DEVELOPMENT OF KENAF SOYMILK AND ITS PHYSICOCHEMICAL PROPERTIES AND SENSORY EVALUATION ANALYSIS

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Abstract:

This study was carried out to develop a plant-based milk from kenaf seed and soybean. The production of this product involved the process of soaking, grinding, filtration, mixing according to the ratio of formulation , alkalinisation and pasteurisation. The physicochemical properties: (physical analyses: colour analysis, total soluble solids and pH) ,(chemical analysis: proximate analysis) along with sensory analysis were conducted. The combination formulation of kenaf seed milk and soybean milk has complemented the formulated plant-based milk nutritional content by producing a significant result for each response ($p < 0.05$). The sensory analysis found that formulation 5 (kenaf seed milk: soybean milk, 120:80) has received the highest score of overall acceptability by panellists.

Keywords: Kenaf seed milk, Soymilk, Plant-based milk, Physicochemical properties, Sensory evaluation

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1. Introduction

Kenaf belongs to the Malvaceae family and is classified in the genus Hibiscus. This plant thrives under three conditions: temperate and tropical atmosphere, sufficient sunlight and abundant radiation. Therefore, the kenaf plant is easily found in the african and asian regions. The kenaf plant reproduces through its seeds. The appearance of kenaf seeds is described as pointed-oval, slate-black and wedge-shaped. Typically, kenaf seeds are 6 mm long and 4 mm wide (Webber III et al., 2002). Kenaf seeds are shown in **Figure. 1**.

Figure 1. Kenaf Seeds

Kenaf seeds are considered underutilised in agricultural practise and are rarely used for food production. However, several research initiatives have been undertaken by Cheong et al. (2016) and Cheong et al. (2018) to develop nanoemulsions from kenaf seeds. From a food development point of view, the developed product has two shortcomings. First, the developed product is not edible as it is made from the oil of kenaf seeds extracted by chemical extraction. Secondly, the remaining extracted kenaf seeds have been discarded, but the utilisation of the entire kenaf seeds remains unattended.

Soymilk is an oil-in-water emulsion produced by various treatments (soaking, grinding , extraction and heat treatment). Studies on the production of soymilk have been actively conducted since the 1970s (Nelson et al., 1976). In addition, soymilk has been accepted as a common plant-based milk product. Two conditions lead to the acceptance of plant-based milk: the plant sources and the physical appearance of the extract should be similar to animal milk. Soymilk and off-flavour are common problems in the production of soymilk. Taste masking is part of the method to reduce off-flavour as soymilk has been blended with fruit juice and other types of plant milk (Kundu et al., 2018; Terhaag et al., 2013).

To overcome the problem of underutilisation of kenaf seeds and off-flavour in soymilk. Thus, this study was conducted to develop a plant-based milk based on a blend of these two milks. The aim of this study was to evaluate the physicochemical properties of the blend of the two products. Sensory evaluation was also carried out to assess the acceptability of the developed products.

2. Materials and Methods

2.1 Materials

Kenaf seeds Ming Hong MH 8234 were bought from Zhanpu Zhonglong Kenaf seeds Co., Ltd, Fujian China, and soybean seeds were purchased from the local market in Sibu, Sarawak. Both samples were kept under chilled temperature (27 ± 2ºC).

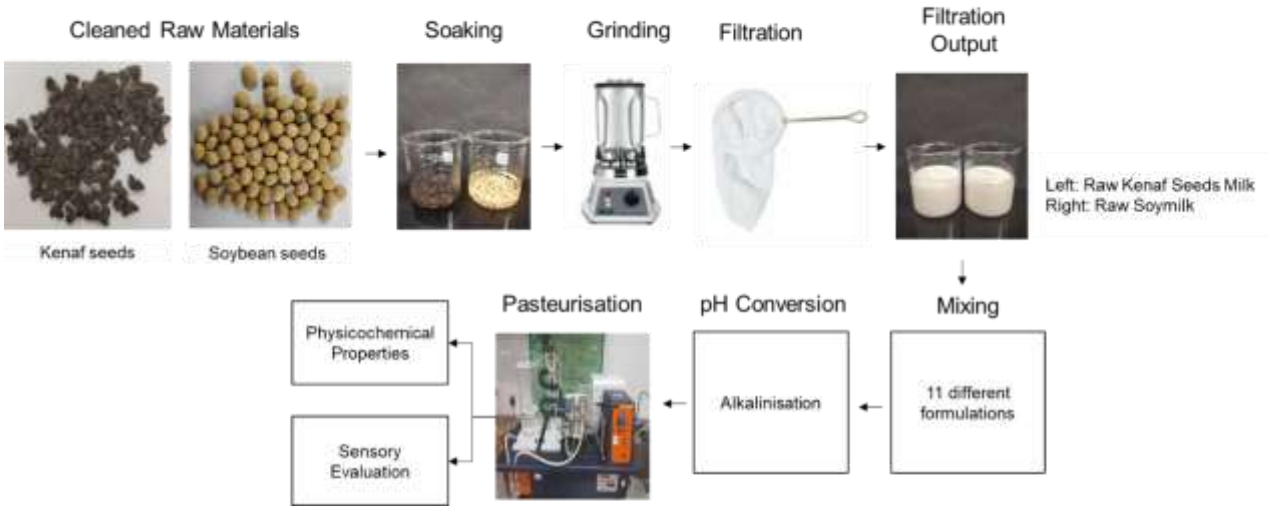

Figure. 2 Kenaf Soymilk Processing Flowchart

2.2 Methods

Figure. 2 shows the graphical image of the kenaf soymilk processing flowchart.

2.2.1 Preparation of Raw Kenaf Seeds and Soymilk

25 g dry kenaf seeds and soybean seeds were weighed separately and washed thoroughly under running water. Both samples were then soaked with filtered water in a ratio of 1:3 (w/v) in a separate container at room temperature (27 ± 2ºC) for 6 hours. Once the designated soaking time was reached, the soaked sample was strained and further ground with a laboratory blender (Waring, USA) at 18,000 rpm at a ratio of 1:6 (w/v). The ground kenaf seeds and soybean slurry were filtered through a double muslin cloth and the crude kenaf seeds and soymilk were obtained.

Preparation of Formulated Kenaf Soymilk

The preparation of each kenaf soymilk formulation was given in the **Table. 1**. Vanilla essence and sucrose were added to the formulations to serve as flavouring agent and sweetener. Each of the samples was kept in the reagent bottle. Before heating, the pH of each formulation was alkalised to 8.0 with 1.0 mol of sodium carbonate. This step was taken to improve the solubility of the emulsion during heat treatment. The formulated sample was pasteurised in the Armfield pasteuriser (PT175, United Kingdom) at 72ºC for 15s and then kept refrigerated at (4 ± 2 ºC) in the chiller and prepared for further analysis.

Table 1. The Formulations of Kenaf Soymilk

Formulation	Ingredients			
	Raw Kenaf Seed Milk (g)	Raw Soymilk (g)	Vanilla Essence(g)	Sucrose (g)
F1	200	0	1.5	10
F2	180	20	1.5	10
F3	160	40	1.5	10
F4	140	60	1.5	10
F5	120	80	1.5	10
F6	100	100	1.5	10
F7	80	120	1.5	10
F8	60	140	1.5	10
F9	40	160	1.5	10
F10	20	180	1.5	10
F11	0	200	1.5	10

Physicochemical Properties

The physicochemical properties are composed of two parts: physical analyses and chemical analyses. The physical analyses were carried out to determine the following: colour analysis, total soluble solids and pH. The colour measurement of each sample was carried out using a calibrated chromameter (Cary 40, Konica Minolta, Japan) and recorded using the CIELAB system. The value of total soluble solids of each sample was measured using a refractometer (Atago, Japan) and the values were recorded in units of °Brix. The pH of each sample was measured using a calibrated pH metre (Sartorius, Germany). Chemical analyses included proximate analysis (crude protein content, crude fat content, ash content and moisture content) and pH and were performed according to (AOAC, 2016). Carbohydrate content was determined by subtracting the total recorded data from the proximate analysis from 100. The pH of each sample was measured using a calibrated pH metre (Sartorius, Germany).

2.4 Sensory Analyses

All the formulations were analysed for beany flavour, colour, appearance, aroma, sweetness and overall acceptance. Sensory analysis was carried out according to the method mentioned by (Isanga & Zhang, 2009).

2.5 Statistical Analysis

Each of the formulation was done in triplicate. Statistical analyses were conducted using SPSS version 23.0. The significance level was set at ($p < 0.05$). The ANOVA and Tukey test were performed for multiple comparisons of means ($p < 0.05$) (Fernández-Ávila et al., 2015).

3. Result and Discussion

Table 2. The Result of Physical Analyses for Each Formulation

Formulations	L	a	b	Brix°	pH
1	55.48 ± 0.29[d]	0.33 ± 0.02[c]	14.60 ± 0.94[a]	9.23 ± 0.71[a]	7.96 ± 0.38[b]
2	53.63 ± 0.29[b]	0.28 ± 0.02[abc]	15.15 ± 0.94[c]	9.17 ± 0.71[a]	7.94 ± 0.38[ab]
3	55.96 ± 0.29[de]	0.29 ± 0.02[bc]	14.55 ± 0.94[a]	9.20 ± 0.71[a]	7.96 ± 0.38[b]
4	51.20 ± 0.29[a]	0.32 ± 0.02[c]	14.80 ± 0.94[ab]	9.20 ± 0.71[a]	7.89 ± 0.38[ab]
5	54.22 ± 0.29[bc]	0.32 ± 0.02[c]	15.52 ± 0.94[de]	9.20 ± 0.71[a]	7.86 ± 0.38[ab]
6	56.57 ± 0.29[f]	0.32 ± 0.02[c]	15.15 ± 0.94[cde]	9.20 ± 0.71[a]	7.91 ± 0.38[ab]
7	55.99 ± 0.29[de]	0.28 ± 0.02[abc]	15.28 ± 0.94[cd]	9.20 ± 0.71[a]	7.82 ± 0.38[a]
8	58.09 ± 0.29[f]	0.25 ± 0.02[ab]	15.68 ± 0.94[ef]	9.23 ± 0.71[a]	7.90 ± 0.38[ab]
9	56.53 ± 0.29[e]	0.25 ± 0.02[ab]	15.93 ± 0.94[f]	9.20 ± 0.71[a]	7.92 ± 0.38[ab]
10	56.57 ± 0.29[e]	0.23 ± 0.02[a]	15.11 ± 0.94[bc]	9.23 ± 0.71[a]	7.91 ± 0.38[ab]
11	55.15 ± 0.29[de]	0.29 ± 0.02[abc]	15.67 ± 0.94[de]	9.20 ± 0.71[a]	7.89 ± 0.38[ab]

Remarks: Results are presented as mean ± standard deviation, Mean values in the same group sharing the same letter are not significantly different ($p < 0.05$).

Table 3. The Result of Chemical Analyses for Each Formulation

Formulations	Crude Protein	Crude Fat	Moisture Content	Ash Content	Carbohydrate Content
1	1.36 ± 0.10[a]	1.55 ± 0.04[d]	91.43 ± 0.08[f]	0.34 ± 0.03[c]	5.33 ± 0.11[ab]
2	1.64 ± 0.10[ab]	1.47 ± 0.04[cd]	91.35 ± 0.08[ef]	0.33 ± 0.03[c]	5.15 ± 0.11[a]
3	1.69 ± 0.10[ab]	1.40 ± 0.04[bc]	91.20 ± 0.08[def]	0.31 ± 0.03[bc]	5.47 ± 0.11[ab]
4	1.71 ± 0.10[ab]	1.39 ± 0.04[abc]	91.17 ± 0.08[def]	0.30 ± 0.03[abc]	5.47 ± 0.11[ab]
5	1.72 ± 0.10[ab]	1.37 ± 0.04[abc]	91.12 ± 0.08[cde]	0.29 ± 0.03[abc]	5.50 ± 0.11[ab]
6	1.86 ± 0.10[bc]	1.37 ± 0.04[abc]	91.07 ± 0.08[bcde]	0.29 ± 0.03[abc]	5.42 ± 0.11[ab]
7	1.97 ± 0.10[bcd]	1.37 ± 0.04[abc]	91.02 ± 0.08[bcd]	0.28 ± 0.03[abc]	5.38 ± 0.11[ab]
8	2.28 ± 0.10[d]	1.36 ± 0.04[abc]	90.99 ± 0.08[bcd]	0.27 ± 0.03[abc]	5.28 ± 0.11[a]
9	2.14 ± 0.10[cd]	1.33 ± 0.04[ab]	90.86 ± 0.08[abc]	0.23 ± 0.03[abc]	5.42 ± 0.11[ab]
10	2.17 ± 0.10[cd]	1.31 ± 0.04[ab]	90.83 ± 0.08[ab]	0.20 ± 0.03[ab]	5.49 ± 0.11[ab]
11	2.19 ± 0.10[cd]	1.26 ± 0.04[a]	90.66 ± 0.08[a]	0.19 ± 0.03[a]	5.69 ± 0.11[b]

Remarks: Results are presented as mean ± standard deviation, Mean values in the same group sharing the same letter are not significantly different ($p < 0.05$)

Table 4. The Result of Sensory Analysis for Each Formulation

Formulation	Beany Flavour	Colour	Appearance	Aroma	Sweetness	Overall Acceptability
1	4.50 ± 2.18[a]	6.57 ± 1.61[a]	6.57 ± 1.76[a]	5.73 ± 2.35[a]	5.30 ± 2.15[a]	5.30 ± 2.07[a]
2	6.03 ± 1.92[ab]	6.90 ± 1.40[a]	7.00 ± 1.23[a]	6.53 ± 1.85[a]	6.40 ± 1.98[a]	6.63 ± 1.88[ab]
3	6.13 ± 1.48[b]	6.90 ± 1.09[a]	6.90 ± 1.18[a]	6.50 ± 1.53[a]	6.47 ± 1.43[a]	6.50 ± 1.46[ab]
4	6.00 ± 2.05[ab]	6.87 ± 1.28[a]	6.87 ± 1.43[a]	6.50 ± 1.68[a]	6.60 ± 1.73[a]	6.57 ± 1.83[ab]
5	6.40 ± 1.54[ab]	6.97 ± 1.22[a]	6.97 ± 1.22[a]	6.77 ± 1.57[a]	6.77 ± 1.43[a]	7.03 ± 1.19[ab]
6	5.33 ± 2.17[b]	6.80 ± 1.24[a]	6.83 ± 1.32[a]	5.87 ± 1.63[a]	5.83 ± 2.04[a]	5.87 ± 2.00[ab]

7	5.63 ± 2.14^{ab}	6.60 ± 1.38^{a}	6.53 ± 1.53^{a}	6.13 ± 1.85^{a}	5.97 ± 1.87^{a}	6.17 ± 1.80^{ab}
8	6.13 ± 1.74^{b}	6.73 ± 1.46^{a}	6.90 ± 1.49^{a}	6.30 ± 1.53^{a}	6.43 ± 1.72^{a}	6.60 ± 1.57^{ab}
9	5.50 ± 1.81^{ab}	6.87 ± 1.33^{a}	6.93 ± 1.36^{a}	5.80 ± 1.47^{a}	5.87 ± 1.91^{a}	5.80 ± 1.65^{ab}
10	6.07 ± 1.70^{ab}	6.90 ± 1.16^{a}	6.90 ± 1.37^{a}	5.93 ± 1.51^{a}	5.77 ± 1.72^{a}	6.17 ± 1.58^{ab}
11	5.80 ± 2.33^{ab}	7.03 ± 1.19^{a}	6.90 ± 1.37^{a}	6.23 ± 1.77^{a}	6.10 ± 2.09^{a}	6.10 ± 1.99^{ab}
Remarks: Results are presented as mean ± standard deviation, Mean values in the same group sharing the same letter are not significantly different ($p < 0.05$).						

3.1 Physical Analyses

3.1.1 Colour Anaysis

In this experiment, the colour of each sample was determined in CIELAB colour space format using a calibrated colorimeter (Konica Minolta, Japan). This method evaluates the quality characteristics of the sample and is used by most researchers in the beverage industry (Mcclements, 2015; Pathare et al., 2013). The CIELAB colour space determines (L, a, b), where L denotes lightness, a denotes reddish to greenish colour and b denotes yellowish to blue colour (Pathare et al., 2013; Roy Choudhury, 2015). The statistical tool ANOVA confirms that the values of L, a & b are significant between formulations ($p < 0.05$). The result presented in this paper shows that the formulations and the colour of the samples are related. Each of the samples has undergone discolouration due to pasteurisation, which is related to the Maillard reaction. The Maillard reaction is generally a browning reaction associated with carbohydrate degradation reactions (Damodaran & L. Parkin, 2019; Pathare et al., 2013). However, the pasteurisation process has improved the nutrient content of soymilk by eliminating nutrient-hostile factors. On the contrary, the Maillard reaction can affect the damage of amino acids of the sample by reducing substances (Kwok & Niranjan, 1995; Ringgenberg, 2011).

3.1.2 Total Soluble Solids and pH

The ANOVA test was applied to assess the significance of the difference between the formulations and the measured values for total soluble solids and pH. Total soluble solids was found to be non-significant ($p > 0.05$) compared to the formulations. On the other hand, pH was found to be significant ($p < 0.05$) towards the formulations. In this experiment, the total soluble solids of each sample related to sugar concentration was measured and recorded using the Brix^{o} unit (Jones, 1995; Magwaza & Opara, 2015). According to (Saidu, 2005), the soymilk's total soluble solids strongly correlate with its protein content. Higher soluble solids content leads to higher crude protein content. However, the data collected between the two readings (total soluble solids and crude protein) were not comparable. The highest value for total soluble solids is slightly lower than the data from (Terhaag et al., 2013) because the additives (gellan, xanthan and soy lecithin) indirectly increased the volume of total soluble solids in the formulation.

During pasteurisation, the proteins of each sample are unfolded and an aggregation process occurs. This natural condition must be prevented as it promotes flocculation and physical instability. Therefore, the pH of all formulations were increased to 8.0 before pasteurisation by using 1.0 mole of sodium carbonate. The sodium carbonate acts as a stabiliser in the formulation and improves the physical stability of the formulation by enhancing electrostatic repulsion. The pH of the processed sample decreased after the heating treatment. This condition was due to hydrogen bonding, ionic and covalent bonds associated with hydrophobic interactions in the emulsion (Gul et al., 2018; Nufer et al., 2009).

3.2 Chemical Analyses

3.2.1 Crude Protein

Table. 3 shows the effects of 11 different formulations on crude protein content. The results show that the crude protein content increased significantly with the intensification of the soymilk. The highest crude protein content measured is 2.19%, while 1.36% is the lowest value. From the observations, it is clear that the high crude protein content is due to soybean. It has been reported that the crude protein content in soybean is about 35.3% - 43.8% (Heunze et al., 2017).

On the other hand, the range of crude protein content in kenaf seeds is 21.4% - 30.5% (Shafa'atu et al., 2020). Statistical analysis revealed that the p-values of these attributes are less than 0.05, indicating that the crude protein response differs significantly among the formulations. Based on the preliminary tests on the pasteurisation process of the six formulations (formulation 1 to formulation 6), phase separation occurred when the pasteurisation temperature reached 60°C. Therefore, all formulations were alkalised to improve their solubility during the pasteurisation process. The separation occurred because the kenaf seed protein did not exhibit sufficient emulsifying properties to stabilise the fat globules by interfacial adsorption (Ab Razak et al., 2022). The same condition was observed by Bernat et al. (2015), as the author found that almond and hazelnut proteins were only weak enough to stabilise the emulsions due to hydrophobic interactions that promote phase separation by flocculation.

3.2.2 Crude Fat

The results on the influence of the different formulations on crude fat content are presented in **Table. 3**. In general, the data collected show a decrease in all 11 formulations. The ANOVA test showed a significant difference between the different formulations as the ($p < 0.05$). It is observed that the crude fat content decreases with increasing amount of raw soymilk. In general, the high crude fat content was dominated by a high proportion of kenaf seed milk. Moreover, the reported crude fat content of kenaf seeds used (27.3%) (Ab Razak et al., 2021) is higher than that of soybean (20% - 25.9%) (Heunze et al., 2017; Teresa Banaszkiewicz, 2018).

3.2.3 Moisture Content

Table. 3 shows the result of moisture content based on 11 different formulations. As shown in **Table. 3**, the moisture content values decrease as the amount of raw soymilk steadily increases. Formulation 1 has the highest moisture content, while formulation 11 records the lowest value. In this experiment, the same amount of water was added to each formulation before the grinding process. The results show that the moisture content of all formulations is more than 90%. Thus, these results are in agreement with the moisture content of groundnut milk (Diarra et al., 2005) and soymilk (Costa, 2013). However, the studies conducted by (Alozie & Yetunde, 2015; Folorunso et al., 2015; Nor Aishah, 2012) on almond and soymilk show lower moisture content compared to the displayed result. (Abagoshu et al., 2017) showed that reducing the moisture content of soymilk improved the nutrient content of soymilk. The observations of the result in **Table. 3** are also in agreement with the findings mentioned there. Reducing the moisture content indirectly improved the nutrient content of crude protein, crude fat and carbohydrates.

3.2.4 Ash Content

The ash content result presented in **Table. 3** shows a clear trend with decreasing amount. Formulation 1 had the highest ash content (0.34 ± 0.03), while formulation 11 had the lowest ash content (0.19 ± 0.03). The groundnut milk (1.84%) and almond milk (6.1%) had higher ash content than the above two results (Manzoor et al., 2019; Yadav et al., 2018). The data collected are significant as the ($p < 0.05$). Determination of ash content in the sample is considered as an assessment of mineral content (Olaleye et al., 2013; Verma & Srivastav, 2017). The extraction method and the ratio of extractant to seed are two variables that affect the extraction of minerals from the seeds (C & Nwakalor, 2009; Maria & Victora, 2018)

3.2.5 Carbohydrates Content

The specific carbohydrate values of the formulations are given in **Table 3**. The result is measured by subtracting all variables (crude protein, crude fat, moisture content and ash content) from 100%. Formulation 2 had the lowest carbohydrate value (5.15%), while formulation 11 had the highest carbohydrate value (5.69%). The p-value of the carbohydrate content among the 11 formulations is 0.0014, and it can be concluded that the data are significant because ($p < 0.05$). When comparing the carbohydrates among the plant-based dairy products, Formulation 11 has the higher value of carbohydrate content than the soymilk of Abagoshu et al, 2017 (5.28%), Ringgenberg, 2011 (2.9%) and Litha, 2007 (1.73%). The nutrient content of the raw material and the processing methods used are factors that influence the nutrient content of the final product. The Illinois process used in the production of soymilk has resulted in a lower carbohydrate content. This is due to the indigestible content of polysaccharides in the material (Abagoshu et al., 2017).

3.3 Sensory Evaluation

The results of the sensory evaluation of 11 kenaf soymilk formulations are presented in **Table. 4**. During the analysis, panellists were asked to rate the six attributes of the sample, such as beany flavour, colour, appearance, aroma, sweetness and overall acceptability. The ANOVA test showed that there was no significant relationship between the recipes and the attributes, as the p-value were greater than 0.05. Regarding the beany flavour attribute, the combination of kenaf seed milk and soymilk is very well accepted compared to the single recipes (formulation 1 and formulation 11). Formulation 5 scored the highest on the attributes of appearance, flavour, sweetness and overall acceptability. Based on the data collected, it can be assumed that most respondents did not tolerate the beany flavour of kenaf seed milk. In addition, formulation 1 contains the highest crude fat content in the recipe, which may trigger the excretion of lipoxygenase that contributes to the beany taste (Damodaran & Parkin, 2017). Formulation 11 had the highest values for colour, which is due to the fact that it has a higher brightness intensity, leading it to mimic milk drinks and be preferred by most discussants (Poliseli Scopel, 2012; Sethi et al., 2016).

4. Conclusion

In this work, the physicochemical properties and sensory attributes of the developed kenaf soymilk were evaluated. The result shows that most of the formulations contributed to the significant responses (physicochemical properties and sensory analysis). Formulation 5 was selected as the most acceptable formulation with the highest rating of beany flavour and overall acceptability in sensory analysis. The results collected indicate that the developed kenaf soymilk has the potential to be an alternative source of plant-based beverages. This research could be further improved by investigating its shelf life through microbiological analysis. Furthermore, the recorded results are also beneficial for the food industry in the production of beverages from kenaf seeds.

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