Characterization of Morphological, Physical and Functional Attributes of Agathi Leaves and Flowers

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ABSTRACT

The study aimed to characterize the morphological, physical, and functional properties of agathi (*Sesbania grandiflora*) leaf and flower powders, highlighting their potential for food applications. Morphological assessments revealed that agathi leaves have an edible index of 76.20 ± 0.42 % and a waste index of 23.75 ± 0.65 %, while flowers showed an edible index of 63.79 ± 0.46% and a waste index of 36.21 ± 0.54 %. Physical properties showed that leaf powder had a higher bulk density (0.36 ± 0.02 g/cm³) and tapped density (0.59 ± 0.02 g/cm³) compared to flower powder (0.29 ± 0.03 g/cm³ and 0.48 ± 0.01 g/cm³, respectively). The flowability (Carr index) was slightly better for flower powder (40.24 ± 0.01 %) than for leaf powder (39.2 ± 0.01 %). Functional properties indicated that flower powder had significantly higher water absorption capacity (597.28 ± 1.22 %) and oil absorption capacity (224.21 ± 1.56%) compared to leaf powder (315.30 ± 1.28 % and 183.16 ± 1.34 %, respectively). Flower powder also exhibited greater solubility (28.77 ± 2.66 %) versus leaf powder (12.92 ± 1.59 %). These results suggest that both agathi powders are valuable ingredients for food formulations, providing functional and nutritional benefits, and are suitable for use in developing, handling, and packaging functional food products.

Keywords: *Sesbania grandiflora*, agathi, morphological, physical, functional

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INTRODUCTION

Sesbania grandiflora, commonly known as agathi or the vegetable hummingbird tree, is a fast-growing, medium-sized tree from the Fabaceae family, reaching 10-15 meters in height with a trunk diameter of up to 30 cm (Kashyap and Mishra, 2012). Native to South and Southeast Asia, it is widely cultivated in countries like India, Malaysia, Indonesia, and the

Philippines (Mohiuddin, 2019). The tree has light grey, deeply furrowed bark, soft white wood, and shallow roots with nitrogen-fixing bacteria. Often used as an ornamental tree for light shade, it also supports betel leaf plantations and boosts cow milk production when its leaves are used as feed (Kavitha *et al*., 2012). The leaves, seeds, pods, and flowers are all edible and versatile in culinary and medicinal applications. Leaves are pinnately compound, growing up to 30 cm long, and bear 20-50 oblong leaflets that turn yellow and shed between August and October (Orwa *et al*., 2009). The flowers, resembling those of pea plants, appear in clusters of 2-5 and come in white, pink, yellowish, or red, with two main varieties: *grandiflora* (white) and *coccinea* (red), blooming between November and December (Duke, 1983).

The edible parts of *Sesbania grandiflora* are used in various cuisines; young leaves are chopped and steamed or fried, while tender pods are prepared like string beans. The leaves have a bitter, tart flavour often balanced with coconut milk or garlic. The flowers, mild in bitterness, are commonly steamed or pressure-cooked to reduce fibrous texture, with white flowers being preferred over red. In the Philippines, white flowers are steamed or added to soups, while in Thailand, they are eaten raw in salads (Karmakar *et al*., 2016). The tree is valued for its strong antioxidant properties due to its high content of flavonoids, phenolic compounds, and other bioactive constituents, which help scavenge free radicals, thereby reducing the risk of chronic diseases such as cancer, cardiovascular diseases, and neurodegenerative disorders (Zarena *et al*., 2014).

MATERIAL AND METHODS

The present research was carried out in the Department of Food Science and Nutrition, University of Agricultural Sciences, GKVK, Bangalore, India. The study was conducted during the academic year 2023-2024. Agathi (*Sesbania grandiflora*) flowers were collected from the horticulture garden, UAS, GKVK, Bangalore. Petals were separated from the flowers and washed. Additional raw materials needed for the product were procured from local vendors of Bangalore, India. The leaves and flowers were cleaned, tray dried at 50 ºC, subsequently ground into a fine powder using a mixer grinder and sieved through a 75 µm mesh sieve. The resulting powders were stored in airtight containers at refrigerated temperature (4 ºC) for future analysis.

Morphological, Physical and Functional Attributes

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The following characterization methods were used in this study: Different morphological parameters like length, width, weight, per cent edible index and waste index were studied (Bhokre *et al*., 2022). Physical parameters such as Bulk density and tapped density (Tahmaz *et al*., 2020), Flowability and Cohesiveness (Jinapong *et al*., 2008) and rehydration ratio (Sheshma and Raj, 2014). Functional parameters including Water absorption capacity and Oil absorption capacity (Onwuka, 2005), Emulsifying activity and stability (Yasumatsu *et al*., 1972), Foaming capacity and stability (Onwuka, 2005), Solubility (Subramanian *et al*., 1986), pH (Mashau *et al*., 2020) and Water activity (Abbey *et al*., 2017).

Statistical analysis

All the results were presented as mean ± standard deviation (SD). Independent samples t-tests were used for two-group comparisons. Statistical analyses were performed using SPSS 20.0 (IBM, USA).

RESULTS AND DISCUSSION

Morphological parameters of fresh agathi leaves

The leaves of the agathi plant are arranged in a pinnate pattern, consisting of small, smooth leaflets that are elongated and oval-shaped. They are usually dark green on top and lighter underneath because of the way chlorophyll is distributed. These leaflets are moderately thin and flexible (Duke, 2012).

The morphological parameters of fresh agathi leaves were evaluated and summarised in Table 1. The assessment of these parameters is essential for understanding the physical characteristics of the agathi leaves. The average length of the compound leaves was 24.23 ± 3.63 cm, indicating variability in the sizes of the collected leaves. The number of leaflets per compound leaf was 31.8 ± 3.87, indicating that agathi leaves have a considerable number of leaflets, which may contribute to the overall surface area available for photosynthesis and nutrient accumulation (Nobel, 1977). The length and width of individual leaflets was 3.14 ± 1.14 cm and 0.95 ± 0.28 cm respectively.

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Additionally, the weight of the compound leaf was 2.44 ± 0.50 g, provides an estimate of the biomass that can be harvested for further processing and use in food products (Gardner *et al.,* 2017). The evaluation of the weight of the leaflet after separating from the rachis and

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the weight of the removed rachis (waste) is important for understanding the yield of usable leaf material. The average weight of leaflets was 1.85 ± 0.38 g, while the average weight of the removed rachis was 0.58 ± 0.11 g. The edible index, recorded at 76.20 ± 0.42 %, indicated that a significant portion of the leaf was suitable for consumption, underscoring its potential for food applications. The waste index, at an average of 23.75 ± 0.65 %, highlighted the importance of minimizing waste to enhance the efficiency of raw material use during processing. Additionally, the leaflets exhibited a dark green upper surface and a lighter green underside, with a smooth texture.

Table 1. Morphological parameters of fresh agathi leaves

Morphological parameters	**Mean ± SD**
Length of Compound leaf (cm)	24.23 ± 3.63
No. of leaflets in each compound leaf	31.8 ± 3.87
Length of the leaflet (cm)	3.14 ± 1.14
Width of the leaflet (cm)	0.95 ± 0.28
Weight of the compound leaf (g)	2.44 ± 0.50
Weight of leaflet after separating from the rachis (g)	1.85 ± 0.38
Weight of the removed rachis (Waste) (g)	0.58 ± 0.11
Edible index (%)	76.20 ± 0.42
Waste index (%)	23.75 ± 0.65
Colour of leaflet	Dark green on the upper surface and lighter green on the underside
Texture of leaflet	Smooth

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Morphological parameters of fresh agathi flowers

The flowers of agathi are large, pendulous, and typically white or red. They have a distinct, elongated, and claw-like shape, which is characteristic of the Fabaceae family. The floral structure includes a prominent standard petal, two wing petals, and a keel composed of two fused petals that enclose the reproductive organs. This unique morphology helps in pollination by attracting specific pollinators (Duke, 2012).

The morphological parameters of fresh agathi flowers were outlined in the Table 2. The average length of the flower was 7.94 ± 0.61 cm, and the average width before opening of the flower was 3.5 ± 0.59 cm. These dimensions suggested that agathi flowers were relatively large, which was characteristic of the species. The mean weight of the flowers was 7 ± 0.76 g, and the mean weight of the petals was 4.46 ± 0.48 g, provided a clear indication of the substantial floral mass that was available for use.

Table 2. Morphological parameters of fresh agathi flowers

Morphological parameters	**Mean ± SD**
Length of the flower (cm)	7.94 ± 0.61
Width of the flower before opening (cm)	3.5 ± 0.59
Weight of the flower (g)	7 ± 0.76
Weight of the petals (g)	4.46 ± 0.48
Weight of the removed calyx, pistil and stamen (Waste) (g)	2.51 ± 0.27
Edible index (%)	63.79 ± 0.46
Waste index (%)	36.21 ± 0.54
No. of petals	5 petals
Colour of the flower	White
Texture of the flower	Smooth and slightly glossy

The weight of the removed calyx, pistil, and stamen, considered as waste, was recorded with a mean of 2.51 ± 0.27 g, contributing to a waste index of 36.21 ± 0.54 %. This indicated that a considerable portion of the flower was usable (edible index of 63.79 ± 0.46 %), which was suitable for food applications. The colour of the flowers was white, and their texture was smooth and slightly glossy. These sensory attributes were important for consumer acceptance and development of food products.

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Similar results were obtained regarding the morphological characteristics of agathi flowers and leaves (Bhokre *et al.*, 2022). Results revealed that the edible index of flowers was 64.62 %, while leaves boasted a higher value of 77.08 %. Conversely, the waste index for flowers was 35.97 %, while leaves had a lower waste index of 22.91 %. These results showed that leaves had a higher edible index and a lower waste index compared to the flowers, which may influence the final yield of the powder.

Physical properties of dried agathi leaf and flower powders

The physical parameters of agathi leaf and flower powders presents in Table 3 revealed significant differences between the two powders in terms of bulk density, tapped density, flowability, cohesiveness, and rehydration ratio.

In terms of bulk density, the leaf powder had a significantly higher value (0.36 ± 0.02 g/cm³) compared to the flower powder (0.29 ± 0.03 g/cm³) ($p \leq 0.05$). This suggests that agathi leaf powder has a denser and more compact structure, possibly due to differences in the structural integrity of leaves and flowers (Rahman and Perera, 2007). The tapped density followed a similar trend, with leaf powder exhibiting a higher tapped density (0.59 ± 0.02 g/cm³) than the flower powder (0.48 ± 0.01 g/cm³). In a related study, Umme Seema *et al*. (2022) developed polyherbal formulations using a combination of fruits, vegetables, medicinal herbs and spices. The bulk density and tapped density of these formulations ranged from 0.50 - 0.56 g/cm3 and 0.60 – 0.67 g/cm3, respectively. These were slightly higher than the values observed for agathi leaves and flowers in this study.

The Carr index revealed that flowability was marginally better in the flower powder (40.24 ± 0.01 %) compared to the leaf powder (39.2 ± 0.01 %). However, both powders fall within the range associated with poor flowability, indicating a tendency to stick together and flow poorly. This could be due to their fine particle size and high cohesiveness (Fitzpatrick *et al.*, 2004). The cohesiveness measured by the Hausner ratio was slightly higher for the flower powder (1.68 ± 0.02) compared to the leaf powder (1.62 ± 0.01), though this difference was not statistically significant. This suggests that both powders had similar tendencies to form agglomerates, which could affect their handling and processing properties (Fitzpatrick and Ahrne, 2005). Similarly, Dadi *et al.* (2019) analysed the Carr index (%) and Hausner ratio of spray dried *Moringa stenopetala* leaves powder. The study found that Hausner's ratio and

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Carr's index were in the range of 1.68 – 2.11, 40.47 – 43.73 per cent respectively which were slightly similar and higher than the values observed in the present study.

The agathi flower powder exhibited a significantly higher rehydration ratio (9.67 ± 0.08) compared to the agathi leaf powder (4.75 ± 0.06), with a statistically significant difference ($p \leq 0.01$) observed between the samples. This difference could be attributed to the higher porosity and lower bulk density of the flower powder, which facilitated more water absorption upon rehydration (Krokida and Philippopoulos, 2005). Consistent with these findings, Bishnoi *et al.* (2020) reported a rehydration ratio of 4.49 ± 0.04 for fenugreek leaves tray dried at 40 °C, that aligns closely with the rehydration ratio observed for agathi leaves in this study.

Table 3. Physical parameters of agathi leaf and flower powders

Samples	**Agathi leaf**	**Agathi flower**	**t- value**
Bulk density (g/cm^3)	0.36 ± 0.02	0.29 ± 0.03	3.19*
Tapped density (g/cm^3)	0.59 ± 0.02	0.48 ± 0.01	5.31**
Flowability [Carr index (%)]	39.2 ± 0.01	40.24 ± 0.01	3.87**
Cohesiveness (Hausner ratio)	1.62 ± 0.01	1.68 ± 0.02	0.89^{NS}
Rehydration ratio	4.75 ± 0.06	9.67 ± 0.08	78.20**

Note: Values are expressed as mean ± standard deviation of three determinations. * Significant at ($p \leq 0.05$), **Significant at ($p \leq 0.01$), NS: Non-significant.

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Functional parameters of agathi leaf and flower powders

The functional parameters of agathi leaf and flower powders presents in Table 4. showed significant differences between the two powders in terms of water absorption capacity, oil absorption capacity, emulsifying capacity, emulsifying capacity, emulsifying stability, foaming capacity, foaming stability, water activity, pH and solubility.

Agathi flower powder exhibited a significantly higher water absorption capacity (WAC) of 597.28 ± 1.22 per cent compared to agathi leaf powder, which had a WAC of 315.30 ± 1.28 per cent. The higher WAC in flower powder might be attributed to its hydrophilic nature, greater porosity and surface area, allowing more water to be absorbed (Adebowale and Lawal, 2003). Similarly, the oil absorption capacity (OAC) was higher in flower powder (224.21 ± 1.56 %) than in leaf powder (183.16 ± 1.34 %), suggesting that the flower powder has a greater affinity for oil and flower's cellular structure facilitates oil entrapment (Chau and Cheung, 1998).

In support of these findings, Sultana (2020) reported water absorption capacities for dried *Moringa oleifera* leaves in the range of 158.00-415.00 per cent. The WAC values for agathi leaf powder in the present study fall within this range, while agathi flower powder exhibited a notably higher WAC, further emphasizing its superior water absorption capabilities. Bhokre *et al.* (2022) had measured the oil absorption capacities for agathi leaf and flower powders after applying different pre-treatments. Their findings, which ranged from 100-190 per cent for leaf powders and 130-200 per cent for flower powders, were consistent with the results of this study. These findings confirmed that agathi flower powder generally exhibited a higher oil absorption capacity compared to leaf powder.

In terms of emulsifying capacity, flower powder showed a higher value (59.16 ± 0.74 %) than leaf powder (53.83 ± 0.62 %), indicating its better capability to stabilize oil-water mixtures, likely due to the presence of protein and polysaccharides in the flower powder, which serve as natural emulsifiers (Naji-Tabasi and Razavi, 2017). Furthermore, agathi flower powder exhibited greater emulsifying stability (57.11 ± 0.46 %) than leaf powder (49.8 ± 0.53 %), implicating prolonged stability of emulsions, which is crucial for food formulations. Similarly, Siddiq *et al.* (2009) evaluated emulsifying capacity and stability of wheat flour blends with defatted maize germ flour (DMGF). They reported that emulsifying capacities ranged from 50-63 per cent and emulsifying stability ranged from 47-58 per cent. The emulsifying capacity and stability observed for agathi leaf and flower powders in this study fell within these reported ranges, indicating that the findings of this study were consistent with those observed for wheat flour blends with DMGF.

Agathi flower powder demonstrated significantly higher foaming capacity (30.26 ± 0.46 %) and stability (92.94 ± 0.87 %) compared to leaf powder (20.93 ± 0.84 % and 90.85 ± 0.79 %, respectively). This superior foaming performance might be attributed to the presence of proteins in flower powder, which can enhance foam formation and stability (Kinsella, 1981). In support of these findings, Hameed and Priya (2022) analysed the foaming capacity of agathi leaf powder treated with different treatments. The findings ranged from 20.06 to 38.92 %, were consistent with the lower foaming capacity observed for agathi leaf powder in the current study. This further highlighted the superior foaming properties of agathi flower powder.

Table 4. Functional parameters of agathi leaf and flower powders

Samples	**Agathi leaf**	**Agathi flower**	**t- value**
WAC (%)	315.30 ± 1.28	597.28 ± 1.22	274.61**
OAC (%)	183.16 ± 1.34	224.2 ± 1.56	23.54**
Emulsifying capacity (%)	53.83 ± 0.62	59.16 ± 0.74	7.15**
Emulsifying stability (%)	49.8 ± 0.53	57.11 ± 0.46	16.05**
Foaming capacity (%)	20.93 ± 0.84	30.26 ± 0.83	12.37**
Foaming stability (%)	90.85 ± 0.79	92.94 ± 0.87	3.25*
Water activity (aw)	0.21 ± 0.01	0.34 ± 0.02	7.84**
pH	6.04±0.03	5.54±0.04	16.97**
Solubility (%)	12.92 ± 1.59	28.77 ± 2.66	8.84**

Note: WAC- Water Absorption Capacity; OAC- Oil Absorption Capacity; Values are expressed as mean ± standard deviation of three determinations; **Significant at ($p \leq 0.01$), * Significant at ($p \leq 0.05$).

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The water activity (aw) in agathi flower powder (0.34 ± 0.02) was higher than in leaf powder (0.21 ± 0.01), indicating that the flower powder had a greater moisture content, which could affect its shelf life and microbial stability (Rahman, 2020). Generally, the water activity for most dried food powders falls between 0.20 and 0.50 to inhibit microbial growth and maintain stability (Fontana, 2000). In a study by Avila-Gaxiola *et al.* (2017), the water activity of Agave tequilana leaves powder was observed to be 0.38, which was slightly higher than the values found in the present study.

The agathi leaf powder had a higher pH (6.04 ± 0.03), which could potentially influence its taste and microbial growth, whereas the flower powder exhibited a slightly acidic pH (5.54 ± 0.04), which might offer better microbial stability (Gyawali and Ibrahim, 2014). Similarly, Hameed and Priya (2022) analysed the pH of agathi leaf powder treated with different treatments and found values ranging from 5.89 to 6.25. These results are consistent with the pH of agathi leaf powder in the present study, although slightly higher than the pH of agathi flower powder.

Lastly, solubility was significantly greater in flower powder (28.77 ± 2.66 %) than leaf powder (12.92 ± 1.59 %), indicating that the flower powder's components had better solubility, which is beneficial for quick dispersion in liquid formulations. This could be due to the flower's composition, which is rich in soluble fibres and polysaccharides (Sivam *et al*., 2011). Bhokre *et al.* (2022) measured the solubility of agathi leaf and flower powders treated with different pre-treatments and found solubility values ranging from 15-20 % for leaf powder and 18-25 % for flower powder, align with the present study's results. However, the solubility values reported by Bhokre *et al.* (2022) were slightly varied, possibly due to the different pretreatments used in their study.

CONCLUSION

The study comprehensively evaluated the morphological, physical, and functional attributes of *Sesbania grandiflora* (agathi) leaves and flowers, demonstrating their significant potential in food applications. The characterization of various physical properties of agathi leaf and flower powders provide insights into their performance in food product development, handling, and packaging. The results revealed that both powders possess valuable characteristics, such as high water and oil absorption capacities, emulsifying properties, and antioxidant activity, making them suitable for use in functional foods. Differences in physical properties like bulk density, cohesiveness, and rehydration ratio between the powders highlight the distinct applications each may have in food formulations.

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Overall, agathi leaves and flowers present promising opportunities for enhancing the nutritional and functional qualities of food products.

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