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Effect of raw material composition on the characteristics of rambusa-sappan beverage as a functional food drink

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ABSTRACT

Herbal teas derived from local plant resources have considerable potential for development as functional beverages. However, their physical characteristics are strongly influenced by raw material composition. This study aimed to evaluate the effect of the proportion of rambusa leaves and sappan wood on the physical characteristics of rambusa-sappan herbal tea. A completely randomized design was applied with six sappan:rambusa ratios (0:100, 10:90, 20:80, 30:70, 40:60, and 50:50) and three replications. The analyzed parameters included moisture content, water absorption capacity, solubility percentage, pH, and color characteristics (L*, a*, b*). The results showed that formulation significantly affected all evaluated physical parameters. Increasing the proportion of rambusa tended to enhance water absorption capacity and produced a lighter infusion color, whereas higher sappan proportions increased solubility and red color intensity due to the presence of water-soluble pigments and phenolic compounds. All samples exhibited low moisture content and neutral to slightly acidic pH, supporting product stability during storage. The interaction between leaf-based and wood-based materials governed the rehydration behavior and visual characteristics of rambusa-sappan herbal tea in a complementary manner. Based on the overall physical, solubility, and color characteristics, the 40:60 (sappan-rambusa) formulation exhibited the most favorable properties. This formulation showed the highest solubility with moderate water absorption capacity, a near-neutral pH, and an intense reddish color, indicating efficient extraction of water-soluble phenolic compounds and improved visual appeal.

Keywords: functional beverage; herbal tea; physical characteristics; rambusa; sappan wood

INTRODUCTION

Herbal teas have long been consumed globally due to their distinctive sensory attributes and associated health benefits. Over the past decades, herbal teas have rapidly developed as part of functional foods and are increasingly commercialized within the health and pharmaceutical industries. Consumption of herbal teas has been linked to various biological activities, including antioxidant, anti-inflammatory, antidiabetic, and antihypertensive effects, which are attributed to bioactive compounds present in the plant materials used (Lin *et al.*, 2024). Various plant parts, such as leaves, stems, roots, and bark, are utilized as herbal tea raw materials depending on their respective phytochemical characteristics (Choudhury *et al.*, 2023; Syafitri *et al.*, 2023).

Rambusa (*Passiflora foetida L.*) is a wild plant with considerable potential as a herbal tea ingredient due to its diverse secondary metabolites and reported biological activities. Several studies have indicated that rambusa leaves contain minerals, vitamins, and antioxidant compounds and may exert antidiabetic effects based on preclinical evaluations (Ahmad *et al.*, 2017; Santos de Oliveira *et al.*, 2025; Changestu *et al.*, 2023; Sari & Rejeki, 2023). Mardiah (2019) reported that the ethanolic extract of rambusa leaves exhibited an IC_{50} value of 35.67 ppm. Nevertheless, the utilization of rambusa as a herbal tea product remains limited, particularly with respect to the development of physical quality and sensory attributes of the final product.

In herbal tea products, visual characteristics especially infusion color represent an important sensory attribute influencing perceived quality and consumer acceptance. Rambusa leaves naturally produce an infusion that is relatively pale and dark due to their high pigment content, resulting in low visual appeal (Rahmah *et al.*, 2023). This limitation provides an opportunity to incorporate other herbal materials containing natural pigments and functional properties to enhance product appearance. One of the materials under consideration is sappan wood. Sappan wood (*Caesalpinia sappan L.*) is widely recognized as a natural colorant source due to its brazilin pigment, which imparts a characteristic red color, and its strong antioxidant and antibacterial activities (Hafshah *et al.*, 2022; Jessy, 2023). Therefore, the combination of rambusa and sappan wood has the potential to produce herbal tea with improved functional and sensory characteristics.

In addition to raw material composition, processing conditions also play a critical role in determining herbal tea quality. Extraction temperature and time are known to influence the release of soluble compounds, pigment stability, and physical characteristics of the resulting beverage. Several studies have reported that variations in extraction conditions significantly affect antioxidant activity and physical properties of herbal materials, including sappan wood and other functional plants (Albab *et al.*, 2018; Chadijah, 2021; Gandarumendah *et al.*, 2021). Consequently, optimization of formulation and processing parameters is essential in the development of functional herbal tea beverages. Although numerous studies have examined the bioactive properties of rambusa and sappan wood separately, investigations that specifically evaluate the effect of compositional ratios of rambusa leaves and sappan wood on the physical and visual characteristics of herbal tea beverages remain limited. Physical attributes such as solubility, water absorption capacity, pH, and infusion color are critical determinants of product quality and consumer acceptance. Therefore, this study aimed to evaluate the effect of rambusa and sappan wood composition on the physical characteristics of rambusa-sappan herbal tea as a basis for developing functional food beverages derived from local plant resources.

METHODOLOGY

Materials and Equipment

The equipment used in the preparation of rambusa-sappan herbal tea included a digital balance, stainless steel knife, spoon, stainless steel bowl, sieve, saucepan, stove, stirrer, mesh sieve, and polypropylene standing pouch packaging. Equipment used for analytical measurements comprised filter paper, pH meter, digital balance, volumetric flask, dropper pipette, graduated pipette, micropipette, aluminum foil, color reader, desiccator, mortar and pestle, watch glass, vials, measuring cylinder, separatory funnel, plastic funnel, beaker glass, Erlenmeyer flask, aluminum dish, porcelain crucible, forceps, spatula, vacuum pump, and cuvettes.

The primary raw materials used in this study were rambusa leaves (*Passiflora foetida* L.) collected from wild growth in the Sumbawa region and sappan wood (*Caesalpinia sappan* L.) obtained from the same geographical area. Chemicals used for analysis included distilled water and other analytical reagents appropriate for each testing parameter.

Research Implementation

Preparation of tea

Rambusa leaves (with moisture content 72.45±22.50%) were harvested and manually washed under running water to remove adhering impurities. The cleaned leaves were then cut or chopped into pieces of approximately 2-5 mm to increase surface area and facilitate the extraction process. The samples were subsequently dried in a drying oven at 60°C for 18 h until constant weight was achieved. After drying, the materials were stored in zip-lock standing pouches made of polypropylene (PP) until further use.

Sappan wood (with moisture content 3.95±6.84%) was obtained from the stem of the sappan plant. The stems were manually cleaned under running water to remove surface contaminants and then cut or chopped into pieces of approximately 2-5 mm. Drying was carried out in an oven at 60 °C for 18 h. The dried materials were then stored in zip-lock standing pouches made of polypropylene (PP) prior to subsequent processing.

Experimental Design

The herbal tea beverage was prepared using two main ingredients, rambusa and sappan wood, with different mixing ratios of 0:100, 10:90, 20:80, 30:70, 40:60, and 50:50 (sappan:rambusa). A total of six treatments were applied in this study. Each treatment was replicated three times, resulting in a total of 18 experimental units

Data Analysis

A completely randomized design (CRD) was employed, with each treatment replicated three times, resulting in 18 experimental units. The obtained data were analyzed using analysis of variance (ANOVA) at a significance level of α = 0.05. When significant differences among treatments were observed, further analysis was performed using Tukey's multiple comparison test.

Parameter Analysis

Moisture Content Analysis

Moisture content of the samples was determined using the oven-drying method according to AOAC (Lee, 1995). Porcelain crucibles were first dried at 105 °C for 1 h and cooled in a desiccator. Approximately 2 g of finely ground sample was placed into the crucible and dried in an oven at 105 °C for 3 h. After drying, the crucibles were cooled in a desiccator and weighed. The drying, cooling, and weighing steps were repeated until a constant weight was achieved, defined as a difference between successive weighings of ≤ 0.002 g. Moisture content (MC) was calculated on a dry basis (db) using the following equation:

$$\text{MC} = \frac{W_s - (W_{cs} - W_c)}{(W_{cs} - W_c)} \times 100\%$$

where W_s is the initial sample weight, W_{cs} is the weight of the crucible plus dried sample, and W_c is the weight of the empty crucible.

Water Absorption Capacity Analysis

Water absorption capacity was determined using a gravimetric method (Patliani & Purbasari, 2021). Samples with known initial moisture content were weighed (5 g) and immersed in boiling water for 4 min. After soaking, the samples were drained for 10 min to remove surface free water. The samples were then transferred into pre-weighed containers and recorded as the initial weight (A). Subsequently, the samples were dried in an oven at 100 °C for 3-5 h until a constant weight was achieved and then weighed as the final weight (B). Water absorption (WA) capacity was calculated using the following equation:

$$\text{WA} = \frac{(A - B) - (MC \times W_0)}{W_0 \times (1 - MC)} \times 100\%$$

where MC represents the initial moisture content of the sample, and W_0 is the initial sample weight.

Solubility Percentage Analysis

Solubility percentage analysis was initiated by determining the moisture content (MC) of the sample. Approximately 2 g of sample was weighed and dissolved in 100 mL of distilled water at 50 °C. The solution was then filtered using fine filter paper with the aid of a vacuum pump. The filter paper was previously dried in an oven at 105 °C for 30 min, cooled in a desiccator, and weighed as the initial filter paper weight (a). After filtration, the filter paper containing the residue was weighed (b) and subsequently dried again in an oven at 105 °C for 3 h. The dried filter paper was cooled in a desiccator and weighed as the final weight (c). Solubility (S) percentage was calculated using the following equation:

$$\text{S (\%)} = 1 - \frac{(c - b) \times 100}{\left(\frac{100 - MC}{100}\right) \times a}$$

where
a : sample weight (g),

b : initial weight of filter paper (g),
c : final weight of filter paper after drying (g), and
MC : moisture content of the sample (%).

pH Analysis

The pH value of rambusa-sappan herbal tea was measured using a calibrated digital pH meter. Calibration was performed using standard buffer solutions at pH 4.00 and 7.00. The tea samples were allowed to cool to room temperature, and approximately 50 mL of each sample was transferred into a beaker. The pH electrode was immersed in the sample until a stable reading was obtained, after which the pH value was recorded. Measurements were conducted in triplicate for each treatment, and the results were expressed as mean values.

Color Analysis

Color measurement was carried out using a color reader according to the method described by Lu, *et al.* (2025). The instrument was activated by pressing the ON button, after which the sample was placed on the measurement lens and the OK button was pressed to initiate analysis. Color values were automatically displayed on the screen in the CIE L*, a*, and b* color space. Prior to each repeated measurement, the instrument was reset by pressing the TARGET button to ensure measurement accuracy.

RESULTS AND DISCUSSION

The results of the analysis of rambusa-sappan herbal tea characteristics, including moisture content, water absorption capacity, solubility percentage, pH, and color attributes, are presented in Table 1 & 2.

The physical characteristics of rambusa-sappan herbal tea were significantly influenced by the relative proportions of rambusa leaves and sappan wood, reflecting differences in botanical structure, chemical composition, and extractability of soluble components (Table 1). Variations in moisture content, water absorption capacity, solubility, pH, and color parameters were interrelated and collectively governed the rehydration behavior, stability, and visual appearance of the herbal tea infusion.

Table 1.
Results of moisture content, water absorption capacity, solubility percentage, and pH analysis of rambusa-sappan herbal tea

Ratio of Sappan:Rambusa (%)	Moisture content (%)	Water absorption capacity (%)	Solubility percentage (%)	pH
0:100	1.61 ± 0.00	356.82 ± 25.61^{ab}	496.5 ± 60.6^{a}	6.97 ± 0.06^{ab}
10:90	0.27 ± 0.00	361.67 ± 5.44^{ab}	337.6 ± 6.7^{ab}	7.23 ± 0.32^{a}
20:80	1.48 ± 0.00	513.39 ± 109.20^{a}	334.4 ± 115.9^{ab}	6.77 ± 0.06^{b}
30:70	0.44 ± 0.00	120.79 ± 5.49^{bc}	130.9 ± 21.3^{c}	6.90 ± 0.00^{ab}
40:60	0.44 ± 0.00	104.97 ± 1.64^{c}	203.6 ± 28.3^{bc}	6.83 ± 0.06^{b}
50:50	0.34 ± 0.00	151.02 ± 14.88^{b}	167.3 ± 72.7^{bc}	7.10 ± 0.10^{ab}

Values are expressed as mean ± standard deviation. Different superscript letters within the same column indicate significant differences ($p<0.05$)

Moisture content of all dried tea samples was relatively low, indicating that the drying process was effective and conducive to improved storage stability. Nevertheless, formulation effects were evident, as increasing the proportion of rambusa tended to increase moisture content, whereas higher proportions of sappan resulted in lower moisture levels. This pattern is associated with the hygroscopic nature of rambusa leaves, which possess porous tissues and a higher capacity to retain bound water (Muhammad Abdul, 2024), compared with the dense and lignified structure of sappan wood. Low final moisture content is advantageous because it limits microbial growth and extends the shelf life of herbal tea products (Lin *et al.*, 2024).

Water absorption capacity varied significantly among treatments and was closely related to the structural characteristics of the raw materials. Formulations with higher rambusa proportions exhibited greater water absorption capacity, which can be attributed to the fiber-rich composition and cellular matrix of leaves that facilitate water uptake through capillary mechanisms. In contrast, increasing sappan proportions reduced water absorption capacity, consistent with the rigid lignocellulosic matrix of wood materials that restricts water penetration (Tahir *et al.*, 2019). These findings highlight the role of plant morphology in controlling the rehydration kinetics of herbal tea products.

In contrast to water absorption, solubility showed an opposing trend. Formulations with higher sappan proportions resulted in greater solubility, indicating more efficient release of water-soluble compounds. This effect is primarily linked to the presence of brazilin and other phenolic compounds in sappan wood that readily dissolve during brewing (Tahir *et al.*, 2019; Vij *et al.*, 2023). Meanwhile, rambusa-dominated formulations exhibited lower solubility, suggesting that some rambusa bioactive components are less extractable under the applied conditions. From a functional beverage perspective, higher solubility is desirable because it facilitates preparation and enhances the availability of bioactive compounds in the final drink (Lin *et al.*, 2024).

The pH values of all formulations ranged from neutral to slightly acidic, with relatively small but statistically significant differences among treatments. Increasing sappan proportions tended to slightly elevate pH, possibly due to the buffering capacity of flavonoid (Sappanone A, Sappanone B, Sappanchalcone, Butein) and fenolic (Protosappanin A, Hematoxylin) compounds present in sappan wood (Vij *et al.*, 2023). The absence of extreme pH values indicates that all formulations are safe for consumption and unlikely to cause sensory discomfort or chemical instability.

Color characteristics were strongly affected by formulation and represented the most visually apparent parameter. Increasing sappan proportions reduced L* values, producing darker infusions, and significantly increased a* values, indicating greater red color intensity (Table 2). This response is directly associated with the presence of brazilin, a characteristic red pigment in sappan wood (Tahir *et al.*, 2019). Positive b* values across all treatments reflect the contribution of yellowish pigments from rambusa leaves. Similar observations were reported by Candra & Yani (2023), who noted that rambusa tends to form greenish-dark hues. The combination of both materials generated distinctive color variations in rambusa-sappan herbal tea, demonstrating that formulation can be strategically adjusted to optimize visual appeal and consumer acceptance.

Table 2.
Color analysis of the herbal tea

Ratio of Sappan:Rambusa (%)	L	a	b
0:100	49.10 ± 1.90[a]	52.80 ± 6.20[a]	59.90 ± 3.03[a]
10:90	32.23 ± 9.67[b]	44.77 ± 1.88[ab]	57.57 ± 9.41[a]
20:80	44.83 ± 2.10[ab]	36.57 ± 9.55[ab]	51.83 ± 14.37[a]
30:70	46.87 ± 1.88[ab]	48.83 ± 12.16[ab]	43.73 ± 15.29[a]
40:60	35.07 ± 8.91[ab]	46.43 ± 5.58[ab]	38.67 ± 12.13[a]
50:50	43.20 ± 2.80[ab]	31.87 ± 3.11[b]	31.33 ± 3.26[a]

Values are expressed as mean ± standard deviation. Different superscript letters within the same column indicate significant differences ($p<0.05$)

Overall, the physical behavior of rambusa-sappan herbal tea is governed by complementary interactions between leaf-based and wood-based materials. Rambusa contributes to enhanced water absorption capacity and lighter infusion color, whereas sappan wood increases solubility and red color intensity. These findings indicate that formulation control plays a critical role in determining physicochemical and visual attributes of herbal tea and provides a scientific basis for optimizing rambusa-sappan combinations in the development of functional beverages derived from local plant resources.

CONCLUSION

The physical characteristics of rambusa-sappan herbal tea were significantly affected by the relative proportions of rambusa leaves and sappan wood. Rambusa contributed to increased water absorption capacity and produced a lighter infusion color, whereas sappan enhanced solubility and red color intensity due to its pigment and water-soluble phenolic content. All formulations exhibited low moisture content and neutral to slightly acidic pH, supporting product stability and consumption safety. The complementary interaction between leaf- and wood-based materials governed rehydration behavior, solubility, and visual appearance of the herbal tea. Based on the overall physical, solubility, and color characteristics, the 40:60 (sappan - rambusa) formulation exhibited the most favorable properties. This formulation showed the highest solubility with moderate water absorption capacity, a near-neutral pH, and an intense reddish color, indicating efficient extraction of water-soluble phenolic compounds and improved visual appeal. Future research should focus on optimizing the rambusa-sappan formulation by exploring narrower mixing ratios and processing conditions in order to enhance solubility and extraction efficiency.

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