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Drying Characteristics of Moringa (*Moringa oleifera*) Leaves

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Abstract

Moringa oleifera belongs to Moringaceae family whose leaves carries bundles of nutrients and vitamins. In this study, moringa leaves were dried and quality was evaluated under different drying temperatures viz, 40, 50, 60, & 70ºC. The initial moisture content of the fresh moringa leaf was found to be 73.20 % on a wet basis or 273.0% on dry basis. In tray drying the final moisture content of dried moringa leaves were recorded as 6.67, 6.31, 5.95, & 5.59% (wb) dried at 40, 50, 60, and 70°C, respectively. The drying time required to reach the respective final moisture content (6.67, 6.31, 5.95, & 5.59% (wb)) were recorded as 4, 3.67, 3.34, & 2.67 h tray drying at 40, 50, 60, & 70°C, respectively. It was recorded that nutritional compositions were significantly retained while drying at 50°C hot air temperature. It was noticed that initially the rate of moisture removal was higher due to higher moisture was available to convert in of vapor form later decreases gradually with drying time. Also, it was noticed that drying temperature significantly regulates the drying rate and time as air temperature increases the drying rate increases up to certain extent and drying time decreases.

Keywords: Moringa leaves, moisture content, drying, tray drying, drying rate

INTRODUCTION

Moringa leaves are one of the common useful multi nutritional leafy vegetable harvesting from *the moringa oleifera* tree. Each part of *moringa* tree carries distinct nutritional and medicinal properties in significant quantity. The leaves, flowers, seeds, and roots of the moringa plant are utilized in the creation of various dishes in Indian cooking. The tender pods can be consumed as vegetables and are said to have a flavor like that of asparagus. The green peas and surrounding white material are removed from larger pods and cooked in various ways, such as soup, delicious rice mix, curries, and pods are also used in making of dals, sambhar chutney, and soups instant, etc. [1–5].

Although Moringa oleifera is indigenous to India, it is grown extensively throughout Ethiopia, the Pacific Islands, Florida, the Sudan Caribbean, the Philippines, South Africa, Asia, and Latin America [2]. *Moringa oleifera* is the best known of the thirteen species in the genus of *moringaceae* family which is common in growing practice and its leaves, flowers and fruits are used as domestic as well as commercial food commodities worldwide [6–8]. *Moringa* varieties may be mainly classified into two groups: perennial and annual. Popular verities *moringa oleifera* are Coimbatore-1 & 2, Valayapatti, Periyakulam-1 & 2 (PKM 1 and PKM 2) Dhanaraj and Bhagya are found in India [9, 10].

In terms of nutrition, moringa leaves are abundant in vitamins, minerals, and other vital nutrients. *Moringa oleifera* provides more than 90 nutrients and 46 types of antioxidants. Compared to other leafy vegetables, moringa leaves have higher levels of minerals like potassium, calcium, and magnesium, iron, zinc, and copper, as well as vitamins like β-

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carotene, including vitamin B like folic acid, vitamin C, vitamin D, and vitamin E. In addition to enhancing nutrition, moringa leaves have antimicrobial, antidiabetic, anticancer, and neuroprotective properties that aid in the treatment of numerous severe illnesses [11–14]. Also, the leaves of *moringa* are considering as highly digestible and outstanding indigenous source of protein, iron, calcium, vitamin A, vitamin C, and carotenoids as compared to other nutritious food. Because of its nutritional enrichment *moringa* leaves are used as supplement of many nutritional compounds in many developing countries of the world where, undernourishment is a major concern. Moringa leaves are a good source of natural antioxidants and other compounds, like ascorbic acid, flavonoids, phenolics, and carotenoids, that enhance the nutritional value of food products that contain fat [15–18]. Nearly three hundred illnesses, including hyperglycemia, asthma, the flu, heartburn, malaria, diarrhea, pneumonia, skin conditions, and infections of the eyes and ears, can be cured with moringa leaves. Higher levels of vitamin A, which is essential for many physiological functions, like vision, reproduction, embryonic growth, and development, immunological competence, cell differentiation, proliferation, and apoptosis, epithelial tissue maintenance, and brain function, are found in Moringa oleifera leaves [19–23].

Fresh moringa leaves contain more than 70 percent moisture content which makes them highly perishable. High moisture content leads to rapid spoilage and limits the shelf life of fresh leaves. The uses of fresh *moringa* leaves to avail health benefits are limited due to its high moisture content and lack of storage facilities. The aim of this study was to assess the effect of different drying methods on quality characteristics of moringa leaves. Moisture reduction could be one of the essential steps to avail and lengthen the shelf- life of fresh *moringa* leaves [24–27].

MATERIALS AND METHODS

The fresh, mature, dark green and healthy leaves of *moringa oleifera* was harvested from single tree throughout the experiment. Further the procured leaves were graded based on their morphological properties, such as dimensions and color. Usually, the leaves were harvested at forenoon hours from 09.00 to 10.00 AM to avoid the analytical bias and result variation. The leaves of *moringa* detached from the branches of the tree later an individual leaf was detached manually. Further green and healthy *moringa* leaves were thoroughly washed by using tap water and spread it as layer on tissue paper to allow the draining off the surface moisture [28].

Determination of Physico-chemical Properties of Fresh *Moringa Oleifera* Leaves

Some physico-chemical properties of fresh *moringa* leaves were determined by measuring their proximate composition using standard analytical procedures [29, 30]. The proximate composition involves the moisture content, fat, protein, ash, fiber, and carbohydrate [31, 32].

Drying of Fresh Moringa Leaves

Drying of fresh *moringa* leaves were carried out by using different drying method namely Shade drying (at ambient condition), Hot air oven drying at different temperatures (40°C, 50°C, 60°C, and 70°C), Sun drying, Solar drying, and Microwave oven drying at different wattage and constant hot air circulation (300, 450, & 600 W + 40°C). The initial moisture content of fresh *moringa* leaves was estimated by hot air oven at 103 ± 2°C for 24 h [33–35].

Hot Air Oven Drying

The drying tests were carried out in a hot air oven dryer at four distinct temperatures: 40, 50, 60, and 70°C. Before the drying temperature stabilized, the dryer was turned on for thirty minutes. On an aluminum tray measuring 100 mm by 40 mm, a known quantity of samples was prepared in sets of three and spread out as a single layer with a thickness of 6–8 mm. The drying chamber was filled with aluminum trays filled with fresh moringa leaves, and it was allowed to dry at 40°C [36]. The experimental process was also repeated for drying temperatures of 50, 60, and 70°C. The weight difference was recorded regularly after each 20 minutes. The drying was terminated when the negligible weight difference was observed. Using experimental data, the effect of drying temperature was investigated, and corresponding drying characteristics curves were plotted [37].

Solar Conduction Drying

The known amount of fresh *moringa* leaves were spread as a single layer on the black surface of solar dryer (Figure 1). During drying period, the difference in sample weights was recorded after every half hour by using electronic precision weighing balance. Drying continued till the constant weight achieved [38–40].

Microwave Oven Drying

The drying tests were conducted using a Samsung CQ138S programmable home microwave with a minimum output of 330W and a maximum output of 900W operating at 2450MHz (Figure 2). On the turntable glass plate inside the microwave cavity, known quantities (20 g) of fresh moringa leaves were evenly distributed. The drying process was conducted at 300–600 microwave watts with continuous hot air circulation at 40°C. During drying the loss of weight was recorded at every 2-minute interval. The drying continued till the negligible weight difference observed [41, 42].

Figure 1. Solar conduction dryer.

Figure 2. Microwave drying.

Dry Matter

As previously mentioned, the oven drying method was used to determine the samples' initial moisture content. The following formula was used to determine the sample's dry matter weight and percentage [43, 44]:

$$DM (\%) = 100 - IMC (wb)$$

Where,

- DM = dry matter, (%)

- IMD = initial moisture content, (wb)

Drying Rate

The amount of moisture lost from the sample of moringa leaves over a specific time was calculated by analyzing the moisture content data collected during the experiments. The following formula was used to determine the samples' drying rate [45].

$$\text{Drying rate} = \frac{\Delta w}{\Delta t \times dm}$$

where,

- Δw = difference in weight, (g)
- Δt = difference in time, (min)
- dm = dry matter, (g)

Moisture Ratio

The moisture ratio (MR) was determined by the following equation [46, 47].

$$\text{Moisture ratio (MR)} = \frac{M - M_e}{M_o - M_e}$$

where,

- M = Moisture content at any time, (%db)
- M_o = Initial moisture content, (%db)
- M_e = equilibrium moisture content, (%db)
- M_e in comparison to M_o and M is very small, hence M_e was neglected.

RESULT

From the experimental observations on proximate analysis, it was found that *moringa oleifera* leaves are rich sources of protein, fat, crude fiber, carbohydrate and ash content. The proximate composition of fresh *moringa* leaves were recorded as moisture content 73.20%, fat content 1.65 g, protein content 6.84 g, fiber content 1.19 g, ash content 2.02 g, and carbohydrate 15.10 g per 100 g of fresh leaves (Figure 3).

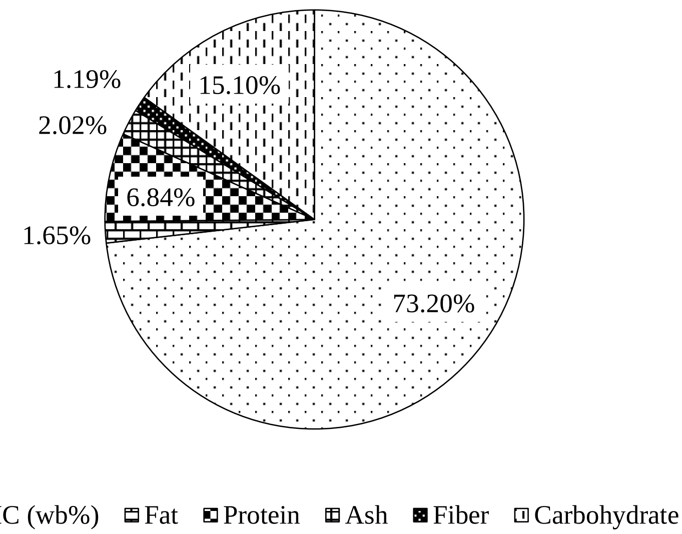

Figure 3. Proximate composition of fresh *moringa oleifera* leaves.

Effect of Drying Methods on Drying Characteristics of Moringa Oleifera Leaves

The effect of shade drying, sun drying, and solar conduction drying on *moringa* leaves were studied and explained their interpretation. Suitable graphical representation was plotted for clear understanding of variation and correlation of drying variables. The final moisture content was considered as equilibrium moisture content for individual drying method. After drying the moisture content was found to be 7.96, 6.35, and 6.05% (db) in shade, sun, and solar conduction drying, respectively [48]. The drying time was found to be 34 h for shade drying, 6 h for sun drying, and 2.30 h solar conduction drying. Experimental findings reveal that moisture removal rate was higher at initial stage and gradually decreased as the drying proceeds for all the drying methods. This might be due to higher moisture availability at the start of drying and lowers with respect to time. Shade drying exhibited slower moisture removal rates as compared to sun and solar conduction drying because of no heat involvement causes lower vapor pressure in shade drying [49]. Also, higher drying rates and lesser drying time were observed in sun and solar conduction drying because of temperature regulates the moisture removal rate. The lesser time required for solar conduction dryer suggests comparatively faster removal of moisture. This was since higher heat trapped inside of the solar conduction dryer due to black trays and polycarbonate cover resulting higher air temperature increases the water air pressure [50, 51].

Effect of Drying Air Temperature on Drying Characteristics in Hot Air-Drying Method

Different curves were used to clearly illustrate the effects of hot air-drying temperature on the drying properties of Moringa oleifera leaves. The plot of moisture content against drying time at various drying air temperatures is displayed. Initially the rate moisture removal was higher due to higher moisture was available to convert in the form of vapor later decreases gradually with the passage of time. Also, it was noticed that drying temperature regulates the drying time in case of hot air drying because as the air temperature increased, the drying time was decreased and vice-versa. The drying rate plot between the quantity of water removed per unit time versus drying time was studied and noticed that the drying rate was increasing up to a certain level and subsequently decrease as drying proceeds. Also, it is clear from the figure that in hot air-drying moisture removal pattern follows a typical drying rate curve. After the peak of moisture removal, the drying rate continuously decreases with respect to time. Although, the drying rate was increasing with respect to time till peak of moisture removal and further increase in temperature resulting quality deterioration took place. Also, from the drying rate plot faster moisture removal rate leads to the overall drying process as there was no constant drying rate period and actual drying was noticed in falling rate drying period. Furthermore, these curves demonstrated a significant relationship between drying air temperature and drying rate, with higher drying temperatures resulting in higher drying rates; consequently, the experiment's highest drying rate values were recorded at 70°C. Similar drying trends and explanation were reported by several researchers during drying of fruits and vegetables as well as leafy vegetables [52, 53].

Effect of Microwave Drying on Drying Characteristics of *Moringa* Leaves

The effect of drying characteristics of *Moringa oleifera* leaves in microwave drying at different microwave watt along with constant convection temperature carried out and plotted against moisture content as well as with respect to time. The plot between moisture versus drying time shows that drying time was decrease as increase in microwave power. Drying at higher microwave power leads to faster moisture removal with respect to time and vice versa. Minimum drying time was found at 600W + 40°C and maximum time at 300W + 40°C. This might be due to high moisture content during the initial phase of drying resulting higher microwave absorption that provokes faster vapor formation and ultimately higher moisture removal. Whereas, after passage of time the reduction moisture causes comparatively less microwave absorption and resulting lower moisture removal that leads to slower drying rate. Also, it is clear from the figure that actual drying took place in falling rate period. The maximum drying rate was noticed at 600W + 40°C and minimum at 300W + 40°C. Similar, drying patterns were reported by [54] for microwave vacuum drying of mint leaves and [55] for Microwave drying characteristics of coriander leaves.

INTERACTION BETWEEN DIFFERENT DRYING METHODS

Fresh *moringa* leaves are taken and drying at different drying methods including hot air oven drying, shade drying, sun drying, solar conduction drying, and microwave drying then find out the drying characteristics and quality evaluation of the *moringa* leaves were carried out.

In shade drying method from the experimental study was done in shaded room. It was found that 34 h drying time requires dried *moringa* leaves with 7.38% (wb) or 7.96% (db) end moisture content. Shade drying is required too much time compared to other drying methods.

In sun drying method was done in exposer of sun rays of the samples. From the experimental data it was found after 6 h of sun drying final moisture content are 5.97% (wb) & 6.35% (db) up to this moisture content drying were completed.

In hot air-drying method, hot air dryers are used to done experiment. From the experimental data it was found that hot air drying of fresh *moringa* leaves comparatively taken lower drying time than other methods. The time taken for drying the *moringa* leaves by hot air drying at 40, 50, 60, and 70°C was found to be 240, 220, 200, and 160 minutes, respectively. Moisture content in dried *moringa oleifera* leaves were 6.67, 6.31, 5.95, & 5.59% (wb) percent at drying of & 40°C, 50°C, 60°C, & 70°C temperature, respectively. Maximum moisture content was observed in drying at 40°C sample whereas minimum moisture content was observed in 70°C sample. Maximum proximate & vitamin composition was found in dried at 40°C samples as compared to other temperatures but it requires higher time and maximum mineral composition was found in dried at 40°C samples as compared to other. Overall performance was good in dried at 50°C sample as compared to other drying temperature samples [56].

In microwave drying, microwaves are used for drying. Fresh *moringa* leaves were carried at different microwave wattage 300W, 450W, & 600W at 40°C constant hot air convection. From the drying data it was noticed that drying at 300 watt for 14 minutes gives superior quality characteristics of dried *moringa* leaves. Also, it was found that the time taken for drying the *moringa* leaves by microwave drying at 300W, 450W, and 600W at 40°C constant convection temperature was found to be 14, 14, and 12 minutes, respectively, final drying are reached at 12–14 minutes and the final moisture content of the samples were ranged from 6.27 to 5.18 (%db). Final moisture content as follows 5.9, 5.85, & 4.92% (%wb) at 300W, 450W, and 600W, respectively [57]. Maximum proximate, minerals, and vitamin composition was found in 300W + 40°C sample as compared to other watt drying samples. Overall performance was good in dried at 300W + 40°C sample as compared to other watt drying samples.

CONCLUSIONS

Effects of different drying parameters were examined during the drying of moringa leaves to understand the drying behavior under certain conditions. Minimum drying time requires in microwave drying takes 12–16 minutes and maximum drying time required in shade drying takes 34 h. Shade drying performance is better as compared to sun and solar conduction drying but it is required too much time as compared to other methods. In hot air drying dried at 50°C sample as compared to other drying temperatures and in microwave dried at 300-watt sample was found better as compared to other dried at watt samples. Overall performance and quality characteristics were found better in hot air-drying method dried at 50°C sample as compared to other drying methods.

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