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Moringa oleifera Leaf-Based Herbal Tea: Antioxidant Potential, Processing Techniques, Formulation, and Quality Evaluation – A Review

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Abstract: *Moringa oleifera is a nutrient-rich plant whose leaves contain phenolics, flavonoids and other bioactive compounds linked to antioxidant activity. Moringa leaf is increasingly used in herbal teas and functional beverages. This review summarises evidence on the antioxidant properties of moringa herbal tea. Dried moringa leaf powder is about one quarter protein by dry weight and shows strong antioxidant activity in FRAP and ORAC assays. In brewed tea, moringa–orange peel blends gave 129.08–150.42 mg gallic acid equivalents per litre of polyphenols, although a green tea sample exceeded every blend. Because pure moringa tea is often poorly accepted for its bitterness, blending with orange peel, herbs, spices, rosella, pandan or jaggery improves taste, colour and aroma while keeping antioxidant activity similar or higher. Brewing conditions matter: in one optimisation study, a 1:20 leaf-to-water ratio, 97°C water and 35 minutes gave the highest phenolic recovery. Packaging and moisture strongly affect shelf life: HDPE packaging kept a blended tea stable for six months, whereas LDPE bags allowed spoilage by day 90. Moringa blends are a decent antioxidant source, but not a substitute for green tea.*

Keywords: Moringa oleifera, Herbal Tea, Antioxidant Activity, Polyphenols, Blending, Shelf Life

Abbreviations: ABTS, 2,2′-Azino-bis(3-ethylbenzothiazoline-6-sulfonic acid); DAD, Diode array detector; DPPH, 2,2-Diphenyl-1-picrylhydrazyl; FRAP, Ferric reducing antioxidant power; GAE, Gallic acid equivalents; HDPE, High-density polyethylene; HIV, Human immunodeficiency virus; HPLC, High-performance liquid chromatography; IC50, Half-maximal inhibitory concentration; LDPE, Low-density polyethylene; ORAC, Oxygen radical absorbance capacity; QE, Quercetin equivalents; SNI, Standar Nasional Indonesia (Indonesian National Standard); TFC, Total flavonoid content; TPC, Total phenolic content.

I. INTRODUCTION

Moringa oleifera, known as the "Miracle Tree," is a medicinal and nutrient-rich plant with several potential health benefits. It contains proteins, essential amino acids, and bioactive compounds such as flavonoids, terpenoids, tannins, and anthocyanins. These constituents contribute to its reported antioxidant, anti-inflammatory, antimicrobial, blood glucose-lowering, and cardiovascular-protective activities [2, 3, 4].

The leaves, flowers, and pods of Moringa oleifera are rich in essential nutrients such as protein, calcium, magnesium, phosphorus, iron, and vitamins A, C, and E, contributing to its nutritional value [18].

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Tea is a popular beverage consumed for both its flavour and potential health benefits. Moringa-based herbal tea has gained interest due to the presence of phenolic compounds and antioxidants, which may contribute to its beneficial effects on health [7].

Moringa oleifera, a member of the family Moringaceae, is recognized for its nutritional and medicinal significance. The plant is commonly grown in tropical and subtropical areas, where it has long been utilized as a dietary source as well as in traditional herbal practices. Its leaves are rich in diverse bioactive and nutritional constituents, including phenolics, flavonoids, tannins, alkaloids, saponins, terpenoids, proteins, vitamins, and essential minerals. These components are responsible for many of the plant's nutritional and biological properties [2, 11].

Herbal tea made from M. oleifera leaves is increasingly being explored as a functional beverage due to its rich phytochemical composition and potential antioxidant properties. Moringa-based tea contains several bioactive compounds, particularly polyphenols and flavonoids, which may contribute to its ability to neutralize free radicals. Research has further shown that aqueous extracts of moringa tea exhibit antioxidant activity when evaluated using different experimental methods [10, 11].

Moringa oleifera is increasingly being incorporated into various herbal and functional food products, including herbal teas, health beverages, and other plant-based preparations. Researchers have also examined the use of moringa leaves alongside other botanical ingredients to enhance antioxidant activity, nutritional characteristics, taste, and overall consumer acceptance. Recent investigations, for instance, have focused on tea formulations containing moringa in combination with citrus peel, ginger, and Javanese turmeric [7, 10].

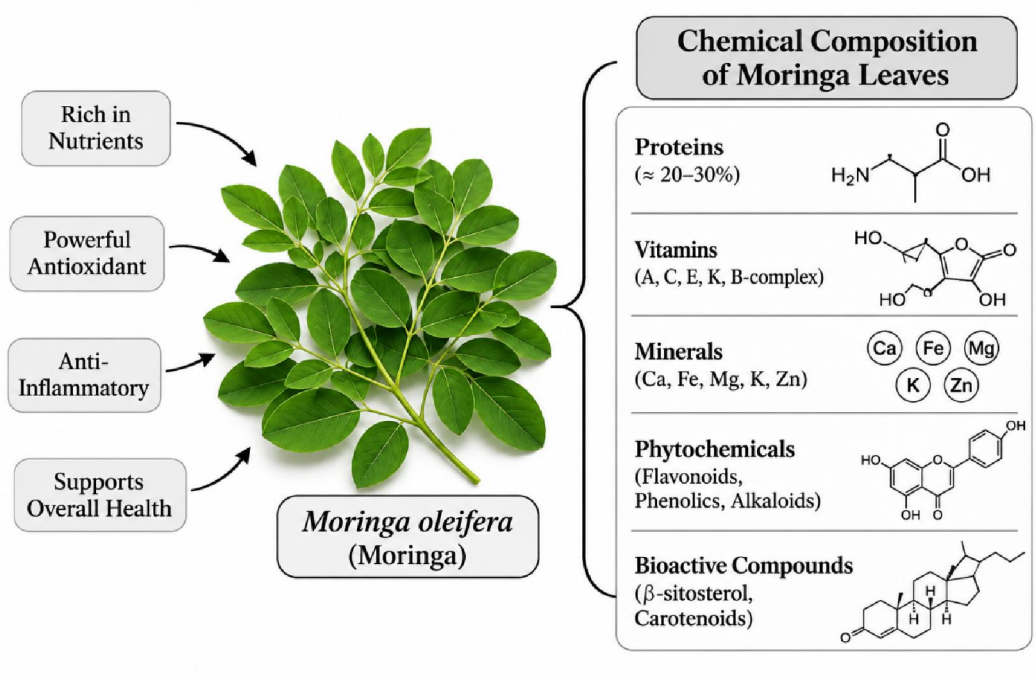
Investigating the antioxidant properties of Moringa oleifera herbal tea has significant relevance in the pharmaceutical field, as it integrates areas such as pharmacognosy, phytochemical investigation, pharmaceutical analysis, and herbal medicine research. Determining the levels of phenolic and flavonoid compounds, along with assessing antioxidant capacity, can provide valuable information about the quality and potential benefits of plant-derived preparations. Analytical techniques such as the Folin–Ciocalteu method for estimating total phenolic content and the DPPH assay for measuring antioxidant activity are commonly applied for the evaluation of herbal products [2].

II. ANTIOXIDANT COMPOSITION OF MORINGA LEAF AND TEA

Moringa oleifera leaves are attracting attention as a food ingredient with health potential, and recent lab work shows why. Researchers in Spain analyzed commercially supplied dried moringa leaf powder and found that protein makes up roughly a quarter of its dry weight [15]. Its phenolic content measured 32.90 mg gallic acid equivalents per gram. In antioxidant tests it scored 396.43 µmol Trolox equivalents per gram on the FRAP assay and 3,197.24 µmol per gram on the ORAC assay [15].

Dried moringa leaves grown in Greece contained 4,512 mg gallic acid equivalents (GAE) per 100 g of dry matter in total phenols [14]. A tea brewed from these leaves contained 736.9 mg GAE per litre of phenols and flavonols, including myricetin (203.7 mg/L), quercetin (17.4 mg/L) and kaempferol (10.6 mg/L), and it showed antioxidant activity, with a protection factor of 4.2 in a lipid oxidation test [14].

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Solvent extracts show a similar picture. A Thai methanol extract of the leaves contained 216.45 mg GAE/g of phenols and 65.38 mg quercetin equivalents/g of flavonoids, and it scavenged DPPH and ABTS radicals with IC50 values of 1.60 and 1.02 mg/mL [5]. HPLC analysis of another leaf extract identified quercetin as the predominant compound [4]. Because these are extract values, they describe the leaf rather than a cup of tea.

Moringa has also been tested as an actual tea. Scientists in Côte d'Ivoire combined dried orange peel with moringa in eleven proportions, then steeped 2 g of each blend in 100 mL of boiling water for five minutes [10]. Polyphenol levels in the brews ranged from 129.08 to 150.42 mg gallic acid equivalents per liter. The mix of 77.89% peel and 22.11% moringa came out on top for polyphenols and for overall antioxidant index. A 70/30 peel-to-moringa blend had the most flavonoids, at 76.80 mg quercetin equivalents per liter [10].

Even so, a pure green tea (Camellia sinensis) sample beat every blend, reaching 592.28 mg of polyphenols per liter. The moringa blends are therefore a decent antioxidant source, not a substitute for green tea [10].

III. BREWING CONDITIONS

How the tea is brewed strongly affects what reaches the cup. A response surface study extracted dried moringa leaf powder in water while varying the solid-to-liquid ratio, temperature (50–100°C) and time (3–37 minutes) across 17 experimental runs [16]. Ratio and temperature had the strongest effects on polyphenol and flavonoid recovery, time contributed less, and tannin extraction changed only slightly [16].

Polyphenol yield rose with leaf quantity up to a ratio of about 1:20 and then levelled off, while flavonoids increased with temperature up to roughly 85°C before stabilising. Very hot, prolonged extraction may oxidise polyphenols and lower yield [16].

The same optimum applied to polyphenols, flavonoids and tannins: a 1:20 ratio, 97°C and 35 minutes. Tea made this way contained 56.96 mg GAE of polyphenols, 34.66 mg of flavonoids (catechin equivalents) and 3.53 mg of tannins per 100 mL. It inhibited about 81% of DPPH radicals, slightly above the vitamin C reference (about 77%), and had a reducing power of 1.75 g ascorbic acid equivalents per 100 g dry matter [16]. The authors note that further investigation is needed to determine the actual functionality of the tea [16].

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Extraction methods

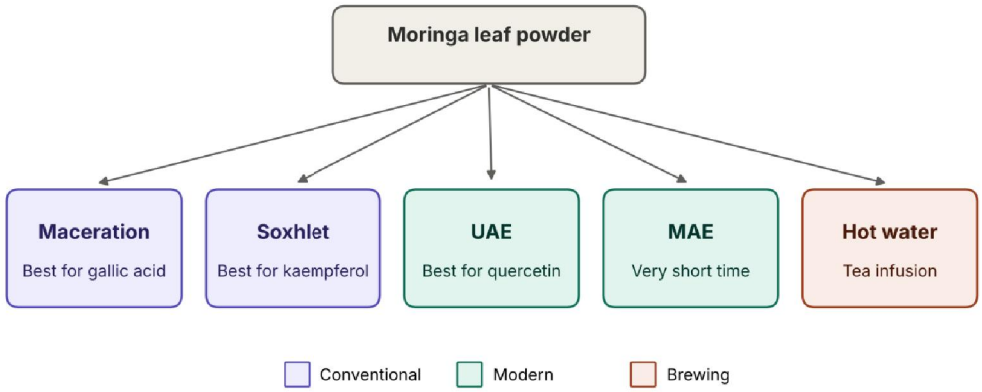


Figure. Extraction routes for Moringa oleifera leaves and the compound each recovers best.

Figure : Extraction routes for Moringa leaves and the compound each one recovers best. Based on Fitri et al. [21], Tariq et al. [20], and Rahmawati et al. [2].

How a moringa leaf is extracted how much of its antioxidant content ends up in the final product. The three methods most often compared are maceration, Soxhlet extraction, and ultrasound-assisted extraction (UAE) [21]. A systematic review of 34 studies found that UAE gave the highest extract yield, total phenolic content, and total flavonoid content, followed by maceration, with Soxhlet last [21]. The gains come from lower operating temperatures and shorter run times, which protect heat-sensitive phenolics such as gallic acid, quercetin, and kaempferol from degrading [21].

The best method also depends on the compound you want. Maceration recovered the most gallic acid, Soxhlet the most kaempferol, and UAE the most quercetin [21]. Solvent choice mattered too. Higher ethanol concentrations raised yields in maceration and UAE, but UAE reached its highest flavonoid content at relatively low ethanol levels [21].

Other reviews describe microwave-assisted extraction (MAE) and supercritical fluid extraction as greener alternatives. They cut time, energy, and solvent use. In one comparison, 5 minutes of MAE matched 60 minutes of UAE and 24 hours of conventional extraction [20]. The same review concludes that no single technique suits every plant, and that conditions must be tuned for each one [20].

For herbal tea, the relevant "extraction" is hot-water infusion. In one study, a 15-minute infusion of fresh leaves at 90 °C had a higher total phenolic content (20.44 mg GAE/g) than a 5-minute tea infusion of dried leaves at 70 °C (7.27 mg GAE/g) [2]. The tea showed slightly stronger DPPH activity, with an IC50 of 31.17 µg/mL against 31.68 µg/mL [2]. The authors attribute the difference to temperature and steeping time, noting that longer, hotter brewing can damage some antioxidants [2].

It also helps to note what the leaf itself contains. Moringa powder extracted with 80% methanol gave 32.90 mg GAE/g total phenolics, with strong FRAP and ORAC values [14]. This supports using the leaves as a source of antioxidants.

IV. BLENDING: BETTER TASTE, SIMILAR ANTIOXIDANT POWER

Pure moringa tea is often poorly accepted for its bitterness and flavour. Blending is the main remedy, and the studies converge on a pattern.

Orange peel. Eleven moringa–orange peel blends gave brews with 129–150 mg GAE/L of phenols. The blend of 77.89% peel and 22.11% moringa ranked highest overall among blends, but a green tea control (Camellia sinensis) beat every blend, at 592 mg GAE/L [10].

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Local herbs and spices. A moringa–Elsholtzia–galangal–cardamom tea scored higher in sensory acceptance than commercial moringa tea (7.96 vs 6.88 on a 9-point scale). Its DPPH activity was almost identical to that of moringa alone, and HDPE or tea-bag packaging kept it stable for six months [12].

Mint and spices. A mint–moringa–spice blend scored the highest antioxidant value of its group, though the spread among the four treatments was small [13].

Ginger and Javanese turmeric. Replacing 25% of moringa with a ginger–turmeric mix left DPPH, phenolics and flavonoids statistically unchanged, while flavour and taste scores improved significantly [7].

Rosella and pandan. Adding rosella calyces or pandan leaves raised measured DPPH inhibition at 40 ppm from 89.4% to as high as 97.1%, approaching vitamin C (98.2%). Rosella improved colour, pandan improved taste and aroma, but several pandan blends exceeded the 8% moisture limit [8].

Jaggery and spices. A jaggery-sweetened ginger–turmeric–pepper tea produced inhibition zones of about 21 mm against S. aureus and B. subtilis, close to the kanamycin standard against S. aureus [17].

Taken together, the studies suggest that flavour and function need not conflict. Blends can fix the sensory problem while holding antioxidant activity roughly constant. Some additions (rosella, orange peel) may also contribute their own antioxidants.

V. QUALITY, SHELF LIFE AND SAFETY

Packaging and storage. Shelf life depends heavily on the packaging. In one blended moringa tea, powder stored in transparent LDPE bags had lost its colour and aroma by day 45, showed mould by day 60 and was spoiled by day 90. The authors attributed this to the poor oxygen and odour barrier of LDPE. The same tea packed in HDPE zipper bags, paper-carton tea bags or airtight HDPE containers showed no spoilage, or loss of colour, aroma or taste, over six months at room temperature [12]. For producers, the practical message is to avoid thin LDPE and use a better barrier.

Moisture. Moisture is the key quality parameter because it controls microbial growth. The Indonesian national standard (SNI) sets a maximum of 8% for tea. Moringa blends with rosella stayed between 5.05% and 6.05%, and the moringa-only control was 7.05%. Two pandan blends rose to 8.15–8.2% and exceeded the limit, so these need longer drying [8]. A moringa–mint–spice study likewise found moisture of 5.27–5.60% across all four blends, which the authors considered safe for storage [13]

Brew stability and physical quality. A jaggery-sweetened moringa–spice tea had a brew pH of 6.83, which stayed within about 6.3–6.7 over 28 days of refrigerated storage, with no change in colour, taste or odour. The authors read this as a sign that no significant oxidation took place [17]. The same study reported a total ash value of 7.5%, loss on drying of 0.5%, and good powder flow (angle of repose 15.2°), which are useful quality indicators for tea-bag filling [17]. Stability was tested under refrigeration only, so it should not be assumed for room-temperature brews.

Safety. Animal studies summarised in a comprehensive review suggest low acute toxicity: oral doses of moringa leaf powder up to 2,000 mg/kg caused no harmful effect in rats, and the lethal dose of an aqueous extract exceeded 2,000 mg/kg [3]. One study concluded that consumption is safe but that intake should not exceed 70 g per day, to avoid cumulative toxicity [3]. The same review lists 25 clinical studies of moringa, mainly on malnutrition, chronickidney disease, HIV infection and reproductive health [3]. Human evidence on brewed tea specifically was not found in the studies reviewed here.

VI. EVALUATION PARAMETERS AND ANALYTICAL METHODS FOR MORINGA OLEIFERA LEAF

The quality and functional potential of Moringa oleifera leaf products are commonly evaluated through phytochemical, nutritional, antioxidant, enzyme inhibitory and sensory parameters. Qualitative phytochemical screening of leaf powder and ethanol extract has confirmed alkaloids, saponins, flavonoids, phenolics/tannins and steroids, while triterpenoids were not detected [1]. Further quantification of anti-nutritional and bioactive constituents, including vitamin C, tannins, saponins, phytate, oxalate, alkaloids, cardenolides and cardiac glycosides, has been performed using spectrophotometric and titrimetric procedures [6].

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Total phenolic content (TPC) is generally determined by the Folin–Ciocalteu method, with absorbance read at 752–765 nm and results expressed as gallic acid equivalents (GAE) [1, 6, 9]. Total flavonoid content (TFC) is estimated by the aluminium chloride colorimetric method, with absorbance read at 415–432.5 nm and results expressed as quercetin equivalents (QE) [1, 3, 9]. Individual phenolic compounds, such as gallic, chlorogenic, caffeic and ellagic acids, catechin, epicatechin, rutin, quercetin and kaempferol, have been separated and quantified using HPLC-DAD with a C18 column and external standards [6].

Antioxidant activity is most commonly assessed by the DPPH radical scavenging assay at 517 nm, where percentage inhibition is calculated from the absorbance of the blank and the sample [1, 9]. Results may also be expressed as IC50, derived from linear regression of inhibition against concentration, with quercetin used as a reference standard [1]. A multi-assay approach provides more reliable evidence, and complementary tests include ABTS•+ scavenging, ferric reducing antioxidant power (FRAP), hydroxyl radical scavenging, Fe2+ chelation and inhibition of Fe2+- or nitroprusside-induced lipid peroxidation in rat pancreas and liver homogenates [6]. Biological relevance has also been examined through in vitro α-amylase and α-glucosidase inhibition assays, which indicate antidiabetic potential [6].

VII. DRYING TECHNIQUES

Drying is an essential post-harvest processing operation for Moringa oleifera leaves because it reduces moisture content, limits microbial deterioration and enzymatic reactions, and improves the storage stability of the final product. However, the selection of an appropriate drying method is important because excessive heat, prolonged exposure to sunlight, and unsuitable drying conditions may cause degradation of heat-sensitive nutrients and bioactive compounds, including phenolics and flavonoids. Therefore, drying conditions should be optimized to maintain the nutritional, physicochemical, and functional properties of Moringa leaves [18,19].

Shade Drying

Shade drying is a conventional technique in which freshly harvested and cleaned Moringa leaves are spread in a well-ventilated area and dried without direct exposure to sunlight. This method generally operates at ambient temperature and reduces the possibility of direct photodegradation of sensitive phytochemicals. Rohit et al. [19] investigated shade drying at approximately 25–28°C for 72 hours. Their findings demonstrated that shade-dried leaves exhibited the highest total phenolic content (9.88 mg gallic acid equivalent/g) when extracted through maceration. The method was also ranked favourably for the recovery of phenolic compounds and antioxidant activity. These observations suggest that controlled shade drying can be beneficial for retaining important bioactive constituents.

Sun drying

involves spreading cleaned Moringa leaves under direct sunlight to facilitate moisture evaporation through natural solar energy. It is an economical and easily accessible preservation technique, particularly for small-scale and rural processing operations. In the study conducted by Rohit et al. [19], leaves were exposed to sunlight for six hours daily over 72 hours at an average temperature of approximately 35°C. Although this method offers low operational costs, prolonged exposure to sunlight and environmental conditions may adversely affect certain phytochemicals and increase the possibility of contamination. Consequently, careful monitoring of drying conditions is necessary to maintain product quality.

Oven Drying

Oven drying is a controlled thermal dehydration method in which Moringa leaves are exposed to heated air under regulated temperature conditions. It provides greater control over processing parameters than conventional open-air drying and can facilitate uniform moisture removal. Rohit et al. [19] employed a ventilated oven maintained at 60°C, with an air velocity of 1–2 m/s, for a total processing period of 72 hours. However, prolonged exposure to elevated temperatures may affect thermolabile nutritional and phytochemical constituents. Thus, temperature and drying duration should be carefully selected to minimize degradation of valuable compounds.

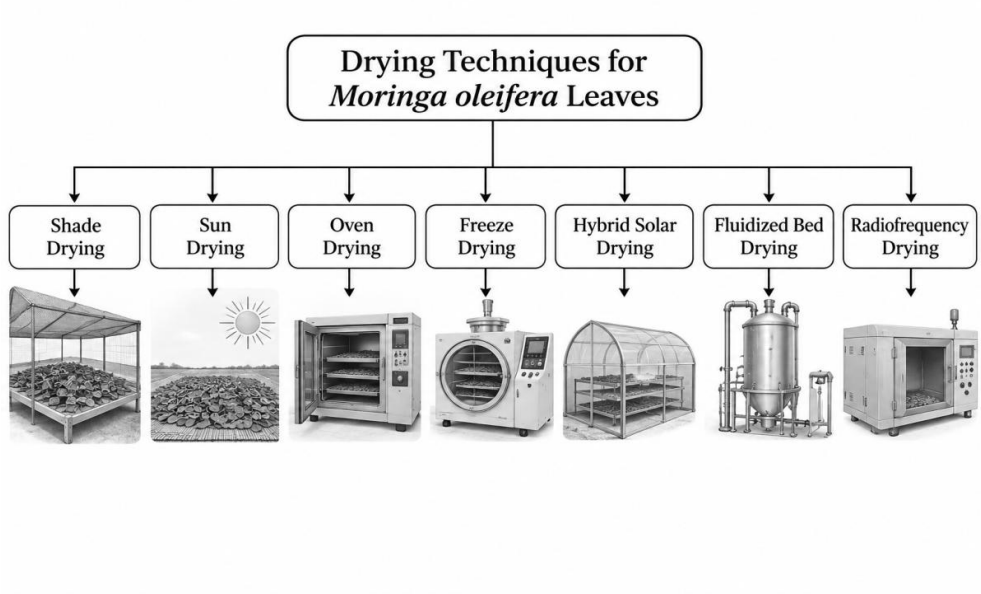
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Freeze drying

also known as lyophilization, is an advanced dehydration technique that removes water from frozen plant material through sublimation under reduced pressure. It generally operates at low temperatures and is useful for maintaining the physical structure and quality of heat-sensitive plant materials. In the study by Rohit et al. [19], Moringa leaves were initially frozen at −80°C for two hours, followed by lyophilization at approximately −30°C under vacuum for 48 hours. Although freeze drying offers advantages in preserving structural characteristics, the study reported comparatively lower total phenolic content than shade drying under the extraction conditions investigated. This indicates that the efficiency of drying may also depend on the subsequent release of bioactive compounds during extraction.

Hybrid Solar Drying

Hybrid solar drying utilizes solar energy along with a supplementary heating arrangement to maintain more consistent drying conditions. This approach helps reduce dependence on conventional energy sources while providing improved control over the dehydration process. Hegde et al. [18] evaluated hybrid solar drying of Moringa leaves at 38°C for six hours. The results indicated that the drying technique could be used for producing Moringa tea curls; however, its nutritional retention was comparatively lower than that obtained through radiofrequency drying in their experimental investigation.



Fluidized bed drying

is an advanced technique in which heated air is passed upward through a bed of plant material, suspending the leaves and improving contact between the drying medium and the product. This promotes relatively uniform heat and mass transfer and facilitates moisture removal. Hegde et al. [18] conducted fluidized bed drying of Moringa leaves at 65°C for three hours. The moisture content was monitored during processing to achieve the desired drying level. This technique provides controlled drying conditions, although the comparatively higher operating temperature may influence the retention of certain heat-sensitive constituents.

Radiofrequency Drying

Radiofrequency (RF) drying is an emerging electromagnetic heating technique in which heat is generated within the material through interaction with an alternating electric field. It allows deeper energy penetration and rapid heating, potentially reducing processing time and excessive exposure to external heat. Hegde et al. [18] used a 10-kW radiofrequency system operating at 40.68 MHz to dry Moringa leaves at 52°C for 30 minutes. Their findings indicated improved retention of several nutritional and bioactive constituents compared with hybrid solar and fluidized bed

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drying. The RF-dried green tea curls showed the highest protein content (19.88%), crude fibre (9.96%), and antioxidant activity (70.02%). These results highlight the potential of RF technology for producing nutritionally enriched Moringa tea products.

VIII. CONCLUSION

Moringa herbal tea is a decent source of antioxidants, supported by the phenolic content of the leaf and by tests on brewed tea, but it does not match green tea. Pure moringa tea suffers from bitterness, and blending with orange peel, herbs, spices, rosella, pandan or jaggery improves acceptance while keeping antioxidant activity similar or higher. Brewing with hot water (about 97°C), a 1:20 leaf-to-water ratio and about 35 minutes gave the highest phenolic recovery in one optimisation study [16]. Good packaging, such as HDPE, and moisture below 8% are needed to keep the product stable, and animal data suggest low toxicity, although human evidence for the tea itself is limited [3, 12]. Taken together, these findings support moringa blends as functional herbal tea products and as a way to add value in the processing industry.

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