

**STUDY ON QUALITY CHARACTERISTICS OF
MORINGA OLEIFERA LEAVES BY DIFFERENT
DRYING TECHNIQUES**

**BY
KALAMNURIKAR SHALAKA SHIRISH**

B. Tech. (Agril. Engg.)

**MASTER OF TECHNOLOGY
IN
AGRICULTURAL ENGINEERING
(PROCESS AND FOOD ENGINEERING)**



**DEPARTMENT OF AGRICULTURAL PROCESS ENGINEERING
COLLEGE OF AGRICULTURAL ENGINEERING & TECHNOLOGY,
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PARBHANI – 431402 (M.S.) INDIA**

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**A thesis submitted to
Vasant Rao Naik Marathwada Krishi Vidyapeeth, Parbhani
in partial fulfillment of the requirement for the degree of**

**MASTER OF TECHNOLOGY
IN
AGRICULTURAL ENGINEERING
(PROCESS AND FOOD ENGINEERING)**



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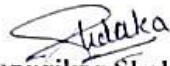
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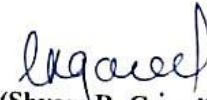
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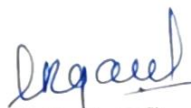

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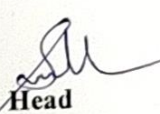
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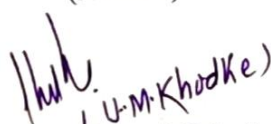
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ABBREVIATIONS

Abbreviation	Elaboration
MO	Moringa oleifera
mg	Milli gram
g	Gram
kg	Kilogram
%	percent
°C	Degree Centigrade
Hr	Hour
min	Minute
W	Watt
GAE	Gallic acid equivalent
RH	Relative humidity
CI	CARR Index
SB	Steam blanching
HW	Hot water Blanching
DW	Dry weight
d.b.	Dry basis
w.b.	Wet basis
i.e.	That is
No.	Number
Fig	Figure
<i>et al.</i>	et al. (and associates)
<i>Viz.</i>	Videelict (namely)

THESIS ABSTRACT

1	Title of the thesis	: Study on Quality Characteristics of Moringa Oleifera Leaves by Different Drying Techniques
2	Full name of the candidate	: Kalamnurikar Shalaka Shirish
3	Full name of the Research Guide	: Shyam R. Garud
4	Department	: Process and Food Engineering
5	College/ University	: Vasanttrao Naik Marathwada Krishi Vidyapeeth, Parbhani
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ABSTRACT

Moringa oleifera (MO) is one of the most useful tropical tree and also commonly known as the 'Miracle tree' or 'Drumstick tree' or 'Horseradish tree'. It belongs to the family Moringaceae and Genus: Moringa, Species: Moringa oleifera. MO leaves because of high nutrition content are consumed both in fresh and dried form. The present investigation focuses on the effect drying characteristics of microwave drying, effect of different drying techniques on phytochemical quality parameters of MO leaves and effect of drying techniques on powder properties of MO leaves powder by different drying methods namely sun drying, tray drying (45, 50 & 55°C) and microwave oven drying (180,540,900W). The leaves weighing 100g were carried out in each drying method. The weight of the samples was measured periodically until it reached a constant weight. Initial moisture content of the samples were 286±2 % (d.b.) and the final moisture content of the dried samples were found within 6.50 % (d.b.). Total drying time required for microwave drying ranges from 11 to 48 min. The moisture content data were converted into drying rate verses time graph and average moisture content verses time graph and concluded that drying progressed, the loss of moisture in the product caused a decrease in the absorption of microwave power and resulted in a fall in the drying rate.

It is also conclude that the total color change, ascorbic acid, chlorophyll content, Total phenolic content and Antioxidant activity content is higher for microwave treatments compared to tray drying, sun drying.

Microwave drying treatment shows best powder properties such as carr index, rehydration ratio, dehydration ratio of MO leaves powder. The highest concentrations of β carotene were found in tray dried sample. After reviewing all result of drying of MO leaves, it was observed that Microwave drying was best drying treatment regarding all aspects such as nutritional and phytochemical profile.

CHAPTER -1

INTRODUCTION

Human consume vegetables, which are plant parts. Vegetables can be eaten either crude or cooked and plays significant role in human nourishment, being generally low in fat and starch content. Especially green leafy vegetables (GLV) are common constituents of Indian diet. GLV are typically low in calories, fat, high protein, fiber, vitamin C content and vitamin K. In India different vegetables are grown and harvested depending upon their place and season. GLV are rich source of micronutrients and also have other antioxidant properties. The most popular GLV are spinach, fenugreek, *Moringa Oleifera* (MO) leaves, mint, Curry leaves etc. Green leafy vegetables are seasonal and perishable due to their high moisture content. The activity of microorganisms is the most important limitation for shelf-life extension. There are significant losses due to a lack of adequate storage, transportation, and processing facilities at the point of production (Pande et al.2000). Because GLVs are economical, reasonable, sustainable, and culturally acceptable, they can be easily incorporated into a regular diet and used to cure micronutrient shortages.

Moringa Oleifera is one of the most useful tropical tree and also commonly known as the 'Miracle tree' or 'Drumstick tree' or 'Horseradish tree'. It belongs to the family Moringaceae and Genus: *Moringa*, Species: *Oleifera* (Fahey, 2005). MO is a tree found in North West India's sub-Himalayan region. In general, the *Moringa* is well-known and used for its medicinal benefits, in addition to being a common vegetable among residents of these areas. *Moringa Oleifera* is also called as the "miracle tree" because of its remarkable healing capabilities for a wide range of diseases, including chronic disorders. Due to the plant's diverse purposes, several studies were conducted to isolate bioactive components from various portions of the plant (Guevara et al., 1999). As a result, herbal plants in medicine, also known as phytomedicine, are still considered as a reliable and extensively used alternative in the medical industry (Abalaka et al., 2009).

Its various medical, industrial, and nutritional applications make it a globally valuable plant. In many regions, the leaves, flowers, pods of the MO tree are consumed as nutritional vegetable. *Moringa* has been pushed by the World Health

Organization as an alternative to imported food sources in the treatment of malnutrition (Khawaja et al., 2011). With an annual production of 2.2 to 2.4 million tonnes of delicate fruits from an area of 43600 acres, India is the world's leading producer of Moringa (Drumstick). and an average of 50 tonnes per ha. The world's largest producer of Moringa is India (Drumstick). Andhra Pradesh leads the states in both area and productivity (15,665 hectares), followed by Karnataka (10,280 ha) and Tamil Nadu (13,250 ha). In Maharashtra, the area under drumstick production was (7000 ha) with the annual production of 2.10 lakh tonnes and the productivity was 30 T/ ha. Tamil Nadu is the pioneering state since it has genotypes from all over the world (Sekhar et al., 2017). Important varieties of Moringa are Valayapatti Moringa ODC-3, PKM-1, Kodikkal Moringa Moolanur Moringa, Chavakacheri Moringa, Chemmurungai, Punamurungai, Kattu Moringa and Palamedu Moringa.

The MO has many essential nutrients, antioxidant, β -carotene, vitamins, anti-inflammatory nutrients, minerals, amino acids. (Fahey et al.,2005). Several research has found that MO contains higher levels of vitamin A, vitamin C, potassium, calcium, and proteins than carrots, bananas, milk, and eggs, respectively (Fahey, 2005). MO leaves have a low fat and carbohydrate content, but are high in amino acids (Rajangam et al.,2001). Various antioxidant substances, such as ascorbic acid, flavonoids, phenolic acids, and carotenoids are present. It is also an effective source of natural antioxidants (Ahmad Faizal et.al, 2014). It is also a valuable source of nutraceuticals and functional components (Makkar and Becker 1996). Moringa leaves also have 7 times more vitamin A than oranges, 4 times more vitamin A than carrots, 4 times more calcium than milk, thirteen times more vitamin and iron than spinach, 3 times more potassium than bananas, 2 times more protein than yoghurt, and protein quality comparable to milk and eggs. Moringa leaves have a higher nutritional value. Its vitamin C is 2,000 times more effective than green tea and 242 times more powerful than apples when it comes to amino acids.

Almost all part of MO such as root, bark, seed, flowers, pods, seed oil, leaf, resin have potential food, agriculture and industrial uses. It has versatile utility as functional food, medicine, and water purifying properties and is thus considered to be world's most useful plant (Abou-Zaid et.al 2014). The tree is considered as a mother's best friend in several parts of the world because it increases milk production and can also cure anaemia, which is frequent in nursing women (Estrella et al., 2000; Anwar

et.al 2007).

People of all ages utilise MO leaves as a dietary source and a very nutritious source of nourishment. Young leaves can be cooked and eaten like spinach, or added to soups and salads (Sanjay and Pankaj Singh, 2012). According to nutritional research, leaves are high in important disease-fighting elements, amino acids (methionine and cysteine), and minerals (iron, sulphur). The leaves are high in vitamin A and C, which can help with scurvy and respiratory problems, and they can also be used as an emetic. The antibacterial and antimalarial activities of the juice derived from the leaves are very significant (Gbeassor et.al, 1990) also among the best plant source of minerals like iron and also an excellent source of protein (Martin, 1985). The leaves of the MO tree shown to have antioxidant activity due to their high polyphenol content (Sreelatha and Padma, 2009; Verma et al., 2009).

MO leaves are highly perishable, Fresh MO leaves have a 2-3 days shelf life. They require processing treatment such as drying and dehydration. They require processing treatment such as drying and dehydration. Dehydration of green leafy vegetables help in reducing the cost of packaging, handling, storing and transporting. Water in food is reduced to a very low level during dehydration, thus achieving better microbiological preservation and retarding many undesirable reactions during storage (Ibarz and Barbosa-Canovas 2000), due to the reduction in water activity. It also preserves them from fast deterioration.

Drying is one of the earliest and most extensively utilised preservation techniques today. It transforms the vegetables into a product that is light, portable, and easy to store. Drying reduces water activity, therefore it reduces postharvest loss and protects them from rapid deterioration. The shelf life of dried agricultural food is substantially longer than that of fresh agricultural food (Patil et al., 2014). Most traditional thermal treatments, including as hot-air drying and sun drying, produce low drying rates throughout the rate-falling period, resulting in undesired thermal deterioration of the completed products (Mousa & Farid, 2002). In general, the commonly used drying method are sun drying, microwave drying and tray drying.

However, most of the conventional thermal treatments such as, hot-air drying, vacuum drying, sun drying result in low drying rates in the falling rate period, which leads to undesirable thermal degradation of the finished products (Mousa & Farid,

2002). The disadvantages also include contamination issues, long drying times, difficulty to handle huge numbers, and attaining uniform quality standards. As a result, Microwave drying (MWD) is an alternative method due to its uniform energy, quick start-up and shutdown conditions, energy savings, the ability to reduce drying time and enhance the final quality of dried products.

Microwave drying has the advantage of having a short processing time, which is beneficial to product quality when compared to other drying procedures (Valerie Orsat, 2006). Due to its uniform, rapid drying rate microwave drying is widely used to dry food materials (Nair and colleagues, 2011). When compared to alternative drying methods, microwave drying was found to be superior in terms of quality, including superior colour, good volatile oil content, and a bigger number of volatile substances with the least amount of processing time. Microwave drying may speed up the drying process during a period of falling rates. During the falling rate stage, conventional drying causes sample shrinkage and low surface moisture content. During microwave drying, however, vapours are created inside the food material due to volumetric heating. Water is a typical polar molecule that is found in many meals. As a result, water molecules convert microwave energy to heat throughout this process. As a result of the heat, water molecules begin to evaporate, and the substance begins to dry (Decareau, 1985). Due to the pressure gradient, these vapours are ordered to leave out. Therefore microwave drying can minimize food materials from shrinking.

After reviewing literature pertaining to drying of MO leaves, it was observed that most research groups studied conventional techniques for drying of MO leaves. Scant attention was given on microwave drying at different power levels and its comparison with conventional drying techniques, so there is need to address the issue. On the basis of above knowledge gap objectives of research work was framed as

1. To study effect of microwave drying on nutritional quality aspects of Moringa Oleifera leaves.
2. To study the drying characteristics of Moringa Oleifera leaves during Microwave drying.
3. To study physical properties of Moringa Oleifera leaf powder.

CHAPTER - II
REVIEW OF LITERATURE

CHAPTER - II

REVIEW OF LITERATURE

2.1 Pretreatment and drying characteristics of Green leafy vegetables.

Singh et al. (1997) investigated the properties of dehydration in four regularly consumed green leafy vegetables. The vegetables were shredded and blanched for two minutes in boiling water at 90°C before being immersed in a 0.2% potassium metabisulphate solution. The leaves take four hours to completely dehydrate in a cabinet drier and two days to dry under the sun (25°C) to reach the necessary moisture content when dried at $60 \pm 2^\circ\text{C}$ with 55-60% relative humidity (9-10%). In spinach, the rate of drying was quick, while in fenugreek leaves, it was slower.

Fathima (2001) investigated the yield and drying time of five green leafy vegetables dried in a microwave oven. Mint, coriander, amaranth, fenugreek and shepu leaves were blanched for two minutes at 98°C before being soaked in cold water. The blanched greens were dried in the microwave at 100% power at a frequency of 2450 MHz. Mint took 16 minutes to dry fully, generating 10.3% product, whereas fenugreek and shepu took 11 minutes to dry entirely, yielding 15.9 percent and 32%, respectively.

Soysal (2004) examined the microwave drying properties of parsley leaves. Seven different microwave output powers ranging from 360 to 900W were utilised to dry parsley. According to the observations, drying time decrease when the microwave output power was increased to 900 W from 360 W (64%). Microwave drying using 900 W output power instead of 30, 40, 50, and 65°C in a hot air oven can cut drying time in half. The drying speeds of parsley leaves ranged from 0.48 to 1.33 kg water/kg dry weight/ minute when the output power was between 360 and 900W.

The effect of drying conditions on the drying rate of five leafy vegetables was studied by Singh et al. (2006). The leaves were dried to a moisture content of four to five percent using a cabinet drier (58-60°C), a low temperature drier ($40 \pm 2^\circ\text{C}$ and 25-40% RH), and a sun drier (40-50°C, 60-80 percent RH). Cabinet driers dried faster, followed by low-temperature driers and solar driers. Drumstick leaves dried in a cabinet drier for seven hours, whereas amaranth, curry leaves, and fenugreek dried

in six hours.

2.2 Nutritional quality aspects of *Moringa oleifera* leaves:

Fugli (2001) mentioned that the MO is an easily accessible source of nutrition and vitamins that is consumed by people of all ages. Furthermore, Moringa leaves can be used as a supplement for infants, children, pregnant women, and nursing moms in both fresh and dried powder form. Moringa leaves used as a remedy for a variety of ailments, inadequacies, and malnutrition. Moringa leaves (100 g) include over 200 mg of vitamin C in the form of ascorbic acid and beta-carotene.

Fuglie (2005) stated that the 8 g serving of dried leaf powder will satisfy a child of 1-3 years with iron 2.3%, 40 % of the calcium, 14 % of the protein, and nearly all the vitamin. As small content as 20 grams of dried leaves powder would provide a vitamins A and C need. This makes it available all year round as a supplement to the diet. Malnutrition in its various forms (kwashiorkor, beriberi, anaemia, and scurvy) is stated as a major issue in the high rates of infant mortality as well as ill health in adults. (Moringa oleifera : The Miracle Tree 2000).

Islam et al. (2006) conclude that Moringa oleifera have been good sources of phytochemicals including β -carotene and polyphenols. In the human system, sufficient doses of these polyphenols decrease cancer progression, induce apoptosis, inhibit dangerous enzymes, and promote helpful enzymes.

Khawaja et al. (2011) reported Moringa oleifera, also known as Moringa in the literature, is a natural and cultivated variety of the genus. Moringa is a species of the Moringaceae family of plants. It's one of the best sources of vitamins A, B (1, 2, 3, 6, 7), C, D, E, and K from plants. Calcium, copper, iron, potassium, magnesium, manganese, and zinc are all vital minerals found in moringa. It contains more than 40 natural antioxidants. Moringa has been included in ancient kings and queens' diets for mental alertness and healthy skin since 150 B.C. Moringa leaves, pods, and fruits, as well as moringa seeds, gums, bark, and flowers, are used to treat mineral and vitamin shortages, support a healthy circulatory system, and promote normal blood glucose levels in over 80 nations, making it one of nature's most beneficial trees.

Busani Moyo (2011) Nutritional characterization of Moringa (*Moringa oleifera* Lam.) leaves describes the dried leaves had crude protein levels of 30.3% and

19 amino acids. Calcium (3.65 percent), phosphorus (0.3 percent), magnesium (0.5 percent), potassium (1.5 percent), sodium (0.164 percent), sulphur (0.63 percent), zinc (13.03 mg/kg), copper (8.25 percent), manganese (86.8 mg/kg), iron (490 mg/kg), and selenium (363 mg/kg) were the minerals found in the dried leaves. Vitamin E had the maximum content of 77 mg/100 g in the dried leaves, compared to beta-carotene, which had 18.5 mg/100 g. A desired nutritional balance can be seen in the amino acid, fatty acid, mineral, and vitamin profiles.

Azubuogu (2012) determined the phytochemicals present in *Moringa oleifera* and *Azadirachta indica* leaves. Qualitative analysis was carried out on the extract; *Moringa oleifera* was found to include saponin, flavonoid, tannin, phenol, steroid, and glycoside, according to the findings. Saponin, flavonoid, tannin, alkaloid, steroid, and glycoside are all found in *Azadirachta indica*. Quantitative analysis of the extract revealed that *Moringa oleifera* and *Azadirachta indica*, respectively, contained (21.8:23.80) flavonoid, (5.0:8.20) alkaloids, saponin (0.70:1.10), phenol (0.76:1.49), Tannin (0.08:0.57), and Glycoside (0.005:0.0062) in percentage flavonoid, alkaloids, saponin (0.70:1) Fahey (2005) stated that the medicinal use of *Moringa* the flowers are used to treat throat infection, common cold, anthelmintic, anti-tumor, rheumatism, diuretic, and tonic and hysteria abortion.

Mishra *et al.* (2012) studied processing of *Moringa oleifera* Leaves for human consumption According to nutritional evaluation *Moringa* leaves contain most essential, disease-preventing vitamins, and also explains how to turn fresh *Moringa* leaves into a dried form for ingestion. *Moringa* trees have also been utilised to treat malnutrition, particularly among newborns and nursing moms, according to the researchers. A tablespoon (8 g) of leaf powder includes roughly 14% protein, 40% calcium, 23% iron, and all of the vitamins. During pregnancy and breast-feeding, six table spoons of leaf powder will provide almost all of a woman's daily iron and calcium needs.

Ahmad Faizal Abdull Razis (2014) studied health and nutrient Benefits of *Moringa oleifera*. He concludes that it is a multi-purpose herbal plant used as human food and an alternative source of treatments. It has anti-fibrotic, anti-inflammatory, anti-microbial, anti-oxidant, anti-tumor, and anti-cancer properties, among other medical and therapeutic properties. Further research into the *Moringa* plant's mode of

action and ingredients could provide great opportunities for developing pharmaceutical drugs that are well-documented.

Chinwe et al. (2015) conducted an experiment on evaluation of phytochemical and nutritional properties of the dried leaf powder of moringa OLEIFERA. Using a standard phytochemical screening approach, several phytochemicals such as alkanoids, tannis, flavonoids, and reducing sugar were found. Functional fruits or a source of vegetable in meal preparation, which are also utilised as nutraceuticals, were explored in the study to provide empirical evidence for their use and advantages.

Gopalkrishnan et al. (2016) carried out an experiment reavelling the nutritional profiling of dried moringa leaves using standard method and found that dry leaves carries higher nutritional values as Vitamin C is more than 7 times that of oranges, protein is more than 9 times that of yoghurt, vitamin A is more than 10 times that of carrots, potassium is more than 10 times that of bananas, calcium is 17 times that of milk, and iron is 25 times that of spinach.

Ali et al. (2017) cited that processing of moringa leaves as natural source of nutrients by optimization leaves were dried with different drying treatments including conventional, laboratory and advanced methods to optimize drying conditions in terms of maximum nutrients preservation color quality. High temperatures, longer drying times, oxygen, and sunlight were all relevant factors in nutrient loss. The leaves were crushed in three different grinding mills in the second phase, and flowability was tested using both conventional and modern approaches including the Carr Index and the Cohesion Index. The optimum choice for maximum nutrients was determined to be oven drying at 50.8°C. Moringa leaves are the most cost-effective natural source of vitamin A, as well as other vitamins, minerals, amino acids, antioxidants, and anti-inflammatory compounds.

Table No 2.1 Ranges of Carr Index for flowability of powders

Carr Index (%)	Flowability
0-10	Excellent
11-15	Good
16-20	Fair
21-35	Passable
26-31	Poor
32-37	Very poor
>38	Extremely poor

Sandeep et al. (2018) reported that Moringa as nutritional security studied *Moringa oleifera* as a potential tree for its wide range of uses. Therefore, There is a desire to concentrate research on value-added Moringa leaf applications. This research will serve as a foundation for future Moringa post-harvest management and value-added in Moringa. Because of the nutritional and therapeutic properties of Moringa OLEIFERA leaves, there is a growing need for value-added products to help people overcome chronic diseases and improve their livelihoods, nutrition, and poverty. The report also mentions a number of items, including Moringa leaf powder, oil, and tablets.

2.3 Drying characteristics using different drying method

Seshadri et al. (1997) carried out experiment on dehydration of drumstick leaves. Drumstick leaves were pretreated by steam blanching for three minutes and blanching followed by sulphitation at room temperature for three minutes before being shade dried. The time it took to dry blanched leaves to a constant weight was 20 hours, blanched and sulphited green leafy vegetables took 32 hours.

Singh et al. (1997) studied the dehydration characteristics of four commonly consumed green leafy vegetables. The vegetables were shredded and blanched for two minutes in boiling water at 90°C before being immersed in a 0.2 percent potassium metabisulphate solution. The blanched leaves took four hours to completely dehydrate in a cabinet drier and two days to dry under the sun (25°C) to reach the necessary moisture content when dried at 60±2°C with 55-60% relative humidity 9-10% percent. In spinach, the rate of drying was quick, while in fenugreek leaves, it was slower.

Lakshmi and Vimala (2000) studied drying characteristics of green leafy vegetables. Curry leaves, Amaranth, mint, curry leaves, gogu and mint leaves dried under sun drying at 30-45°C and cabinet drying at 60-70°C respectively. Sun drying required 5-10 times longer period compared to cabinet drying to bring down the moisture to 9-11%. Amaranth, curry leaves, gogu and mint respectively required 2.5, 1.0, 3.0, and 2.5 h for drying in cabinet drier. Low dehydration ratio resulted in high yield of cabinet dried product.

Pande et al. (2000) studied coriander and fenugreek leaves were dried in solar drier. The leaves were fed into perforated trays at a rate of 3.3 kg/m² tray area and 3.7 kg/m² respectively, using a forced circulation solar hot-air dryer. Coriander dried in 3.5, 3.0, 2.5 hours at 40, 45, and 50°C while fenugreek took 4.5, 3.5, 3.0, and 2.5 hours at 40, 45, 50, and 60°C respectively. When temperature had a substantial impact on moisture reduction, the drying rate was higher in the first 30 minutes.

Ahmed et al. (2001) studied drying characteristics and quality attributes of coriander leaves with at different drying temperature of 45, 50, 55, 60 and 65°C. They concluded that total time is increased with the increase in air temperature. Also coriander leaves dried at 45°C and final product retains maximum chlorophyll and also rehydration capacity.

Kendall et al. (2004) reported that the drying lowers weights and volume of the product hence lowers costs in transportation and storage. However, drying allows lowering in nutritional value of the product, for example loss of vitamin C, and changes of colour and appearance that might not be desirable.

Ndawula et al. (2004) reported that the vitamin A and vitamin C are especially prone to oxidative destruction in the presence of heat, light, oxygen, enzymes, moisture and metal ions. Thus sun drying causes marked losses in these vitamins due to exposure of the drying vegetables to greater solar radiation particularly ultra violet (UV) rays, which catalyses β carotene oxidation leading to loss of vitamin activity. For best retention of nutrients in dried foods store in a cool, dark, dry place and use within a year.

Singh et al. (2006) investigated the effect of drying conditions on the drying rate of five leafy vegetables. The leaves were dried under cabinet drier (58-60°C), low temperature drier ($40 \pm 2^\circ\text{C}$ and 25-40% RH) and solar drier (40-50°C, 60-80% RH) to a moisture content of four to five per cent. The drying rate was faster in cabinet drier followed by low-temperature drier and solar drier. Drumstick leaves took seven hours for drying in cabinet drier whereas amaranth, curry leaves, and fenugreek required six hours in the same drying condition.

Satwase et al. (2013) reported the preservation of green leafy vegetables was very important. The leaves of *Moringa oleifera* have various uses in human life. They

prepared powder of *Moringa oleifera* leaf powder by applying drying technique viz. Sun drying, Shadow drying, Cabinet drying and Oven drying. The drying was done at 60°C to minimize the drying lossess. The results obtained from cabinet dried sample were better than other and it had highest nutrient retention followed by shadow, sun drying and oven dried sample. The rehydration ratio calculated at 55°C, 65°C, 75°C temperature for 60,45, 30 minutes respectively. The rehydration ratio of cabinet dried sample was more than other samples. The study revealed that the cabinet tray drying method was observed suitable for dehydration of drumstick leaves.

Dawn et al. (2016) studied that effect of drying on moringa leaves under conventional and controlled conditions. Freshly harvested, mechanically stripped and washed *moringa oleifera* leaves were dried by different drying methods viz., sun drying, solar drying, shade drying, vacuum drying and cabinet drying by using different temperatures (45, 50, 55 and 60°C). The effect of drying on Colour and biochemical constituents of *moringa* leaves was studied. They found that the drying rate increased with drying time. On basis of quality evaluations of dried *moringa* leaves result revealed that in cabinet drying at 50°C sample resulted in better quality in terms of color and nutrient content.

Patil (2015) studied that Drying of Green Leafy Vegetables using Microwave Oven Dryer Green leafy vegetables (GLVs) are highly perishable but can be preserved by various methods including dehydration which is eco-friendly and easily adoptable. Microwave drying characteristics of GLVs were assessed at five different microwave output powers ranging from 135-675 W were used for drying GLVs. The Results indicated that the drying of GLVs on microwave oven drier was conducted at five different output powers from 135 to 675 W from its initial moisture of 4.45kg/kg dry matter up to moisture content resembling to optimum condition. Microwave oven drying can greatly reduce the drying time of leafy vegetables with internal resistance to mass transfer.

Umar et al. (2015) investigated that the effects of different drying techniques on the nutrients of *moringa oleifera* leaves. Fresh samples of *moringa oleifera* leaves was dried using four different methods viz; freeze-drying, oven drying, sun-drying and shade-drying. Proximate analysis was carried out on fresh and dried samples for moisture, protein, fiber, fat and carbohydrate. Elemental analysis was conducted for

iron, magnesium, potassium, calcium and phosphorus. They observed that in various drying processes, moisture content reduction from 72.5% in the fresh sample to 5.88%, 5.37%, 6.43% and 7.23% for freeze-dried, oven-dried, sun-dried and shade-dried leaves respectively were achieved. Overall performance of the four drying methods base on nutrients retention and moisture removal indicates that freeze-drying is most efficient whereas sun drying is the least.

Upadhyay *et al.* (2015) reported that the *moringa oleifera* plant provides a rich and rare combination of quercetin, zeatin, sitosterol, kaempferol and caffeoylquinic acid. *Moringa oleifera* plant is very important for its medicinal value and high nutritional value. Various parts of *moringa oleifera* plant such as the leaves, fruit, seed, bark, roots, flowers and immature pods act as cardiac and circulatory stimulants, antipyretic, antioxidant, antitumor, antiepileptic, anti-inflammatory, antiulcer, diuretic, antispasmodic, cholesterol lowering, antihypertensive, hepato-protective anti-diabetic, antibacterial and antifungal activities, and are being employed for the treatment of different ailments in the indigenous system of medicine, particularly in South Asia.

Ali (2017) studied Processing of Moringa leaves as natural source of nutrients By optimization leaves were evaluated the color and nutritional value of Moringa leaves with respect to drying treatments. It was found that microwave-drying method is rapid and more uniform than conventional drying method. Microwaves are penetrate in the food and heat not only in outer surface but also inside the food and improves quality of products and drying is very rapid as compare to other drying. Study evaluated that microwave drying preserve more nutrients and retain natural color quality of Moringa leaves as compared to conventional methods including shade and direct sunlight. In addition, noted Conventional drying treatments were less appropriate for drying of Moringa leaves due to high evaporation rate of vitamins and color loss.

Clement *et al.* (2017) studied the effect of drying temperature on protein and vitamin content such as vitamin A and vitamin C of *moringa oleifera* leaves. They observed that protein content, vitamin A and vitamin C of *moringa oleifera* leaves varies with temperature. Also, they noted that *moringa oleifera* dried at room temperature and 60°C contains higher level of protein content, vitamin A and vitamin

C compared to those dried under the sun and at 105°C. They also observed that *moringa* leaves dried at room temperature takes longer time (4 days), compared to those dried at 60°C (8 h). They found that *moringa* leaves were better dried at 60°C.

Jain et al. (2017) investigated the effect of drying temperature on the drying kinetics of curry leaves. Initial moisture content of fresh curry leaves were recorded as 161.7 % (db) and dried at 50, 55, and 60°C using hot air tray dryer. They found that the time required for drying of curry leaves at 50°C, 55°C and 60°C were 90, 135 and 180 min, respectively under thin layer tray drying. They noticed that drying rate was higher when the drying carried out at 60°C as compared with drying performed at 50°C and 55°C.

Rathnayake et al. (2017) studied the effect of cutting and steam blanching before dehydration on organoleptic properties and dehydration pattern of *moringa oleifera* leaves. Fresh *moringa* leaves were taken and harvested from same location. Samples are dehydrated under four conditions according to two factor factorial design. Organoleptic properties of dehydrated leaves were compared for four sensory attributes as color, taste, aroma, and overall acceptability using five point hedonic scales. Drying curves were plotted and L* a* b* values were determined for each treatment combination. They found that, cutting and blanching can darker the colour and alter the flavor of dehydrated products. Further the leaves surface area have a significant effect in dehydrating time while blanching can increases the rate of moisture removal.

Singh et al. (2019) studied about effects of drying on quality characteristics of fenugreek leaves. The different drying methods were used as tray drying 40, 50, 60°C, fluidized bed drying 40, 50, 60°C, shade drying and open sun drying. They observed that tray drying at 60°C requires lesser time (4 h), followed by fluidized bed drying at 60°C (6 h), open sun drying (8 h) as compare to other method. Also, they found that shade drying continues up to 12 h in blanched sample. Further, they mentioned that the maximum sensory score had recorded in case of tray drying at 60°C.

2.4 Phytochemical quality parameters of MO leaves

Sreelatha and Padma (2009) reported that Antioxidant Activity and Total Phenolic Content of *Moringa oleifera* Leaves in Two Stages of Maturity concludes that

Antioxidants play an important role in scavenging and regulating free radicals, safeguarding humans from infections and degenerative diseases. The findings reveal that *Moringa oleifera* extracts, both mature and tender leaves, have high antioxidant activity against free radicals, protect key biomolecules from oxidative damage, and provide considerable protection against oxidative damage. . Overall, *Moringa oleifera* leaves appear to have a high level of antioxidant activity. Only minimal changes in antioxidant activity were discovered between mature and tender leaves in the study. Their ingredients act as scavengers for free radicals and protect cellular macromolecules from oxidative damage.

Arpita das (2011) cited that Effect of freeze drying and oven drying on antioxidant properties of fresh wheatgrass studied that total phenolics, total flavonoids, and antioxidant activities of powder from seven-day-old fresh wheatgrass (*Triticum aestivum* L.) examined by freeze drying and hot air drying. Fresh wheatgrass samples contained the highest levels of ascorbic acid and chlorophyll in the quantitative analysis of antioxidative components, but the lowest levels of total flavonoids and phenolics

Mbah et al., (2012) Effect of drying techniques on the proximate and other nutrient composition of *Moringa oleifera* leaves from two areas in Eastern Nigeria. The purpose of this study was to determine the composition of *Moringa oleifera* leaves in terms of proximate, micronutrients, and anti-nutrients. The leaves were picked fresh, cleaned, and washed before drying (sun, shade, or oven), wrapped, and preserved intact for further analysis. And result conclude that the nutrients and anti-nutrients in *Moringa oleifera* leaves were affected by different drying processes. The leaf's protein, fibre, carbohydrate, vitamin B1, vitamin A, calcium, and zinc levels improved with each drying procedure. The anti-nutrients (tannin, oxalate, and saponin) in *Moringa oleifera* were reduced by the various drying procedures, although tannin was enhanced.

Shaikha et al. (2014) determined the phytochemical composition and nutritive contents of *Moringa peregrina* and *Moringa oleifera* extracts from the leaves and fruits. The powdered plant samples were examined separately for their phytochemical constituents like total phenol content, micro and macro elements using appropriate methods. According to the nutritional values obtained, the phytochemical and

proximate analysis results showed the high percentage in *M. Oleifera*. There was no significant difference in dry matter content between two species. The ash content, total phenol content, protein, micro elements (Ca, K, Mg, Na, P) and macro elements (Cu, Co, Fe, Mn, Zn) were higher in *Moringa oleifera* when compared to *M. Peregrina*. Their nutritional properties in different parts may provide incentive for proper evaluation of these plants as dietary food as well as medicinal agents essential for human health.

Yuparat Potisate et al. (2015) reported Microwave Drying of *Moringa oleifera* (Lam.) Leaves: Drying Characteristics and Quality Aspects determines drying characteristics using microwave drying (MWD) at different MW powers from 150 to 900 W and also Quality aspects in terms of total phenolic content (TPC), DPPH radical scavenging activity, color as well as rehydration ratio. The commercial processing of *Moringa oleifera* leaves could be improved by using MWD, as the drying time was considerably reduced and the dried *Moringa oleifera* leaves had a higher TPC, DPPH radical scavenging activity. *Moringa oleifera* leaves contain significant amounts of bioactive compounds with high antioxidant activities. The effective moisture diffusivities could be calculated in a range from 3.17×10^{-11} to 1.75×10^{-10} m²/s and 3.64×10^{-11} to 1.71×10^{-10} m²/s for whole-leaf and half-leaf, respectively and were increased with microwave output power. Microwave drying application significantly increased the phytochemical compounds of *Moringa oleifera* leaves. Dried whole-leaf using MWD at 900W had the highest TPC, DPPH radical scavenging activity when compared with conventional drying.

Afzal Hossain (2017) explained that green leafy vegetables selected to evaluate the effects of water boiling and oil frying on their total phenolic content (TPC), total flavonoid content (TFC), reducing power (RP), and antioxidant capacity. GLV are rich in phenolics and flavonoid as antioxidants. Cooking has a determining effect on the levels of bioactive components and antioxidant capacities of vegetables. Although cooking results in vitamin C loss, this study provides the first report on the increase of vitamin C in cooked leafy vegetables (Indian spinach leaf). This study demonstrated that the oil frying process would be better for enhancing antioxidants and the free-radical scavenging potential of the 4 green leafy vegetables investigated in this study.

Bamidele (2017) examined that the total phenolic content, antioxidant activity, and mineral content of all the green leafy vegetables included in this study are all affected by blanching time. It may be concluded that the longer these vegetables are blanched, the lower their mineral content and prospective health benefits also. so With these results, it could be concluded that blanching time for these vegetables should range between 1 to 5 min to prevent the loss of health benefiting compound present in them.

Surbhi Sahay et al. (2017) studied potential of *Moringa oleifera* as a functional food ingredient used as naturally obtained from plants having less effect and more popular in these years. *Moringa oleifera* is rich in macro and micro nutrients which are important for normal metabolic activity of body and prevents most of the diseases. Most of the parts of *Moringa oleifera* including leaves, seeds are edible and other parts like bark, pods have use in biodiesel production and water purification. and *Moringa oleifera* has tremendous therapeutic properties including anticancer, antimicrobial, antiulcer, antioxidant, and curing malnutrition. This study highlights the benefits of *Moringa oleifera* as good ingredient in food products as well as in other industrial purpose to work as a background for future research projects.

CHAPTER - III
MATERIALS AND METHODS

CHAPTER - III

MATERIALS AND METHODS

The present study was carried out in Department of Process and Food Engineering, College of Agricultural Engineering and Technology, Vasantrya Naik Marathwada Krishi Vidhyapeeth, Parbhani. The materials and methods adopted in the current research are classified under appropriate headings.

3.1 Collection of Moringa oleifera leaves:

The prominent variety of Moringa oleifera Coimbatore -1 (Odisi) majorly grown in Marathwada region was selected for the experiments. MO leaves were collected from College of Horticulture, Vasantrya Naik Marathwada Krishi Vidhyapeeth, Parbhani. The drumstick leaves were selected by observing visual appearance. Leaves of desirable maturity were selected for drying and further processing into powder.

The leaves were picked early in the morning.

3.2 Equipments

The equipments and sophisticated machineries viz: Microwave oven, Tray drier, Double beam Spectrophotometer, Centrifuge, Orbital Shaking Incubator, Hunter lab Colorimeter were utilized in the present investigation of College of Agricultural Engineering and Technology, VNMKV, Parbhani.



Plate No 3.1 Fresh Moringa leaves

3.3 Pre-treatments:

3.3.1 Blanching:

Hot water blanching and steam blanching were selected as the two blanching treatments. The *Moringa oleifera* leaves were separated, cleaned with distilled water (DW), sprayed on muslin cloth, and then blanched for 3 to 5 min.



Fig. 3.2 Hot Water Blanching Fig 3.3 Steam Blanching

3.4 Drying Methods:

Drying of 100 gm leaves were carried out in each drying method namely:

1. Sun drying,
2. Tray drying (40°C, 50°C & 55°C) and
3. Microwave oven drying (180, 540 & 900 W).

3.4.1 Sun drying:

The leaves were spread out on a 100 mm x 100 mm perforated stainless tray and kept outside for sun drying. The ambient temperature during sun drying was ranged from 25°C to 40°C. The relative humidity varied from minimum of 45% to maximum of 60%.

3.4.2 Tray drying:

Drying studies were carried out using a tray dryer. For placing and removing the food material, the dryer has one tray and one front door. The air velocity inside drying chamber is controlled by a single knob. The air enters the plenum chamber and



Plate No 3.4 Microwave oven drying



Plate No 3.5 Tray Dryer



A



B



C

Plate No 3.6 Fresh Moringa leaves sample(A), Dried Moringa Leaves sample (B), Powder of Moringa leaves

is heated by the heating unit before passing through the food material, absorbing moisture, and exiting the drier as humid air. Stainless steel trays measuring 340 × 270 mm are used in the dryer. Tray can hold between 50 and 100 g of MO leaves. A 2.5 kilowatt heater heats the air, which may be controlled using a thermostatic controller. The dryer, which operates on single phase current flows of 50, 375 W AC, is sucked into by the fan.

3.4.3 Microwave oven drying

The drying trials were conducted using a programmable household microwave (LG MC-8083MLR) with a maximum output of 900W at 2450 MHz. The microwave cavity was 530 mm x 322 mm x 500 mm in size. The oven contains a fan to circulate air in the drying chamber and keep the magnetron cold.

Moringa oleifera leaf Powder

After drying, the dried leaves were powdered in a mixer cum grinder, sieved through a 0.4 mm wire mesh, and stored at room temperature before being used for chemical analysis (Ukey et al., 2014).

3.5 Analysis of Drying Data

3.5.1 Moisture content

Moisture content of the fresh and dried sample was measured by using hot air oven method. At first weight of the empty can be measured using digital balance. Then the sample along with can was measured and kept in hot air oven at 60°C for 24 hours using following equation:

$$\text{Moisture Content \%} = \frac{[(W_2 - W_1) - (W_3 - W_1)]}{(W_3 - W_1)} \times 100$$

Where,

W_1 = Weight of the moisture dish along with its cover

W_2 = Weight of the moisture dish along with sample

W_3 = Weight of the moisture dish along with the dried sample

3.5.2 Drying rate

The time and temperature were noted down from the individual drying experiments. The removal of water with time as mentioned against each drying temperature was observed regularly. The drying rate of each time interval for each drying temperature was calculated by considering the water removed per unit time for the interval.

3.6 Quality Analysis

3.6.1 Beta carotene

B-carotene in leaves was estimated as per procedure described by Srivastava et al. (1998). Leaves (5 g) were crushed in 10-15 ml acetone with an addition of few crystals of anhydrous sodium sulphate in a pestle and mortar. The supernatant was discarded into a beaker and the process repeated twice to transfer the combined supernatant to a separatory funnel. Petroleum ether (10-15 ml) was added and mixed thoroughly. On standing two layers were separated. The lower layer was discarded and upper layer collected in a volumetric flask. The volume was made up to 100 ml with petroleum ether. The optical density was recorded at 452 nm using petroleum ether as blank.

Beta carotene content present in the moringa leaves was analyzed by following acetone-petroleum ether extract method and quantity of beta carotene (μg) present in 100 g of the sample was calculated as given below:

3.6.2 Ascorbic acid

5 g of sample was grinded in a mortar and pestle by adding 10 ml of 3% metaphosphoric acid (HPO_3). It was then transferred to a beaker and 40 ml of metaphosphoric acid was added to it. Then it was centrifuged for around 10-15 minutes and the aliquot or the filtrate was collected. 5ml of standard ascorbic acid solution and 5 ml of 3% metaphosphoric acid was taken in a conical flask and mixed together. It was titrated against the prepared dye solution to get the dye factor and a onion pink color end point.

Dye factor = 0.5/ titre

Then, 2-10 ml of the aliquot or filtrate sample was taken and titrated with the dye



to a pink end which persists for at least 15 seconds. The aliquot of the sample taken should be such that the titre should not exceed 3 to 5 ml. Ascorbic acid (mg/100g) was calculated using following expression;

$$\text{Ascorbic acid content (mg/100g)} = \frac{\text{Titre} \times \text{dye factor} \times \text{volume made up}}{\text{extracted liquid taken for estimation} \times \text{wt or sample taken for extraction} \times 100}$$

3.6.3 Color measurement

The color of the Moringa leaves will be determined before and after drying measured by using hunter color lab calorimeter. Before testing a sample, the instrument was calibrated with standard black and white tiles. The color reading was expressed in terms of L*, a*, and b* values. The L* value represents the light dark spectrum with range of 0 (black) to 100 (white), the value a* represent green red spectrum while the b* value represent blue-yellow spectrum. The values are the averages of five readings from different locations of leaves.

The ΔE^* was used to express color degradation/change value as a single numerical value. The ΔE^* is defined as the magnitude of total color differences and is from following Equation.

$$\Delta E = \sqrt{(L - L^*)^2 + (a - a^*)^2 + (b - b^*)^2}$$

3.6.4 Bulk density

Bulk density is an important parameter when a powder is freely poured into a hopper. It is the ratio between mass and volume of a freely poured powder in a container. A pre-weighed 10 ml measuring cylinder filled up to 10 ml with the sample will be taken

$$\text{Bulk density} = \text{Mass/Volume}$$

3.6.5 Tapped density

Tapped density is the maximum packing density of powder that is achieved under the influence of an externally applied force. It is the ratio of the mass of the powder to the volume of powder bed after tapping.

3.6.6 Carr Index (CI)

The Carr Index (CI) is the ratio between the difference between tapped density and the bulk density to the tapped density (Carr, 1965) and measure by the following relationship

$$\text{Carr Index(CI)} = \frac{\text{Tapped density} - \text{bulk density}}{\text{Tapped density}} \times 100$$

3.6.7 Determination of rehydration ratio

$$\text{Rehydration ratio} = \frac{\text{Weight of rehydrated sample}}{\text{weight of dehydrated sample}} \times 100$$

3.6.8 Determination of dehydration ratio

$$\text{Dehydration ratio} = \frac{\text{Weight of dehydrated sample}}{\text{initial weight of fresh leaves}} \times 100$$

3.6.9 Chlorophyll

One gram of fresh moringa leaves powder was taken and then smashed by using mortar and pestle and transferred into 200 ml conical flask. Thereafter, 20 ml of 80% acetone was added into the flask and further gently grinded by using of mortar & pestle as reported by Kaushal et al. (2015). Calculate absorbance value at 645 and 663 nm.

$$\text{Total chlorophyll content mg/100 g} = (20.2 \times A_{645} + 8.02 \times A_{663}) / (W \times 1000)$$

W = weight of sample extracted

V= final volume of extract

A= absorbance value

3.5.9 DPPH Antioxidant Scavenging Activity:

Antioxidant activity: Antioxidant assay was carried out using the 2,2-diphenyl-1-picrylhydrazyl (DPPH). spectrophotometric method outlined by Take 1 g of finely ground Moringa Oleifera leaves powder and extract by using 25ml of 99% methanol with covering of Al foil. Put the sample in the incubator for 2.5 hrs with 100 rpm speed and maintain at room temperature. About 4 mg of DPPH solution in methanol and shake well, keep it in dark cabinet at cool condition before absorbance at 517nm. Centrifuge the sample which was incubated at 6000-8000 rpm for 15 min at

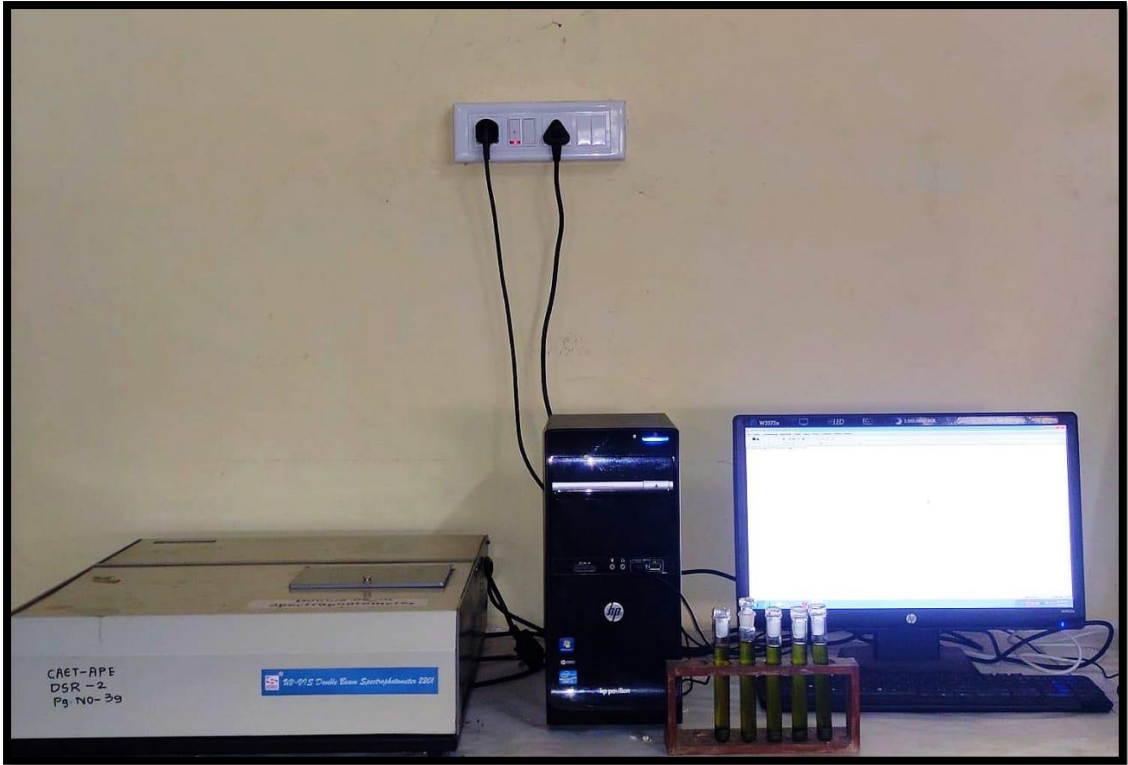


Plate No 3.8 Double beam Spectrophotometer



Plate No 3.9 Hunter Lab Colorimeter

room temperature. Filter that sample by using filter paper. Prepare a solution series using extracted solution and methanol. BHA is used to calibrate spectrophotometer to test stability of DPPH. DPPH Antioxidant Scavenging Activity was calculated using following expression.

$$\text{Antioxidant activity (\%)} = \frac{100 - [(\text{Abs of sample} - \text{Abs of blank})]}{\text{Abs of positive control.}} \times 100$$

3.5.11 Total phenolic content (TPC)

The total phenolic content (TPC) of the extracts was determined by using the Folin–Ciocalteu method 0.2 ml of the extract was mixed with 0.5 mL Folin–Ciocalteu reagent and 7.8 ml of distilled water. The mixture was allowed to stand for 10 min before adding 1.5 ml of 20% sodium carbonate and placed inside a water bath at 40°C for 20 min. The absorbance of the solution was measured at 760 nm using a UV/Vis Spectrophotometer. A standard curve was developed with solutions of gallic acid in methanol:water mixture (50:50 v/v). While measuring the TPC for the extracts, the 0.2 ml extract was replaced with the gallic standard solution, and the total phenolic values were expressed as milligrams of gallic acid equivalents g⁻¹ dry weight.



Plate No 3.10 Centrifuge



CHAPTER - IV

RESULT AND DISCUSSION

CHAPTER - IV

RESULT AND DISCUSSION

MO leaves powder was prepared using three drying methods as sun drying, tray drying, and microwave drying. The observations and results of various experimental works are described in this chapter, with possible literature support given where required. The current research focuses on the effect of drying methods on drying behavior as well as qualitative analysis of MO leaves. The entire chapter is divided into three sections based on the results of the experiments. The first section describes drying characteristics of microwave drying. Later on second section reveals the effect of different drying techniques on phytochemical quality parameters of MO leaves and in third section effect of drying techniques on powder properties of MO leaves powder results are explained using tables, charts and graphs for better understanding of research phenomena. The results obtained are discussed under following suitable headings and subheadings.

4.1 Drying Characteristics of MO leaves.

4.1.1 Effect of microwave treatment on drying characteristics

Three microwave power level (180, 540 and 900W) were studied and data related to moisture content, moisture ratio, drying time for drying of MO leaves was collected. It was observed that drying time required at 180, 540 and 900W were found decrease with increase in the power levels (Table 4.1). Initial moisture content on dry basis was $286 \pm 2\%$ and it reduced to 8.02 to 6.50 % (d. b.) for different power levels.

Table 4.1 Effect of microwave treatment on drying characteristics

Method of drying	Power level (W)	Final moisture content, % (d. b.)	Total drying time (min)
Microwave drying	180	8.02	48
	540	6.39	24
	900	6.50	11

4.1.2. Effect of power level on drying characteristics

The drying rate of MO leaves was higher during initial phase of moisture content of the material was very high during the initial phase of the drying which resulted in a higher absorption of microwave power and higher drying rates due to the higher moisture diffusion. As the drying progressed, the loss of moisture in the product caused a decrease in the absorption of microwave power and resulted in a fall in the drying rate. The drying rate increases with the increase in microwave power levels. Therefore, microwave power level has an important effect on drying rates. Results agree with previous studies (Funebo & Ohlsson, 1998; Maskan 2000). Figure 4.1.1 and 4.1.2 shows that, the variation of moisture content of Moringa leaves from 8.02 to 5.46 % (d.b.) took 11-48 min, depending on microwave output power applied. By working at 900W instead of 180W, the drying was shortened by 60%.

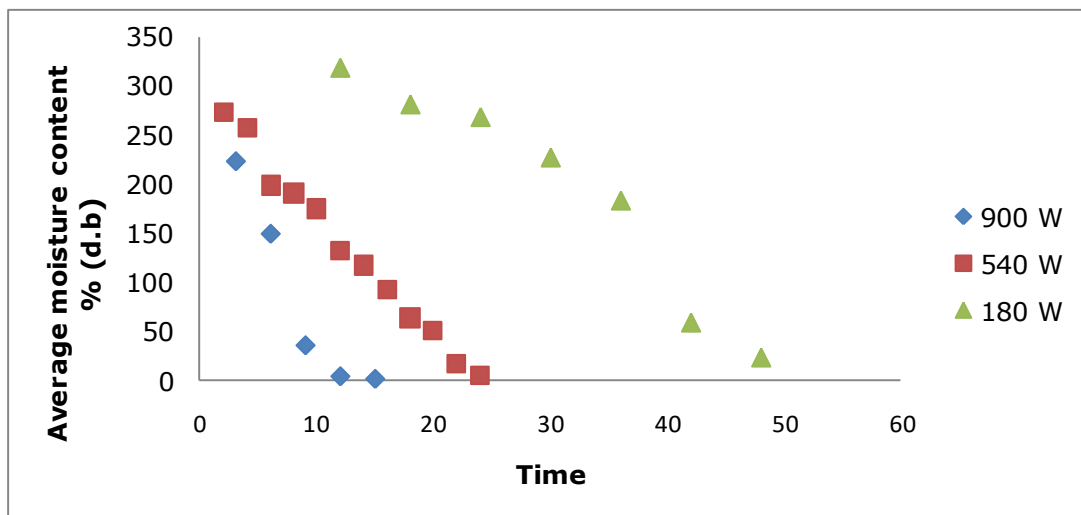


Figure 4.1.1 Variation of average moisture content (d.b.) with time in Microwave treatment

As the microwave output power was increased causing a noticeable reduction in total drying time. After a very short constant rate period, falling rate period was followed in which moisture content decreased to about $5 \pm 1\%$ dry basis for all microwave output powers. However, these results agree with the study of parsley leaves dried in a domestic microwave oven reported as Soysal (2004) who claims that after a short heating period, a long constant rate period and a falling rate period were observed. The variation in constant rate period may be due to shape and size of the leaves. In the present work, the initial heating period decreased with increase in output power and

constant rate period is very short. However, careful observations indicate that there was no significant drying rate variation achieved at 540 W.

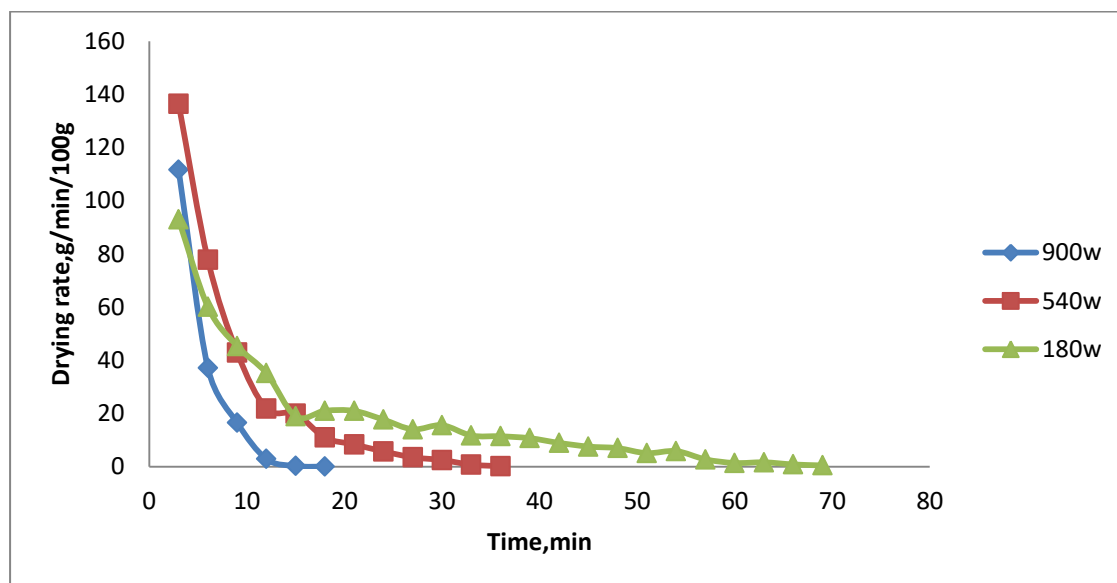


Figure 4.1.2 Variation of drying rate with time in Microwave treatment

4.2 Effect of different drying techniques on phytochemical parameters of MO leaves

4.2.1 Effect of different drying techniques on color

The mean surface colour values i.e., L (lightness), a (+ redness, - greenness), and b (+ yellowness, - blueness) of leaves dried at various drying techniques were obtained. Total colour difference i.e., ΔE was calculated and presented in Fig. 4.2.1. Results indicated that there is significant loss in L, a, b values in case of all the dried leaves in comparison to fresh ones. Reduction in 'L' and 'b' values and increase in 'a' value indicated that drying produced brownish (dark green) products.

It is observed from Fig. 4.2.1, that the total color change is higher for microwave treatments compared to tray drying. It can also be concluded that hot water blanching resulted in lower colour change than the steam blanched sample in all the drying treatments. The lowest value of ΔE^* was observed during hot water blanched and hot air-dried sample at 45°C and it was increased as the drying temperature increased from 45 to 55°C. Steam blanched samples of all the three drying techniques resulted in higher change in colour as compared to hot water blanching treatment. Total colour difference in case of all steam blanched samples have not changed significantly due to

power levels in microwave and rise in temperature in tray drying. It is verified from results that the degree of colour change was depend on drying air temperature and microwave power. Overall color variations may be caused due to not only by the non-enzymatic browning reaction but also by the destruction of pigments present in the leaves (Lopez et al., 2013)

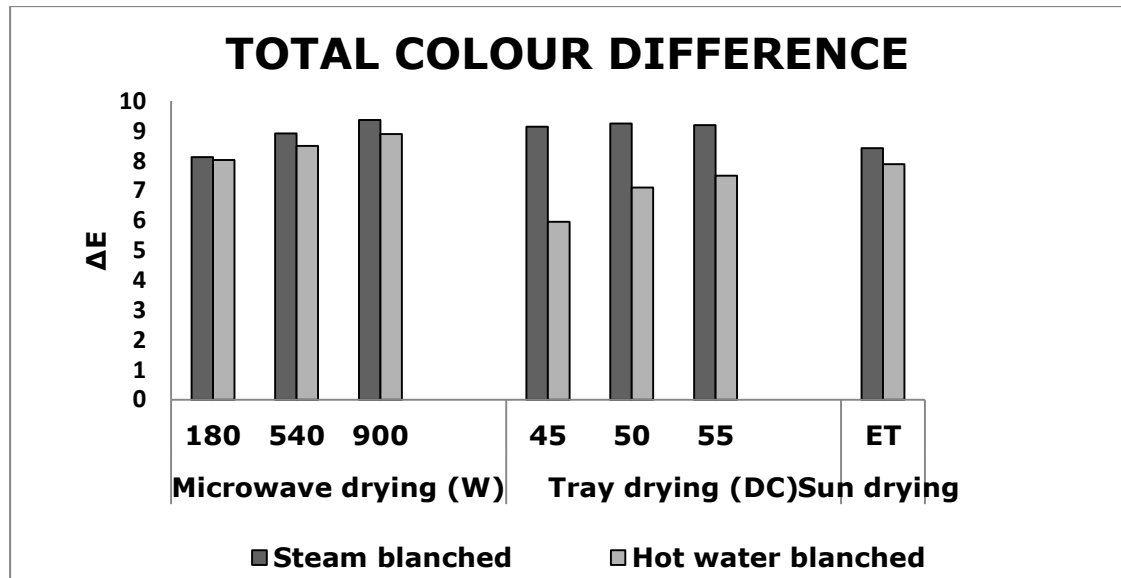


Figure 4.2.1 Effect of different drying techniques on color

4.2.2 Effect of different drying techniques on ascorbic acid

Effects of microwave, tray and sun drying treatments on ascorbic acid content were analyzed. Ascorbic acid is usually taken as the index of nutrients quality of drying process, as it is highly sensitive vitamin (Krokida, Karathanos, Maroulis, & Marinos-Kouris, 2003). The ascorbic acid content of fresh leaves was more than their dried counterparts. It can be seen from Fig.4.2.2 that microwave drying resulted in higher ascorbic acid retention compared to tray drying treatment. Peter et al., 2010 observed similar result and concluded that ascorbic acid content was reduced due to increase in drying time and temperature. Previous studies on fruits (apricot and kiwi) and vegetable (potato) drying by microwave and tray drying on ascorbic acid concentration also concluded that the degradation of ascorbic acid was heat and time dependent (Khraisheh *et al.*, 2004; Özkan *et al.*, 2007; Karatas and Kamişli, 2007; Diamante *et al.*, 2010).

Maximum of 98.79 mg/100g of ascorbic acid content was observed in case of hot water blanched microwave dried sample at 180 W. From Fig. 4.2.2 it is observed

that in the ascorbic acid content was significantly decreased due to increase in microwave power levels.

Minimum ascorbic acid content was observed in case of hot water blanched and sun-dried samples. Vega-G_alvez et al., 2009 also presented similar results in case of red pepper. During sun drying, vitamin C was retained minimum which means vitamin C is highly sensitive to sunlight flowed by long duration and temperature.

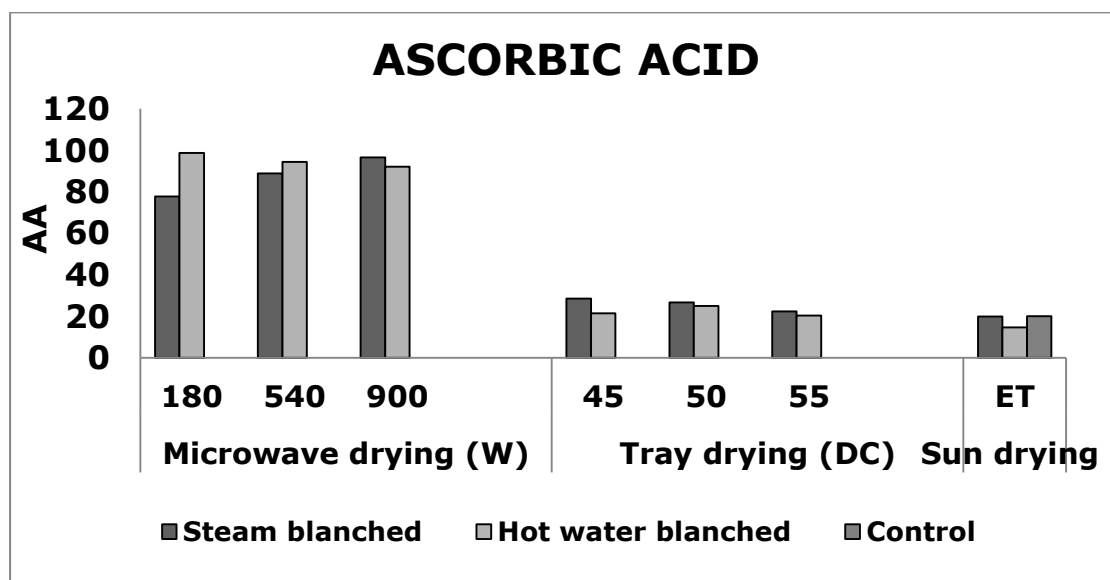


Figure 4.2.2 Effect of different drying techniques on ascorbic acid

4.2.3 Effect of different drying techniques on β -carotene

In case of all the dried samples β -carotene is available in a rich concentration as compared to fresh samples due to increasing in dry matter. The highest concentrations of β carotene were found in tray dried sample at 45°C. No significant difference was observed among tray dried samples. Lower values of β carotene content were observed in microwave dried samples compared to tray dried samples. But no significant difference in β carotene content among the microwave treatment was observed.

The lowest values of β carotene were found in sun dried sample. It concludes that sunlight is the main reason behind degradation of β carotene and Moringa leaves are very sensitive to sunlight. Parallel results were obtained by Ndawula et al. (2004), and concluded sun drying caused more than 80% loss of β carotene in cowpea leaves and mango fruit.

Muratore et al. (2008) also presented studied the effect of drying temperature and time on retention of β carotene in tomatoes slices, and determined that length of drying is more crucial then drying temperature.

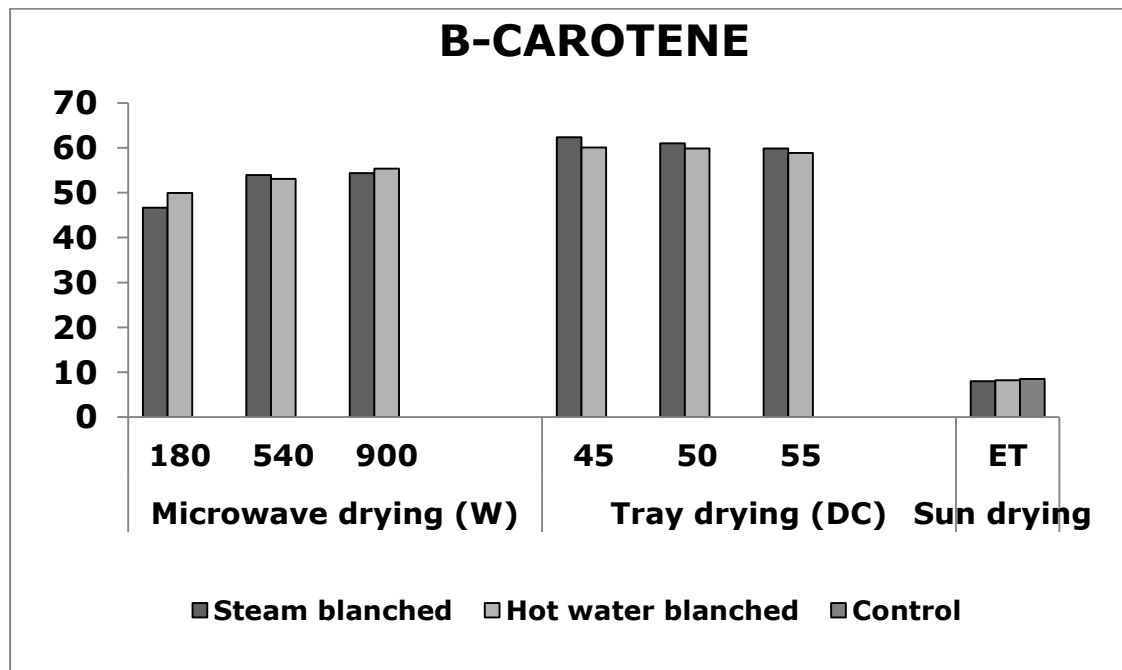


Figure 4.2.3 Effect of different drying techniques on β -carotene

4.2.4 Effect of drying treatment on chlorophyll content

In case of all dried sample, it was observed that chlorophyll content of final product decreased with increase in drying air temperatures which might be due to the temperature sensitivity of the pigment. It is also verified from results that the degree of chlorophyll change was dependent on drying air temperature. Chlorophyll content decreased with increase in temperature. Ahmed et al. (2001) also similar results for coriander leaves drying. Fig.4.2.4 that microwave drying retained in higher chlorophyll content as compared to tray drying treatment. Chlorophyll content of sun dried with pretreatment hot water blanching and steam blanching Moringa leaves was almost on par with the fresh leaves. In microwave oven drying the chlorophyll content was observed maximum at 540W and 720W.

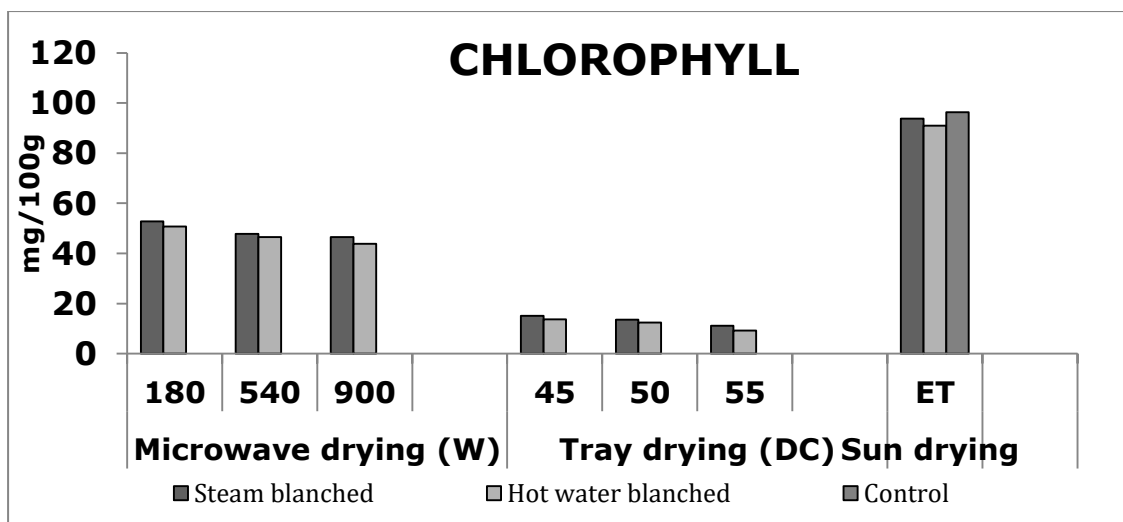


Figure 4.2.4 Effect of different drying techniques on chlorophyll content

The comparison among Microwave drying evidently indicates that chlorophyll content of the samples subjected to high power will be retained less compared to the chlorophyll content of the samples at less power level.

4.2.5 Effect of different drying techniques total phenolic Content and DPPH Radical scavenging activity

The antioxidant activity in plants is primarily due to total phenolic content, which is the primary contributor to antioxidant activity in herbs (Siti Mahirah et al., 2018). The total phenolic content (TPC) was calculated using Gallic acid calibration curves. Antioxidant activity is measured in terms of DPPH radical scavenging activity. It was also found that dried samples showed a significant increase in TPC, DPPH radical scavenging activity. The extraction of total phenolic content depends upon temperature. It can be seen from Fig. 4.2.5 that microwave drying resulted in higher phenolic content and antioxidant activity retention compared to tray drying treatment. Drying methods that use high temperature cause a dramatic loss of phenolic compounds and antioxidant activity, as concluded by Antia Orphanides (2013). Similar results were approved by Sejali et al. (2011), i.e., lower temperature would increase more phenolic content. Similar trends for an increase in antioxidant activity and TPC content when moringa leaves were subjected to microwave drying at 900 W were reported by Potisate & Phoungchandang, (2015).

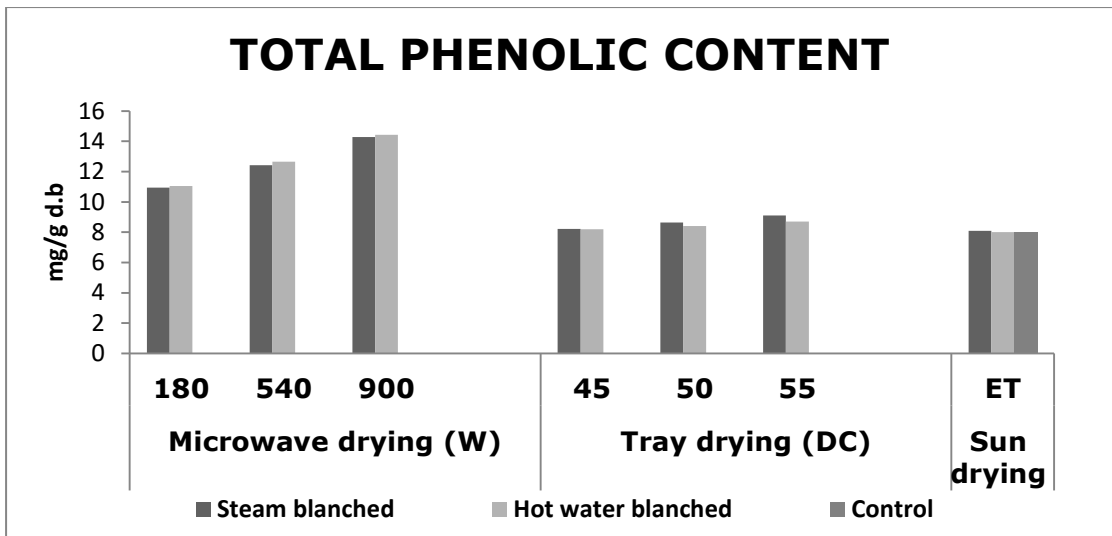


Figure 4.2.5 Effect of different drying techniques total phenolic Content

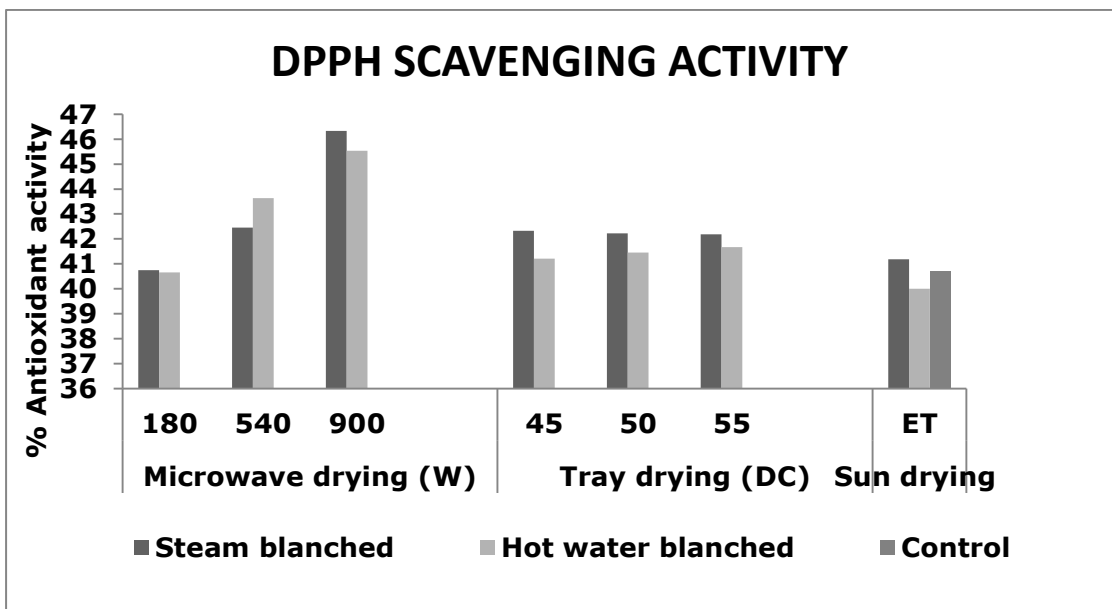


Figure 4.2.5 Effect of different drying techniques on DPPH Radical scavenging activity

4.3 Effect of different drying techniques on powder properties of MO leaves powder

4.3.1 CARR Index

Carr Index (CI) is an indicator of flowability of the powder depends on the bulk and tapped density of powder. Carr Index (CI) is a measurement of flowability of powder products based on the values of bulk and tapped density. Pre-treatment or blanched improved the flowability of oven-dried powder by decreasing the CI as

compared to control powder which was in agreement with the findings of Singh and Prasad (2013) which was in agreement with the findings of Singh and Prasad (2013). CI value of tray dried sample shows good flowability as compare to microwave dried sample.

Raja et al. (2019) also reported that oven- dried *Carica papaya* L. leaf powder of better flowability was produced by blanching pretreatment. The differences in the flowability of powder may be caused by aspects like moisture available in the powder sample and its bulk density. Carr index greater than 25 is considered to be poor flowability and below 15 Good flowability

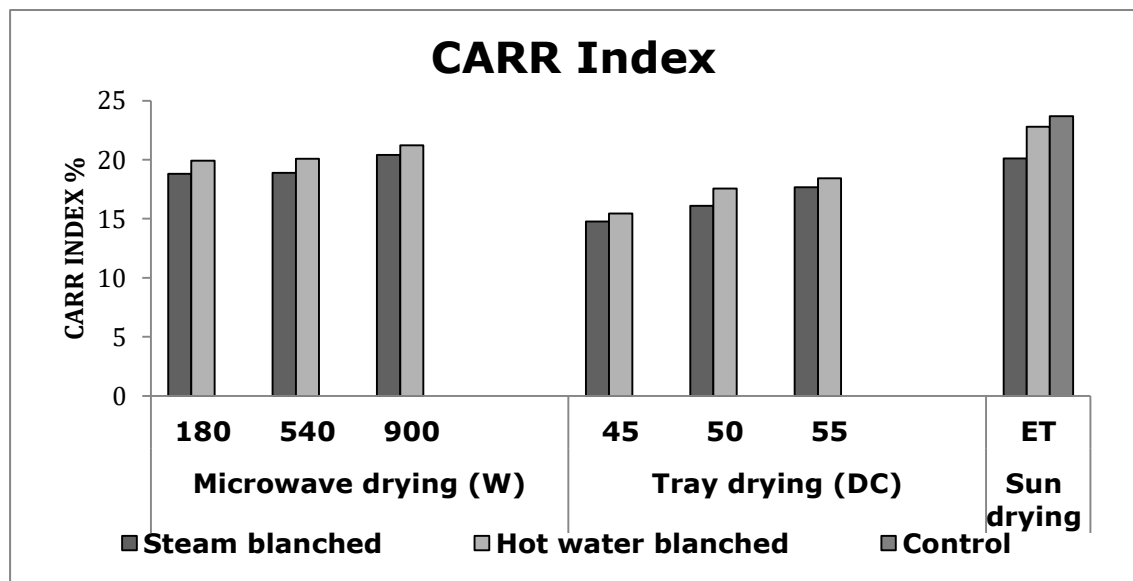


Figure 4.3.1 Effect of different drying techniques on CARR index

4.3.2 REHYDRATION RATIO

Figure 4.3.2 shows the results for rehydration ratio of three drying techniques. Microwave drying rehydration ratio is low as compared to tray and sun drying. Similar result obtained by Potisate (2015) and conclude that the best rehydration ratio was obtained in samples that had short drying times. For sun drying RR is very high when compared to microwave drying and tray drying.

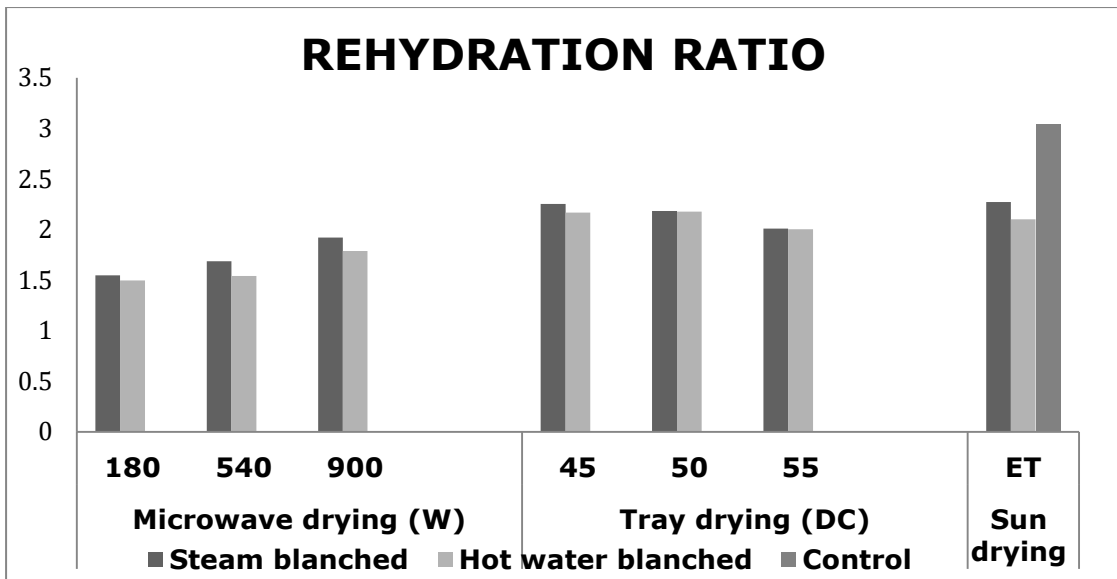
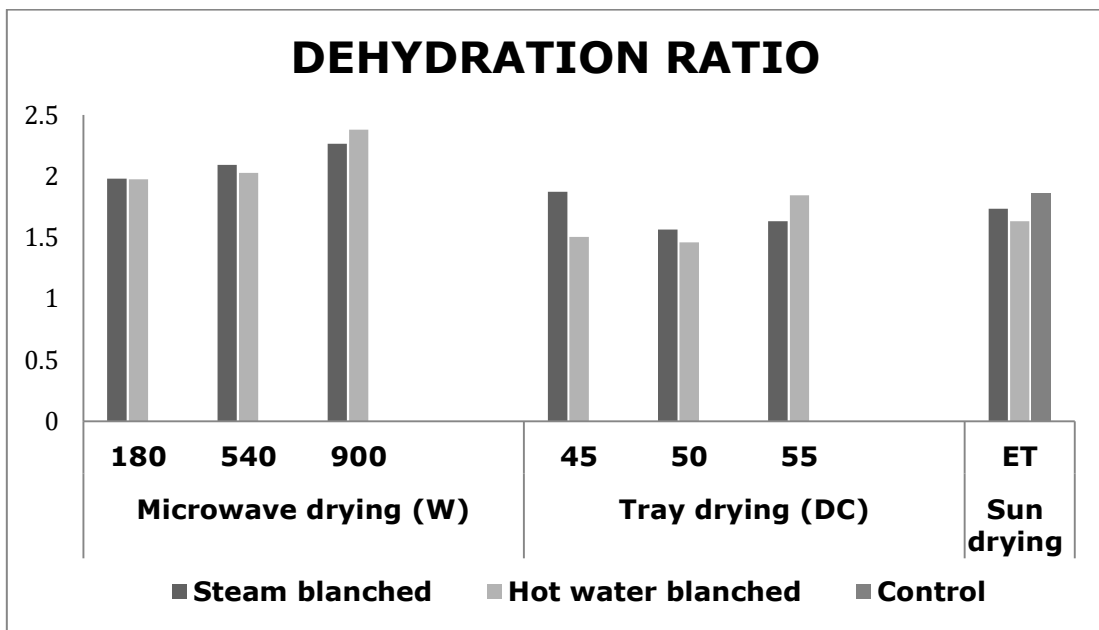


Figure 4.3.2 Effect of different drying techniques on rehydration ratio

4.3.3 DEHYDRATION RATIO

Effects of microwave, tray and sun drying treatments on dehydration ratio were analyzed. Microwave drying gives higher dehydration ratio than sun drying due to faster drying rate. these similar result given by Md.sajjad et.al (2018) in case of carrots.



4.3.2 Effect of different drying techniques on dehydration ratio

CHAPTER - V
SUMMARY AND COCLUSIONS

CHAPTER - V

SUMMARY AND COCLUSIONS

Moringa oleifera (MO) is one of the most useful tropical tree and also commonly known as the 'Miracle tree' It is an outstanding source of nutritional components such as vitamin C, beta carotene, phenolics well as rich in antioxidant content.

MO leaves were cut from the main branches and hot water blanching and steam blanching were selected as the two blanching treatments. The Moringa oleifera leaves were separated, cleaned with distilled water (DW), sprayed on muslin cloth, and then blanched for 3 to 5 min. Drying of leaves were carried out by different drying treatments namely Sun drying, Tray drying (40°C, 50°C & 55°C) and Microwave oven drying (180, 540 & 900 W).

The results obtained during present investigation are summarized and concluded as under

- In the case of microwave drying the final moisture content of the samples were ranged from 8.02 to 6.50 % (d.b.) and drying time at 180,540,900W was ranged from 18 to 48 minutes.
- The drying rate increases with the increase in microwave power levels. Therefore, microwave power level has an important effect on drying rates. As the drying progressed, the loss of moisture in the product caused a decrease in the absorption of microwave power and resulted in a fall in the drying rate.
- Total colour change is higher for microwave treatments compared to tray drying. It can also be concluded that hot water blanching resulted in lower colour change than the steam blanched sample in all the drying treatments.
- Microwave drying resulted in higher ascorbic acid retention compared to tray drying treatment and concluded that ascorbic acid content was reduced due to increase in drying time and temperature. Maximum of 98.79 mg/100g of ascorbic acid content was observed in case of hot water blanched microwave dried sample at 180 W.

- In case of all the dried samples β -carotene is available in a rich concentration as compared to fresh samples due to increasing in dry matter. The highest concentrations of β carotene were found in tray dried sample at 45°C. No significant difference was observed among tray dried samples. Lower values of β carotene content were observed in microwave dried samples compared to tray dried samples.
- Chlorophyll content decreased with increase in temperature. In case of all dried sample it was observed that chlorophyll content of final product decreased with increase in drying air temperatures which might be due to the temperature sensitivity of the pigment. It is also verified from results that the degree of chlorophyll change was depend on drying air temperature.
- Microwave drying resulted in higher phenolic content and antioxidant activity retention compared to tray drying. Drying methods that use high temperature causes a dramatic loss of phenolic compounds and antioxidant activity.
- CARR Index of microwave, tray and sun drying treatments ranges from 15 to 25. CI value of tray dried sample shows good flowability as compare to microwave dried sample.
- Rehydration ratio dependent on the drying time, which in turn is dependent on the drying temperature. Microwave drying rehydration ratio is minimum as compared to tray and sun drying. The best rehydration ratio was obtained in samples that had short drying times. For sun drying RR is very high when compared to microwave drying and tray drying.
- Microwave drying gives higher dehydration ratio than sun drying due to faster drying rate.
- Microwave drying is better drying method in terms of drying time than conventional drying such as tray drying and sun drying.
- Phytochemical quality parameters such as total color change, ascorbic acid, chlorophyll content, Total phenolic content and Antioxidant activity content is higher for microwave treatments compared to tray drying, sun drying.

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APPENDIX

APPENDIX

Drying data of Moringa Oleifera leaves for Microwave drying techniques at
900W Power

Data sheet 1

Time (min)	Initial Wt.(g)	Moisture present,(g)	Moisture removal,(g)	MC (%wb)	MC (%db)	Drying Rate
0	2	1.54	0.46	77	334.78	0.00
3	2	1.38	0.62	69	222.58	37.40
6	2	1.196	0.804	59.8	148.76	12.30
9	2	0.52	1.48	26	35.14	12.62
12	2	0.069	1.931	3.45	3.57	2.63
15	2	0.019	1.981	0.95	0.96	0.17

**Drying data of Moringa Oleifera leaves for Microwave drying techniques at
540W Power
Data sheet 2**

Time (min)	Initial Wt.(g)	Moisture present,(g)	Moisture removal,(g)	MC (%wb)	MC (%db)	Drying Rate
0	5	1.721	3.279	75.68	311.18	0
2	5	1.341	3.659	73.18	272.85	19.16
4	5	1.216	3.784	72.04	257.65	3.80
6	5	1.398	3.602	66.52	198.68	9.83
8	5	1.818	3.182	65.58	190.52	1.02
10	5	1.674	3.326	63.64	175.02	1.55
12	5	2.159	2.841	56.82	131.58	3.62
14	5	2.304	2.696	53.92	117.01	1.04
16	5	2.605	2.395	47.9	91.93	1.57
18	5	3.062	1.938	38.76	63.29	1.59
20	5	3.326	1.674	33.48	50.33	0.65
22	5	4.291	0.709	14.18	16.52	1.54
24	5	4.758	0.242	4.84	5.086	0.48

**Drying data of Moringa Oleifera leaves for Microwave drying techniques at
180W Power
Data sheet 3**

Time (min)	Initial Wt.(g)	Moisture present,(g)	Moisture removal, (g)	MC (%wb)	MC (%db)	Drying Rate
0	5	1.092	3.908	78.16	360.4051565	0
6	5	1.086	3.914	78.28	357.8754579	4.03
12	5	1.529	3.471	76.1	318.4100418	3.29
18	5	1.195	3.805	69.42	281.097561	2.07
24	5	1.312	3.688	73.76	268.1885125	0.54
30	5	1.358	3.642	72.84	227.0111184	1.37
36	5	1.766	3.234	64.68	183.1257078	1.22
42	5	3.148	1.852	37.04	58.83100381	2.96
48	5	4.056	0.944	18.88	23.27416174	0.74

Comparison between drying temperatures for colour parameters during Hot water Blanched Microwave drying

Data sheet 4

Microwave drying Power level,W	Colour		
	L*	A*	B*
Fresh leaves	41.22	-9.14	19.44
180SB	34.48	-3.27	20.15
540SB	35.68	-3.42	23.46
900SB	35.40	-4.67	23.85

Comparison between drying temperatures for colour parameters during Hot water Blanched Microwave drying

Data sheet 5

Microwave drying Power level,W	Colour		
	L*	A*	B*
Fresh leaves	41.22	-9.14	19.44
180HW	35.12	-4.02	20.48
540 HW	35.43	-3.80	22.03
900HW	29.89	-5.65	15.86

(SB – Steam Blanching),(HW – Hot water Blanching)

**Comparison between drying temperatures for colour parameters during Hot
water Blanched Tray Drying**

Data sheet 6

Tray drying Temperature,°C	Colour		
	L*	A*	B*
Fresh leaves	41.22	-9.14	19.44
45HW	36.53	-5.46	19.40
50HW	36.32	-4.56	16.9
55HW	36.25	-3.46	18.64

**Comparison between drying temperatures for colour parameters during Steam
Blanched Tray Drying**

Data sheet 7

Tray drying Temperature,°C	Colour		
	L*	A*	B*
Fresh leaves	41.22	-9.14	19.44
45SB	42.13	-5.44	18.31
50SB	40.95	-3.23	20.22
55SB	37.44	-3.87	24.03

(SB – Steam Blanching), (HW – Hot water Blanching)

**Comparison between different power levels for different quality parameters
during steam blanched Microwave drying treatment**

Data sheet 8

Drying Methods Microwave Drying (W)	Ascorbic acid (mg/100g)	Betacarotene (µg/100g)	Chlorophyll (mg/100g)	DPPH Antioxidant Scavenging Activity	Total Phenolic Content
Fresh leaves	20	8.5	96.28	40.71	32.83
180SB	77.7	46.65	52.76	40.75	11.05
540SB	88.85	53.98	47.76	42.45	12.65
900SB	96.5	54.4	46.51	46.33	14.43

**Comparison between different power levels for different quality parameters
during Hot water blanched Microwave drying treatment**

Data sheet 9

Drying Methods Microwave Drying (W)	Ascorbic acid (mg/100g)	Betacarotene (µg/100g)	Chlorophyll (mg/100g)	DPPH Antioxidant Scavenging Activity	Total Phenolic Content
Fresh leaves	20	8.5	96.28	40.71	32.83
180HW	98.70	49.98	50.75	40.65	10.95
540HW	94.35	53.08	46.54	43.64	12.42
900HW	92.13	55.4	43.87	45.54	14.29

**Comparison between different power levels for different quality parameters
during Steam blanched Tray drying treatment**

Data sheet 10

Drying Methods Microwave Drying W	Ascorbic acid (mg/100g)	Betacarotene (µg/100g)	Chlorophyll (mg/100g)	DPPH Antioxidant Scavenging Activity	Total Phenolic Content
Fresh leaves	20	8.5	96.28	40.71	32.83
45SB	28.51	62.4	15.51	42.32	8.21
50SB	26.64	61	13.64	42.22	8.64
55SB	22.41	59.9	11.21	42.19	9.1

**Comparison between different power levels for different quality parameters
during Hot water blanched Tray drying treatment**

Data sheet 11

Drying Methods Microwave Drying W	Ascorbic acid (mg/100g)	Betacarotene (µg/100g)	Chlorophyll (mg/100g)	DPPH Antioxidant Scavenging Activity	Total Phenolic Content
Fresh leaves	20	8.5	96.28	40.71	32.83
45HW	21.41	60.09	13.7	41.21	8.19
50HW	24.96	59.9	12.4	41.45	8.4
55 HW	20.4	58.89	9.19	41.67	8.7

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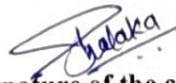
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Academic qualification

Course/ Degree	Name of college/Institute	University/ Board	Year of passing	Percentage (%)/ CGPA	Class/ Grade
SSC	Bal Vidya Mandir, Parbhani	Maharashtra State Board	2012	87.80%	First class
HSC	Shri Shivaji College, Parbhani	Maharashtra State Board	2014	68.92%	second class
B. Tech (Agricultural Engineering)	College of Agril. Engg. and Technology, Parbhani	Vasantrao Naik Marathwada Krishi Vidyapeeth	2019	72.9%	Second class

Place: Parbhani

Date : 11 / 01 / 2022


Signature of the candidate

Kalamnurikar Shalaka Shirish