 1.70 | 4.15a ± 1.53 | 5.23a ± 1.15 | 5.44a ± 1.13 | 3.46d ± 1.13 | 4.90ab ± 1.19 |
| Aroma              | 5.00a ± 1.19 | 4.86ab ± 1.06 | 4.52b ± 1.11 | 4.96ab ± 0.92 | 4.77ab ± 1.10 | 3.77c ± 1.02 | 4.69ab ± 1.26 |
| Taste              | 5.31a ± 1.32 | 5.19a ± 1.33 | 4.40b ± 1.30 | 5.44a ± 1.17 | 5.31a ± 1.31 | 3.83c ± 1.24 | 4.58b ± 1.38 |
| Texture            | 4.69ab ± 1.55 | 4.79a ± 1.70 | 4.19b ± 1.50 | 4.77a ± 1.21 | 4.83a ± 1.26 | 2.98c ± 1.08 | 4.69ab ± 1.26 |
| Flavour            | 4.96ab ± 1.35 | 4.92ab ± 1.61 | 4.47b ± 1.22 | 5.00ab ± 1.43 | 5.23a ± 1.31 | 3.65c ± 1.23 | 5.02a ± 1.16 |
| Overall            | 5.23a ± 1.26 | 5.10a ± 1.34 | 4.60b ± 1.33 | 5.46a ± 1.17 | 5.33a ± 1.24 | 3.60c ± 1.09 | 5.10a ± 1.13 |
### Table 4. Model coefficients, p-values and regression coefficients

| Attribute     | $\hat{\beta}_1$ | $\hat{\beta}_2$ | $\hat{\beta}_3$ | $\hat{\beta}_{12}$ | $\hat{\beta}_{13}$ | $\hat{\beta}_{23}$ | $\hat{\beta}_{123}$ | $R^2$ | $R^2_{adj}$ | p-value | Lack of fit |
|---------------|-----------------|-----------------|-----------------|---------------------|---------------------|---------------------|---------------------|------|------------|----------|-------------|
| Appearance    | 10.492          | 8.872           | 8.345           | 55.57               | -38.168             | -11.468             | 0.009               | 0.95 | 0.90       | 0.009    | 0.56        |
| p-value       | 0.0075          |                 |                 |                     |                     |                     |                     |      |            |          |             |
| Aroma         | 9.99            | 9.71            | 8.99            | 27.68               | -15.115             | -2182               | 0.87                | 0.71 | 0.0619     | 0.413    |             |
| p-value       | 0.059           |                 |                 |                     |                     |                     |                     |      |            |          |             |
| Taste         | 10.632          | 10.371          | 8.77            | 37.47               | -20.52              | -24.375             | 0.91                | 0.79 | 0.034      | 0.494    |             |
| p-value       | 0.019           |                 |                 |                     |                     |                     |                     |      |            |          |             |
| Texture       | 9.351           | 9.536           | 8.136           | 49.654              | -28.846             | -27.696             | 0.84                | 0.63 | 0.097      | 0.268    |             |
| p-value       | 0.0902          |                 |                 |                     |                     |                     |                     |      |            |          |             |
| Flavour       | 9.917           | 9.84            | 9.0             | 23.393              | -47.207             | -34.94              | 401.6               | 0.98 | 0.93       | 0.0156   |             |
| p-value       | 0.016           |                 |                 |                     |                     |                     |                     |      |            |          |             |
| OAC           | 10.443          | 10.186          | 9.146           | 50.96               | -25.141             | -29.057             | 0.93                | 0.85 | 0.0178     | 0.245    |             |
| p-value       | 0.0204          |                 |                 |                     |                     |                     |                     |      |            |          |             |
| pH            | 7.852           | 7.065           | 7.135           | -13.978             | -13.831             | -5.648              | 174.28              | 0.99 | 0.99       | <0.0001  |             |
| p-value       | <0.0001         |                 |                 |                     |                     |                     |                     |      |            |          |             |
| °Brix         | 141.15          | 138.195         | 136.81          | 14.599              | -11.217             | -10.667             | 0.99                | 0.98 | 0.0002     | 0.454    |             |
| p-value       | <0.0001         |                 |                 |                     |                     |                     |                     |      |            |          |             |
| MC            | 51.05           | 27.80           | 36.81           | 6.19                | 279.85              | 575.34              | -7315.33            | 0.99 | 0.99       | <0.0001  |             |
| p-value       | <0.0001         |                 |                 |                     |                     |                     |                     |      |            |          |             |
| $a_w$         | 1.76            | 1.49            | 1.66            | 5.30                | 1.10                | 3.55                | -75.23              | 0.968| 0.903      | 0.0244   |             |
| p-value       | 0.0102          |                 |                 |                     |                     |                     |                     |      |            |          |             |
binary mixtures influenced significantly. The Tineyi-Tincozi binary blends were synergetic whereas the Tincozi-Umfomfo and Tineyi-Umfomfo binary blends were antagonistic as indicated by the negative coefficients.

3.1.3. Water activity

The results of water activity for the different treatments ranged from 0.75 to 0.88 (Table 2) and the proportions of the fruits significantly (p < 0.05) affected the water activity. The water activity of the treatment with 50% Tineyi was the highest and was not significantly different (p > 0.05) from the treatment with 30:10:10% (Tineyi:Tincozi:Umfomfo). The treatments with 50% Tincozi and with equal proportions of the three fruits had the least water activity compared to the other samples. Water activity has its most useful application in predicting the growth of bacteria, yeasts and moulds. For a food product to have a useful shelf life without relying on refrigerated storage, it is necessary to control either its acidity level (pH) or the level of water activity or a suitable combination of the two. Published works indicated that the water activity for most processed jams ranges from 0.82 to 0.86. With the values of pH and water activity presented in Table 2, the jams produced will be safe from development of the majority of the bacteria (Abid et al., 2018; Garrido et al., 2015; Schmidt & Fontana, 1989).

The trends in the water activity as influenced by the blend proportions are presented in the ternary mixture plot (Figure 1(c)). The ternary plot indicated that the minimum water activity is towards the centroid of the ternary plot where the three fruits are in comparable proportions. The relationship between the proportions of the fruits and water activity was described by a special cubic model ($R^2 = 0.97$ and $R^2_{adj} = 0.90$). The linear and binary (Tineyi-Tincozi) blends significantly (p < 0.05) affected the water activity. The fact that all the blend coefficients are positive and there is a need to minimize the water activity indicates that these blend are antagonistic (Smith, 2000).

3.2. Sensory evaluation

3.2.1. Appearance

The results of sensory evaluation are presented in Table 3 showed a significant (p < 0.05) difference between treatments due to the blending proportion. The sample with 10:30:10% (Tineyi:Tincozi:Umfomfo) had the maximum score of 5.44 ± 1.13 (between “like” and “like very much”). However, there was no significant difference between this sample and the samples with 50% Tineyi, and 30:10:10% (Tineyi:Tincozi:Umfomfo). The treatment with 10:10:30% (Tineyi:Tincozi:Umfomfo) was the least preferred with score 3.46 ± 1.13 which was between “dislike” and “neither like nor dislike”. This treatment was significantly (p < 0.05) different from the others (p < 0.05).

The significant difference between samples containing 50% Tineyi, 50% Tincozi and sample containing 10:10:30% (Tineyi:Tincozi:Umfomfo) might be attributed to the natural colour of the different fruits and the variation in total soluble solids (TSS) of each indigenous fruit. The relationship between color values and TSS has been reported for other jam products (Basu & Shivhare, 2013). Sample with 10:30:10% (Tineyi:Tincozi:Umfomfo) appeared to be dark purple in colour which could be a contributing factor for the sample to be liked more than the other samples. The color of this treatment was dominated by the dark purple appealing colour of Tincozi. The trend of changes in appearance as a function of the blending proportion is presented in the ternary mixture plot (Figure 2(a)). Increase in Tineyi and Tincozi resulted in an increase in the appearance score whereas increase in the proportion of Umfomfo resulted in a decrease in the appearance score. The relationship between the blend proportion and appearance was adequately ($R^2 = 0.95$ and $R^2_{adj} = 0.90$) described by a quadratic Scheffe model with a non-significant lack of fit (Table 4). The linear blends showed a significant (p < 0.05) influence on the appearance score. The binary (Tineyi-Tincozi) blend exhibited a significant (p < 0.05) synergetic effect whereas the other binary blends (Tineyi-Umfomfo and Tincozi-Umfomfo) showed antagonistic effects indicated by the negative coefficients (Table 4).
3.2.2. Aroma
The aroma score for the different treatments are presented in Table 3. The sample with 50% Tineyi had the highest mean score (5 ± 1.19) which is “like” intensity. The sample with 10:10:30% (Tineyi:Tincozi:Umfomfo) had the least mean score 3.77 ± 1.02 which is between “dislike” and “neither like nor dislike” and was a significantly different (P < 0.05) from the rest of the treatments. The changes in aroma score as a function of the blend proportions is presented in ternary mixture plot (Figure 2(b)). Increase in the proportion of Tineyi and Tincozi resulted in increased aroma score whereas increase in the proportion of Umfomfo showed a decrease in the aroma score. The functional relationship between the blend proportion and aroma was satisfactorily (R² = 0.87 and R²adj = 0.71) described by a quadratic polynomial Scheffe model. The binary (Tineyi-Tincozi) blend had a significant (p < 0.05) synergetic effect whereas the two binary blends (Tineyi-Umfomfo and Tincozi-Umfomfo) exhibited a significant (p < 0.05) antagonistic effects indicated by the negative model coefficients (Table 4) (Smith, 2000).
3.2.3. Taste
The taste scores of the different treatments are presented in Table 3 where the blending proportions affected the taste scores significantly (p < 0.05). The sample with 50% Tineyi, 50% Tincozi 30:10:10% (Tineyi:Tincozi:Umfomfo) and 10:30:10% (Tineyi:Tincozi:Umfomfo) were the most liked with a mean score of more than five indicating taste class between “like” and “like very much”. The samples containing 50% Umfomfo and the treatment with equal proportion of the three fruits were neither liked nor disliked. The sample with 10:10:30% (Tineyi:Tincozi:Umfomfo) was the least liked with the average score of 3.83 ± 1.24 which is between “dislike” and “neither like nor dislike”. The results showed that treatments containing higher quantities of Tineyi and Tincozi were liked which could be due to the delicious natural sweet taste of the fruits. Jam which had high quantities of Umfomfo were neither liked nor disliked. This might have resulted from natural sweet taste with a bitter after taste of Umfomfo. Low pH and high titratable acidity of Umfomfo might have also contributed to the low taste score of the samples in these treatments (Dlamini et al., 2009).

The changes in the taste attribute as a function of the blend proportion of the fruits is presented in the ternary mixture plot (Figure 2(c)). Increase in the proportion of Tineyi and Tincozi resulted in the increment of the taste score. It is worth noting that increase in the proportion of Umfomfo adversely affected the taste score. The relationship between the taste score and the proportion of the fruits was adequately described by a quadratic Scheffer model (R² = 0.91 and R²_adj = 0.80) with non-significant lack of fit. The linear and binary (Tineyi-Tincozi) blends significantly (p < 0.05) and positively affected the taste whereas the other binary blend (Tincozi-Umfomfo) affected significantly but in antagonistic way which was evident from the negative sign of the binary blend coefficient (Table 4).

3.2.4. Texture
The treatments which contained 50% Tineyi, 50% Tincozi, 30:10:10% (Tineyi:Tincozi:Umfomfo), and 10:30:10% (Tineyi:Tincozi:Umfomfo) had mean scores between 4 and 5 indicating hedonic ratings between “neither liked nor disliked” and “liked”. These treatments were not significantly different (p > 0.05) from each other. The sample with 10:10:30% (Tineyi:Tincozi:Umfomfo) got the least mean texture score of 2.98 ± 1.08 which is between “dislike very much” and “dislike”.

The changes in the texture as a function of the blend proportions are presented in the ternary mixture plot (Figure 2(d)). Increase in the proportion of Tineyi and Tincozi resulted in higher texture score whereas increase in the proportion of Umfomfo showed a decrease in the texture score. The high texture score of jams with higher content of Tincozi and Tineyi might have been due to the fact that the pulp from these two fruits are much compatible in terms of texture which contributed to the characteristic texture of the jams. A better textural score was also observed for yoghurts flavoured with Tineyi and Tincozi puree as compared to Umfomfo (Dlamini et al., 2009). A quadratic Scheffe model fairly (R² = 0.84 and R²_adj = 0.63) described the relationship between the blend proportions and the texture score with a non-significant lack of fit. It was noted that the effect of the binary blend (Tineyi-Tincozi) was significant (p < 0.05) and synergetic indicated by the positive coefficient whereas the binary blend (Tincozi-Umfomfo) was significant but antagonistic indicated by the negative coefficients (Table 4).

3.2.5. Flavour
The results of the flavour score for the different treatments are presented in Table 3. The treatment with 10:10:30% (Tineyi:Tincozi:Umfomfo) appeared to be the least with an average score of 3.65 ± 1.23 which is between “dislike very much” and “dislike” and significantly different (p < 0.05) from the rest of the treatments. The sample with 10:30:10% (Tineyi:Tincozi:Umfomfo) had the maximum score but not significantly different from some of the treatments (Table 3). Increase in the proportion of Tineyi and Tincozi resulted in an increase in the flavour score whereas increase in the proportion of Umfomfo affected the flavour score adversely (Figure 2(e)). This might have resulted from the strong influence of Umfomfo on the flavour of jams. Poor flavour score of yoghurt flavoured with Umfomfo was reported as compared to yoghurt flavoured with Tineyi and Tincozi (Dlamini et al., 2009). The dependence of flavour on the proportion of the fruits was adequately (R² = 0.98 and R²_adj = 0.93) described by a special cubic model. The linear and binary (Tineyi-Umfomfo and Tincozi-Umfomfo) blends significantly
affected the flavour score (Table 4). The binary blends exhibited antagonistic effect as indicated by the negative blend coefficients (Smith, 2000).

3.2.6. Overall acceptance
The results of the overall acceptability indicated that treatments with 50% Tincozi, 50% Tineyi, 30:10:10% (Tineyi:Tincozi:Umfomfo), 10:30:10% (Tineyi:Tincozi:Umfomfo) and 16.7:16.7:16.7% (Tineyi:Tincozi:Umfomfo) were acceptable with score ranging from 5.1 ± 1.13 to 5.5 ± 1.17 which is between “like” and “like very much” (Table 3). The treatments with 50% Umfomfo and 10:10:30% (Tineyi:Tincozi:Umfomfo) were the least with their acceptability score and they were not liked by the consumer panels and were also significantly (p < 0.05) different from the rest of the treatments. The low overall acceptability might be attributed to the distinct aroma and bitter after taste of Umfomfo. The low pH and high titratable acidity of Umfomfo puree might have also contributed to the low acceptability score (Dlamini et al., 2009).

The effect of blending on the overall acceptability of the samples is presented in the ternary plot (Figure 1(f)). Increase in the proportion of Tineyi and Tincozi resulted in increased overall acceptability whereas increase in the amount of Umfomfo negatively affected the overall acceptability. This trend was consistent with all the other sensory attributes evaluated. The dependence of the overall acceptability on the blending proportion was adequately (R² = 0.93 and R²adj = 0.85) described by a quadratic Cheffe’s model. The linear and binary blending significantly (p < 0.05) affected the overall acceptability (Table 4). The binary blend (Tineyi-Tincozi) affected the overall acceptability in a synergetic manner indicated by the positive binary blending coefficient whereas the other binary blends (Tincozi-Umfomfo and Tineyi-Umfomfo) affected the acceptability in an antagonistic way evidenced by the negative binary blending coefficient (Rababah et al., 2012).

3.3. Optimization

3.3.1. Graphical optimization
To determine a region for optimal combination of the three fruit pulps that gives an acceptable product in terms of water activity, appearance, flavour, aroma, taste, and overall acceptability, there was a need to superimpose the ternary plots of the responses to get an overlay plot. The optimum region obtained by superimposing the six contour plots is depicted in the shaded region of Figure 3. This optimum region provides the coordinates of possible optimal levels of Tineyi, Tincozi and Umfomfo. The criteria for the optimal region were sensory attributes greater or equal to the “like” intensity and minimized water activity. The ranges of the three fruit to be blended in the optimal region are 8.6–15%, 7–32% and 7.5–32% for Umfomfo, Tineyi and Tincozi, respectively.

3.3.2. Numerical optimization
Using the criteria of maximizing all the sensory attributes and limiting the water activity in the ranges of 0.73 to 0.85, the optimal proportions which gave the best result were 20:18:12% (Tineyi:Tincozi:Umfomfo) which resulted in mean scores of 5.62, 5.04, 5.45, 5.15, 5.58, 5.71 and 0.80 for appearance, aroma, taste, texture, flavour, overall acceptability and water activity, respectively and an overall desirability of 0.914.

4. Conclusion
The results from the study revealed that the blend proportions of the three fruits significantly affected the sensory attributes and physico-chemical attributes of jams produced. There was a consistent negative influence of Umfomfo on many of the quality attributes assessed. The results of the study indicated that there is a possibility of producing jam by blending the three indigenous fruits: tincozi (syzygium cordatum), Tineyi (phyllogeiton zeyheri) and Umfomfo (cephalanthus natalensis oliv.). The three fruits could be blended in the ranges of 8.6–15%, 7–32% and 7.5–32% for Umfomfo, Tineyi and Tincozi, respectively for an acceptable product. Further study could be done to understand the relationship between the physico-chemical properties and sensory descriptors using quantitative descriptive sensory analysis.
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References
Abid, M., Yaich, H., Hidouri, H., Attaia, H., & Ayadi, M. A. (2018). Effect of substituted gelling agents from pomegranate peel on colour, textural and sensory properties of pomegranate jam. Food Chemistry, 239, 1047–1054. doi:10.1016/j.foodchem.2017.07.006
Basu, S., & Shihhare, U. S. (2013). Rheological, textural, microstructural, and sensory properties of sorbitol-substituted mango jam. Food Bioprocess Technology, 6, 1401–1413. doi:10.1007/s11947-012-0795-8
Chauhan, O. P., Archana, B. S., Singh, A., & Bawa, A. S. (2013). Utilization of tender coconut pulp for jam making and its quality evaluation during storage. Food Bioprocess Technology, 6, 1444–1449. doi:10.1007/s11947-012-0920-8
CODEX. (2009). Standard for jams, jellies and marmalades CXS 296-2009 adopted in 2009. Amended in 2017. Available at www.fao.org/input/download/standards/11254/CXS_296e.pdf
Diamini, A. M., Mamba, R., & Silaula, S. M. (2009). Attributes and consumer acceptance of yoghurt flavoured with non – Cultivated indigenous swazi fruits. African Journal of Food Agriculture Nutrition and Development, 9(1), 636–651. doi:10.4341/agfon.v9i1.19218
Ebert, A. W. (2014). Potential of under utilized traditional vegetables and legume crops to contribute to food and nutritional security, income and more sustainable production systems. Sustainability, 6, 319–335. doi:10.3390/su6010319
Garrido, J. I., Lozano, J. E., & Genovese, D. B. (2015). Effect of formulation variables on rheology, texture, colour, and acceptability of apple jelly: Modelling and optimization. LWT - Food Science and Technology, 62, 325–332. doi:10.1016/j.lwt.2014.07.010
Hmar, B. Z., Mishra, S., & Pradhan, R. C. (2017). Physico-chemical and sensory analysis of Kendu (Diospyros malaxoxylon Roxb.) jam using fuzzy logic. Journal of Food Measurement and Characterization, 11, 1928–1935. doi:10.1007/s11694-017-9575-5
Lowell, H. T., & Heymann, H. (2010). Sensory evaluation of food: Principles and practices (2nd ed.). New York, NY: Springer New York.
Levaj, B., Bunić, N., Dragović-Uzelac, V., & Kovačević, D. B. (2010). Gel strength and sensory attributes fig (Ficus carica) jams and preserves as influenced by ripeness. Journal of Food Science, 75(2), S120–S124. doi:10.1111/j.1750-3841.2009.01474.x
Loffer, L., & Loffer, P. (2005). Swaziland tree atlas – Including selected shrubs and climbers. southern Africa Botanical diversity Network; Report No. 38, 202.
Moliehe, T. S., Shandu, J. S., Basson, A. K., Simelane, B. M., Lazarus, G., & Singh, M. (2017). Pharmacodynamic and cytotoxicity effects of Syzygium cordatum (S.Nic, 48 (UZI)) fruit-pulp extract in gastrointestinal tract infections. Tropical Journal of Pharmaceutical Research, 16(6), 1349–1355. doi:10.4314/tjpr.v16i6.13
Moliehe Tsolanku Sidney, M. T., Sibosonga, S. J., & Kotze, B. A. (2015). The antibacterial and antiflavoured activities of the crude methanolic Syzygium cordatum (S.Nic, 48 (UZI)) frui pulp and seed extracts. Journal of Medicinal Plants Research, 9(33), 884–891. doi:10.5897/JMPR2015.5789
Montgomery, D. C. (2001). Design and analysis of experiments (5th ed.). New York, NY: John and Wiley and Sons New York.
Rababah, T. M., Al-u’datt, M., Almajwali, A., Brewer, S., Feng, H., Al-Mahasneh, M., … Yang, W. (2012). Evaluation of the nutraceutical, physicochemical and sensory properties of Raisin Jam. Journal of Food Science, 77(6), C609–C613. doi:10.1111/j.1750-3841.2012.02708.x
Schmidt, S. J., & Fontana, A. J. (1989). Water activity values of select food ingredients and products. In G. V. Barbosa-Canovas, A. J. Fontana, S. J. Schmidt, & T. P. Llabas (Eds.), Water activity in foods - fundamentals and applications (pp. 453). Iowa: Blackwell publishing.
Ščibisz, I., & Mitek, M. (2009). Effect of processing and storage conditions on phenolic compounds and antioxidant capacity of hibush blueberry jams. Polish Journal of Nutrition Sciences, 59, 45–52.
Seeram, N. P. (2006). Berry fruits: Compositional elements, biochemical activities and the impact of their intake on human health, performance and disease. Journal of Agricultural and Food Chemistry, 54(3), 627–629. doi:10.1021/jf0571988x
Smith, W. F. (2000). Experimental design for formulation. ASA VA Alexandria.
Tisekwa, B., & Ndlangamandla, S. B. (1996). Suitability and limitations of some indigenous fruits of Swaziland for manufacturing jams and jellies. UNISWA Journal of Agriculture, 5, 106–115.
Williams, J. T., & Haq, N. (2002). Global research on underutilized crops: An assessment of current activities and proposals for enhanced cooperation (pp. 54). Southampton: ICUC.
