STUDY ON DRYING KINETICS OF MORINGA LEAVES USING CABINET, FLUIDIZED BED AND INFRARED DRYER

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THESIS

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2021

DECLARATION

We hereby declare that this project report entitled "**STUDY ON DRYING KINETICS OF MORINGA LEAVES USING CABINET, FLUIDIZED BED AND INFRARED DRYER**" is a bonafide record of project work done by us during the course of project and that the report has not previously formed the basis for the award to us of any degree, diploma, associateship, fellowship or other similar title of any other university or society.

Place: Tavanur

Date: 05-07-2021

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CERTIFICATE

Certified that this project report entitled "**STUDY ON DRYING KINETICS OF MORINGA LEAVES USING CABINET, FLUIDIZED BED AND INFRARED DRYER**" is a record of project work done jointly by AKSHATHA VARMA A (2017-02-002), ARDRA S (2017-02-012), BHAGYA K C (2017-02-017) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship, fellowship to them.

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SYMBOLS AND ABBREVIATIONS

KCAET	Kelappaji College of Agricultural Engineering and Technology
%	Percentage
&	And
/	Divided by
=	Equal to
±	Plus or minus
AOAC	Association of analytical communities
B.C	Before Christ
°C	Degree Celsius
Ca	Calcium
Cm	Centimetre
Db	Dry basis
DNA	Deoxyribonucleic acid
E.g	Example
EMC	Electromagnetic compatibility
et al.	And others
etc.	Et cetera
FAO	Food and agricultural organisation
Fb	Fluidized bed
G	Gram
H	Hour
HP	Horse power

H_2SO_4	Sulphuric acid
IR	Infra-Red
J	Journal
J	Joules
K	Potassium
Kcal	Kilo calorie
Kg	Kilo gram
KJ	Kilo joule
Kwh	Kilowatt-hour
M	Metre
µm	Micrometre
MHz	Megahetrz
M. oleifera	Moringa Oleifera
m/s	Metre per Second
Mg	Milligram
Min	Minutes
Ml	Millilitre
Mm	Millimetre
N	Normal
N	Newton
NaOH	Sodium hydroxide
Rpm	Revolution per mint
s	Second
Spp.	Species
Spss	Statistical package for the social sciences

TAC	Total available carbohydrate
v/s	Versus
Viz	Namely
Wh	Watt-hour
w/w	Weight per weight
Wb	Wet basis

CHAPTER 1

INTRODUCTION

Moringa (*Moringa Oleifera*) is a type of local medicinal Indian herb which has turn out to be familiar in the tropical and subtropical countries. The other terms used for Moringa are Horseradish tree, Mulangay, Mlonge, Benzolive, Drumstick tree, Sajna, Kelor, Saijihan and Marango.

Table 1.01. Scientific classification

Kingdom	Plantae
Division	Magnoliphyta
Class	Magnoliopsida
Order	Brassicales
Family	Moringaceae
Genus	Moringa
Species	M. Oleifera

(Source: Fahey, 2005)

The Moringa plant has found a great deal of economic, nutritional and medicinal use globally. It is a small native tree of the sub-Himalayan regions of North West India. Traditionally, besides being a daily used vegetable among people of these regions, the Moringa is also widely known and used for its health benefits. Among commoners, it has earned its name as 'the miracle tree' due to its amazing healing abilities for various ailments and even some chronic diseases.

The history of Moringa dates back to 150 B.C. Historical proofs reveal that ancient kings and queens used Moringa leaves and fruit in their diet to maintain mental alertness and healthy skin. Ancient Maurian warriors of India were fed with Moringa Leaf Extract in the warfront. The Elixir drink was believed to add them extra energy and relieve them of the stress and pain incurred during war. These brave soldiers were the ones who defeated "Alexander" the Great. There are 13 varieties of Moringa; Moringa Oleifera is the most well-known. Every part of this tree is edible, from the leaves, trunks, stems, all the way down to its root. The flowers can be eaten or used to make tea and provide good amounts of both calcium and potassium. The young pods can be cooked and reportedly have a taste reminiscent of asparagus. The green peas and surrounding white material can be removed from larger pods and cooked in various ways (Dhakar, R.C., and Maurya, D.S., 2011).

Moringa leaves are considered significant source of β-carotene, Vitamin C, protein, iron, potassium, calcium and phosphorus and are commonly dried and crushed into a powder and stored without refrigeration for months without loss of nutritional values (Fahey, 2005) and used in soups and sauces. Moringa leaves contains phytochemical, having potent anticancer and hypotensive activity and are considered full of medicinal properties and used in Siddha medicine (Rajangam *et al.,* 2001). Various nutritional and medicinal properties of M. oleifera leaves have been reported by various researchers.

Moringa tolerates a wide range of environmental conditions. It will tolerate extremely high temperatures in the shade and can survive a light frost. The drought-tolerant tree grows well in areas that receive annual rainfall amounts ranging between 250 and 1500 mm. It prefers a well-drained sandy loam or loam soil, but tolerates clay. Moringa is planted either by direct seeding, transplanting, or using hard stem cuttings. Leaves can be harvested after plants grow 1.5 to 2.0 m, which usually takes 3 to 6 months. They are harvested by snapping leaf stems from branches or by cutting the entire branches 20 to 40 cm above the ground (Abdulkarim *et al.,* 2005).

Fig.1.01. Moringa leaves

Drying cause changes in the food properties including discolouring, aroma loss, textural changes, nutritive value, and changes in physical appearance and shape. Higher drying temperature reduces the drying time but may result in poor product quality, heat damage to the surface and higher energy consumption. On the other hand, mild drying conditions with lower temperature may improve the product quality but decrease the drying rate thus drying period is lengthened. The colour measurements of food materials are used in an alternate way to determine the quality variations as they are faster than a complete physicochemical examination. Dry leaves could be sprinkled on any food to improve nutritional value.

Fresh leaves used for culinary and medicinal purposes are highly perishable by nature. To preserve leaves for longer duration and to ensure their easy availability for off-seasonal use without considerable deterioration in nutrient levels, an appropriate drying method is essential for the removal of moisture to a safe activity value. Low moisture content of products made from dried leaves helps improve their shelf life, reduce shipping weight and minimize the transportation cost. An optimized process of drying leaves is to ensure desired final moisture content retaining the original high level of nutrients as that of fresh leaves (Kumar *et al.,* 2014).

The selection parameters for the drying technique of individual leaves is based on local climate conditions, drying air temperature, relative humidity of air, drying time, size, shape, and age of leaves, etc.

So, the removal of moisture from leaves by vaporisation depends on the rate of heat and mass transfer, which is related with the following two basic phenomenon,

(1) Vaporisation of moisture from the surface of the material, and (2) movement of moisture from the internal parts of material to its surface.

Considering the above facts a study was undertaken on “Drying processes for the production and evaluation of dried Moringa leaf and optimisation of drying method” with the following objectives.

1. To conduct cabinet drying, fluidised bed drying and infrared drying of Moringa leaf
2. To evaluate the qualitative and qualitative analysis of dried Moringa leaves
3. To optimize the best drying method for Moringa leaves.

REVIEW OF LITERATURE

CHAPTER 2

REVIEW OF LITERATURE

This Chapter deals with the review of literature on Moringa, health and nutritional benefits of Moringa leaf, studies on the effect of drying on chemical composition of Moringa leaf, analysis of various components in Moringa leaf and various products from Moringa leaf.

2.1. *Moringa Oleifera*

Leafy vegetables occupy an important position in the Indian diet. India produces about 12% of the total world's production of vegetables but it is not enough to meet the country's requirements. Beside post-harvest loss reduction, improved processing and storage of processed products can play a significant role in availability of these products (Satwase *et al.*, 2013).

Moringa Oleifera is a soft wooded tree whose fruits, roots and leaves have been advocated for traditional, medicinal and industrial uses. Moringa leaves are reported to be a rich source of β-carotene, protein, vitamin C, calcium and potassium. They act as a good source of natural antioxidants and thus enhance the shelf-life of fat containing foods. This is due to the presence of various types of antioxidant compounds such as ascorbic acid, flavonoids, phenolic and carotenoids**.** Leaves are eaten as vegetables, and when pressed, are used in traditional pharmacology to treat many aliments, such as diabetes, gastric ulcers and so many others (Foline *et al.*, 2011).

There are 13 varieties of Moringa. Moringa Oleifera is the most well-known. Every part of this tree is edible, from the leaves, trunks, stems, all the way down to its root. The flowers can be eaten or used to make tea and provide good amounts of both calcium and potassium (Talhaliani *et al.*, 2000).

According to Subadra *et al*., (1997) the leaves are excellent source of protein with low sources of fat and carbohydrates. The leaves are incomparable as a source of the sulphur containing amino-acids: methionine and cystine which are often in short supply in the plant kingdom.

2.1.1. Nutritional Importance

In developing tropical countries, Moringa trees have been used to combat malnutrition, especially among infants and nursing mothers. Three non-governmental organizations in particular - Trees for Life, Church World Service and Educational Concerns for Hunger Organization - advocate Moringa as “natural nutrition for the tropics”. Every part of Moringa is a storehouse of important nutrients and antinutrients and the leaves are rich in minerals like calcium, potassium, zinc, magnesium, iron and copper (Kasolo *et al*., 2010). Vitamins like beta carotene of vitamin A, vitamin B such as folic acid, pyridoxine and nicotinic acid, vitamin C, D and E are present in Moringa Oleifera (Mbikay, 2012).

The immature pods are the most valued and widely used of all the tree parts. The pods are extremely nutritious, containing all the essential amino acids along with many vitamins and other nutrients. The pods also yield 38 to 40% of non-drying, edible oil known as Ben Oil. This oil is clear, sweet and odourless, and never becomes rancid. Overall, its nutritional value most closely resembles olive oil. The thickened root is used as a substitute for horseradish although this is now discouraged as it contains alkaloids, especially moriginine, and a bactericide, spirochin, both of which can prove fatal following ingestion. The Bark can be used for tanning and also yields a coarse fibre. The flowers, which must be cooked, are eaten either mixed with other foods or fried in batter and have been shown to be rich in potassium and calcium (Dhakar *et al.*, 2011).

Moringa tree is a plant rich in a number of nutrients such as proteins, fibre and minerals (Moyo *et al*., 2011) that play important role in human nutrition. According to Yang *et al*., (2006), Moringa leaves have significantly higher antioxidant contents when compared to fruits such as strawberries known for high antioxidant contents.

Moringa trees are known to overcome protein deficiency in developing countries as the leaves and other parts of the tree contain high amount of crude proteins and amino acids compared with soy bean. Moringa is an excellent non-animal source of protein for vegans and vegetarians. Moringa leaves contain all of the essential amino acids, which are the building blocks of proteins. Arginine and histidine, are especially important for infants who are unable to make enough protein for their growth requirements (Manzoor *et al.*, 2007).

A recent study showed that iron from Moringa can overcome iron deficiency and modulate the expression of iron-responsive genes better than conventional iron supplements (Saini *et al*., 2014).

2.1.2 Medicinal Importance

Moringa has an impressive range of medical uses with high nutritional value. The moringa plant provides a rich and rare combination of zeatin, quercetin, beta-sitosterol, caffeoylquinic acid and kaempferol. It is also used for various ailments in the indigenous medicine including the treatment of inflammation and infectious diseases along with cardiovascular, gastro intestinal, haematological and hepatorenal disorders (Anwar *et al*., 2007).

Moringa plant is also called as panacea. It is utilized to treat more than 300 diseases. The existence of abundant phytochemicals gives it a good rank of medicinal agent. Many researchers found that Moringa plant has a vital role as an anti-diabetic agent. Moringa plant is also used as anti-cancerous agent as it has good properties and can overcome the problems of cancers (Bharalli *et al*., 2018). There is a specific ability of Moringa in which it acts like anti-neoproliferative agent and stops the development of cancer cells.

Moringa is also helpful for the patients suffering from AIDS. The patients with HIV virus are fed with Moringa to hinder the growth of virus (Bhatnagar *et al*., 2010). It is also used in traditional medicine against various kinds of illnesses like recovery from liver impairment. Now it is being studied as a bio-enhancer of nutrients and drugs because of its antibiotic properties (Lopez, 2011).

2.2 Drying

Drying is one of the oldest methods of food preservation used to prevent post-harvest loss. Fresh produce do contain up to 95 % water and thus is sufficiently moist to support both enzyme activity and growth of microorganisms. Dehydrated foodstuff has a higher shelf life, making it available throughout the year. Preservation of foods by means of dehydration is one of the oldest methods and used on large scale from the time immemorial. These dehydrated products can be used in various preparations even in off-season (Foline *et al.,* 2011).

Traditional drying methods such as sun and solar drying have been reported to have many drawbacks due to inability to handle large throughput of mechanical harvesters, promoting the insect and mold development due to high relative humidity during harvesting and drying. Sun drying is the most common method used to preserve agricultural products in most tropical countries. However, this technique is extremely weather dependent, and has the problems of contamination with dust, soil, sand particles and insects. Also, the required drying time can be quite long. Therefore, using solar and hot-air dryers which are far more rapid, providing uniformity and hygiene are inevitable for industrial food drying processes (Doymaz., 2004).

Drying of agricultural products can either be done by traditional sun drying or industrially through the use of hot air drying (Tunde-Akintunde *et al.*, 2005). For heat-sensitive food products, the methods of supplying heat to the product and transporting the moisture from the product become the critical considerations for selecting the right dryer to achieve the desired product moisture content. As the temperature and drying time increases the colour of the moringa leaves becomes darker. The change in lightness value of moringa leaves is possibly because of chlorophyll degradation. The natural green colour of leaves is due to mixture of chlorophyll which is directly related to magnesium. During drying magnesium molecules are changed to pyropheophytin and pheophytin. Therefore at higher temperatures greenness is reduced. Visually, dark green colour of leaves seems as dull green yellow due to degradation of chlorophyll. The possibility of employing recent hybrid drying technologies for drying of foodstuffs and the ability of these technologies to minimize quality degradation in the final dried product has been considered in recent years. In view of the hybridize technologies, heat pump drying, fluidized bed drying, infrared drying, microwave drying, radio frequency drying, and pressure regulating drying systems were designed to improve drying efficiencies (Chow and Chua 2001).

2.3 Drying Methods

2.3.1 Cabinet drying

Cabinet/tray dryers are used for batch drying of solid foods at small to moderate scale (2000 to 20000 kg per day). These dryers are frequently found in rural installations where they are used for drying fruits and vegetables and herbs. They are inexpensive and simple to construct. This is a multipurpose, batch-operated hot air drier. It consists of an insulated cabinet, equipped with a fan, an air heater and space occupied by trays of food. In cabinet dryers, food may be loaded on trays or pans in comparatively thin layers up to few centimetres. Fresh air enters the cabinet by the fan through the heater coils, and is then blown across the food trays to exhaust. Here, the air is heated by the indirect method. Screens filter out any dust that may be in the air. The air passes across and between the trays in some designs have perforated trays and the air may be directed up through these. Air inlet temperatures are usually in the range of 50-80°C. Depending on the product and the conditions, the duration of a batch is typically 2 to 10 hours.

Cabinet dryers are usually for small operations. They may run up to25 trays high and operate with air temperatures of about 95°C and with air velocities of about 2.5-5m/sec across the trays. They commonly are used to dry fruits and vegetables pieces, and depending on the food and the desired final moisture, drying time may be of the order of 10 or even 20 hours.

2.3.2 Fluidised Bed Dryer

A fluidized bed technology is the one where direct contact between the particles and the air is achieved, thereby making the drying process efficient. Therefore, it is extensively used in the chemical industries, pharmaceutical industries, mineral processing industries and thermal power generation for drying, granulation, blending, combustion and gasification processes. The dryer was simple, compact, portable, and easy to operate.

Fluidized bed dryer works on a principle of fluidization of the materials. In fluidization process, hot air or gas flow is passed at high pressure through a perforated bottom of the container containing granules to be dried. This gas or air will move upwards through the spaces between the particles. As the velocity increases, upward drag forces on the particles increase and at a stage become equal to the gravitational forces beneath. Hence the bed is said to be fluidized and the particles are suspended in the fluid. This condition is called fluidized state (Haron *et al.,* 2017).

The main purpose of using a fluidized bed is to enhance the rate of drying. It consists of multiple phases such as solid particles, moisture in solid particles, air and moisture in air. The high turbulence generated in the bed is responsible for high heat and mass transfer, as well as adequate mixing of the solids and gases within the bed. This serves as a primary advantage of the fluidised bed dryer. One of the disadvantages in fluidised bed dryer is that since the solid particles are at temperature equivalent to the temperature of the gas it needs to be cooled to the temperature useful for further processing of particles. Fluidization largely depends on the characteristics of the particles.

2.3.3. Infrared Drying

Infrared heating or drying involve a heat transfer by radiation between a hot element and a material at lower temperature that needs to be heated or dried (Sadin *et al.,* 2014). IR radiation encompasses the portion of the electromagnetic spectrum, which falls between the region of visible light and microwaves. When electromagnetic radiation impinges on food surface, it causes changes in the electronic, rotational, and vibrational states of atoms and molecules (Sakai *et al.*, 1994). Changes in electronic and rotational state correspond to wavelength in the range of 0.2– 0.7 μm (ultraviolet and visible rays) and above 1000 μm (microwaves), respectively. IR radiation causes changes in the vibrational state of the molecule. After penetration in food materials, IR rays vibrate the constituent molecules at a frequency of 60,000 –150,000MHz, which results in intermolecular friction and brings about rapid internal heating (Fasina *et al.,* 2001). IR radiation does not require any medium for its propagation. It is transferred from the heating element to the product surface without heating the surrounding air (Bal *et al.,* 1970).

IR drying has several advantages over conventional drying system. These advantages include short process time, improved energy efficiency, uniform or even product temperature, superior quality of final products, and high degree of process control parameters, high heat transfer coefficient, space saving, and eco-friendliness. IR drying is known as a means of dehydration that allows a high rate of water evaporation without quality losses, like changes in color, shrinkage, surface hardening, sample deformation, loss of aroma, the gap between the surface and bottom moisture content, and loss of ascorbic acid (Muhmmed *et al.*, 2014).

IR heating has been identified as a promising method to obtain high-quality dried food products, including fruits, vegetables, grains, and other high-value products. Other non-food applications of IR drying include drying of paints, coatings, adhesive, paper, board, and textile (Priyanka *et al.,* 2020).

Comparison of IR drying with convective drying of apple showed that drying time of the process can be shortened to about 50% when heating is done with IR energy (Nowak and Lewicki., 2004). The total energy consumption was defined as the sum of the electrical energy consumed during drying process and included the energy used to heat the air, energy to drive fan, energy to drive the conveyor, and energy used in the infrared heaters. Specific energy consumption was lower, and thermal efficiency was higher for the IR-hot air setting when compared to both IR and hot air settings (El-Mesery and Mwithiga, 2015).

MATERIALS AND METHODS

CHAPTER 3

MATERIALS AND METHODS

This Chapter deals with the methodologies used to perform the drying of sample.

3.1. Raw materials

The raw materials used for the development of the dried Moringa leaves were freshly harvested Moringa leaves from backyard of canteen and ladies hostel of our campus.

3.2. Leaf harvesting

Harvesting can be done by removing the leaves, picking them directly off the tree. They are easily removed at the base of the petiole. It should be harvested at the coolest time of the day: early morning or late in the evening

Leaf harvested is done by hand picking and the damaged leaves are discarded manually just after the collection of fresh leaves.

Plate 3.01Leaf harvesting

3.3. Drying

Drying of fresh Moringa leaf having initial moisture content of 73.87-78.33% (wb) was carried out using three different drying methods: cabinet drying, fluidized bed drying and infrared drying at different temperatures and drying characteristics were noted.

3.3.1. Cabinet drying

50 g of Moringa leaves were distributed uniformly on trays in a cabinet at 50°C, 60°C, and 70°C temperatures. A digital balance with accuracy ± 0.001 g was used to measure the mass of samples. Leaves were dried until the readings became constant. These readings were used to draw the drying curve.

Plate 3.02 Cabinet Dryer

3.3.2. Fluidized bed dryer

50 g of Moringa leaves is introduced into drying chamber and is heated at 50°C, 60°C,and 70°C temperatures. A digital balance with accuracy ± 0.001 g was used to measure the mass of samples. Leaves are dried by introducing hot air through a perforated distribution plate into drying chamber at constant air velocity ( ). The leaves get suspended in the air. Leaves were dried until the readings became constant. These readings were used to draw the drying curve.

Plate 3.03 Fluidized bed dryer

3.3.3. Infrared dryer

50 g of Moringa leaves were distributed uniformly on trays in a cabinet at 50°C, 60°C, and 70°C temperatures and at an airflow rate of 7m/s. A digital balance with accuracy ± 0.001 g was used to measure the mass of samples. Leaves were dried until the readings became constant. These readings were used to draw the drying curve.

Plate 3.04 Infrared dryer

3.4. Colour measurement

The colourimeter was used to measure the L*, a* and b* values of fresh and dried Moringa leaves at four different temperatures. Readings of each sample were taken. The L* measures the whiteness, ranges from (black at 0 to white at 100). The a* measures green when negative and red when positive and the b* measures blue when negative and yellow when positive (Ali *et al.*, 2014).

Plate3.05 Hunter lab colour flex meter

3.5. Moisture content determination

Using Infrared Moisture Analyser,

- Connect the machine to a suitable power source.
- Then in the screen display will on and it automatically go to off, then we press on (top left) button in the analyser.
- Open the lid and place the sample port and tare it then put the sample to be measured and close the lid.
- Press the start button.
- A beep sound indicates the moisture is analysed.
- The moisture content will be displayed on the screen.
- Press the esc button and open the lid and take out the product and sample port.
- Close the lid and off the power.

Plate 3.06 Infrared moisture analyser

3.6. Quantitative analysis

3.6.1 Ash

Ash content gives the total mineral content in a sample. For the determination of ash content of a given sample a known weight of Moringa powder taken in a crucible was placed in a muffle furnace at 600°C for 2 hours. The crucible was removed from the furnace carefully and cooled it in a desiccator to room temperature and weighed again.

Ash content (%) = (Z – X /Y – X) x 100

Where

Weight of empty crucible - X g

Weight of crucible + sample - Y g

After complete ashing, weight of crucible + ash - Z g

3.7 Test for detection of compounds

Standard protocols were used for qualitative analysis of samples to check for the presence of Carbohydrates, flavonoids, and sterol.

3.7.1 Test for carbohydrates

Take 1 ml of each sample, add few drops of Molisch's reagent and add 1 ml of concentrated sulphuric acid at the side of the tubes. The mixture was then allowed to stand for 2-3 minutes. Formation of red or dull violet colour (a ring formation) indicated the presence of carbohydrates in the sample extract.

3.7.2 Test for Flavonoids

Take 3ml of each extract was added to 10ml of distilled water the solution was shaken. Add 1ml of 10% NaOH solution to the mixture. Formation of yellow colour indicated the presence of carbohydrates in the sample extract.

3.7.3 Test for Steroids

Take 1ml of each extract in a separate test tube; add 5 drops of concentrated H2SO4. Formation of red colour indicated the presence of steroids in the sample extract.

RESULS AND DISCUSSION

CHAPTER 4

RESULT AND DISCUSSIONS

4.1. Drying characteristics

4.1.1 Cabinet Drying

Fig 4.10 shows the drying curve of the repeated experiments of drying Moringa leaves in a cabinet dryer. During the drying experiments, the temperature of the dryer was set at 50°C, 60°C,and 70°C. 50 g Moringa leaves of 38.3, 37.14, 36.94 (g water/g dry matter) initial moisture content were dried to 2.87, 2.24, 2.36 (g water/g dry matter) respectively in the cabinet dryer. Final drying of leaves took 130, 120, 105 min respectively. The changes in the moisture contents per amount of the dry matter of Moringa leaves with time are also shown in Fig 4.10.

Temperature (° C)	Drying time(min)	Weight of sample(g)	Water content(g)	Moisture content %(wb)
50	0	50	38.3	76.6
50	15	37.14	25.44	50.88
50	30	30	18.3	36.6
50	45	22.855	11.15	23.31
50	60	15.57	6.87	13.74
50	75	15.714	4.014	8.028
50	90	14.57	2.87	5.74
50	115	14.57	2.87	5.74
50	130	14.57	2.87	5.74

Table 4.01. Moisture content determination for cabinet drying, 50° C

Temperature (° C)	Drying time(min)	Weight of sample(g)	Moisture content(wb)	Water content %(g)
60	0	50	74.2	37.14
60	15	33.84	41.88	20.94
60	30	29.34	32.88	16.44
60	45	25.54	25.28	12.64
60	60	19.74	13.68	6.84
60	75	16.24	6.68	3.34
60	90	15.14	4.48	2.24
60	105	15.14	4.48	2.24
60	120	15.14	4.48	2.24

Table 4.02. Moisture content determination for cabinet drying, 60° C

Temperature (° C)	Drying time(min)	Weight of sample(g)	Moisture content %(wb)	Water content(g)
70	0	50	73.88	36.94
70	15	34.5	51.30	23.35
70	30	16.8	24.40	12.20
70	45	20.37	14.6	7.3
70	60	17.35	8.56	4.28
70	75	12.1	4.72	2.36
70	90	12.1	4.72	2.36
70	105	12.1	4.72	2.36

Table 4.03. Moisture content determination for cabinet drying, 70° C

4.1.2 Fluidized bed dryer

Fig 4.11 shows the drying curve of the repeated experiments of drying Moringa leaves in a fluidized bed dryer. During the drying experiments, the temperature of the dryer was set at 50°C, 60°C,and 70°C. 50 g Moringa leaves of 36.45, 36.7, 36.6 (g water/g dry matter) initial moisture content were dried to 1.05, 3.085, 2.65 (g water/g dry matter) respectively in the fluidized bed dryer. Final drying of leaves took 120, 90, 60 min respectively. The changes in the moisture contents per amount of the dry matter of Moringa leaves with time are also shown in Fig 4.11.

Temperature (° C)	Drying time(min)	Weight of sample(g)	Water content(g)	Moisture content %(wb)
50	0	50	36.45	72.9
50	15	45.1	31.55	63.1
50	30	39.8	26.25	52.5
50	45	33.6	20.05	40.1
50	60	25.7	12.15	24.3
50	75	17.4	3.85	7.7
50	90	14.6	1.05	2.1
50	105	14.6	1.05	2.1
50	120	14.6	1.05	2.1

Table 4.04. Moisture content determination for Fluidized bed drying, 50° C

Temperature (° C)	Drying time(min)	Weight of sample(g)	Water content(g)	Moisture content %(wb)
60	0	50	36.7	73.4
60	15	26.1	23.9	47.8
60	30	16.2	18	36
60	45	15	3.085	6.17
60	60	15	3.085	6.17
60	90	15	3.085	6.17

Table 4.05. Moisture content determination for Fluidized bed drying, 60° C

Temperature (° C)	Drying time(min)	Weight of sample(g)	Water content(g)	Moisture content %(wb)
70	0	50	36.6	73.2
70	15	13.4	7.86	15.72
70	30	12.6	2.65	5.3
70	45	12.6	2.65	5.3
70	60	12.6	2.65	5.3

Table 4.06. Moisture content determination for Fluidized bed drying, 70° C

4.1.3 IR dryer

The changes in the moisture contents per amount of the dry matter of Moringa leaves with time for IR dried Moringa leaves are shown in Table 4.07, 4.08, 4.09. During the drying experiments, the temperature of the dryer was 50℃, 60°C,and 70°C. The 50 g Moringa leaves of 36.45, 36.14, 36.6 (g water/g dry matter) average initial moisture content were dried to 3.85, 2.74, 2.65 (g water/g dry matter) respectively in the IR dryer. It took, 90, 75, 60 min respectively to complete the drying process.

Temperature (° C)	**Drying time(min)**	**Weight of sample(g)**	**Water content(g)**	**Moisture content %(wb)**
50	0	50	36.45	72.9
50	15	38.4	31.55	63.1
50	30	20.6	26.25	52.5
50	45	18.56	20.05	40.1
50	60	15.75	12.15	24.3
50	75	17.4	3.85	7.7
50	90	17.4	3.85	7.7

Table.4.07. Moisture content determination for IR drying, 50° C

Temperature (° C)	**Drying time(min)**	**Weight of sample(g)**	**Water content(g)**	**Moisture content %(wb)**
60	0	50	36.14	72.28
60	15	38.6	24.74	49.48
60	30	19.1	5.2	10.48
60	45	16.6	2.74	5.48
60	60	16.6	2.74	5.48
60	75	16.6	2.74	5.48

Table.4.08. Moisture content determination for IR drying, 60° C

Temperature (° C)	Drying time(min)	Weight of sample(g)	Water content(g)	Moisture content %(wb)
70	0	50	36.6	73.2
70	15	29.5	7.86	15.72
70	30	15.14	2.65	5.3
70	45	15.14	2.65	5.3
70	60	15.14	2.65	5.3

Table.4.09. Moisture content determination for IR drying, 70° C

4.2. Drying curve of Moringa leaves using different dryers

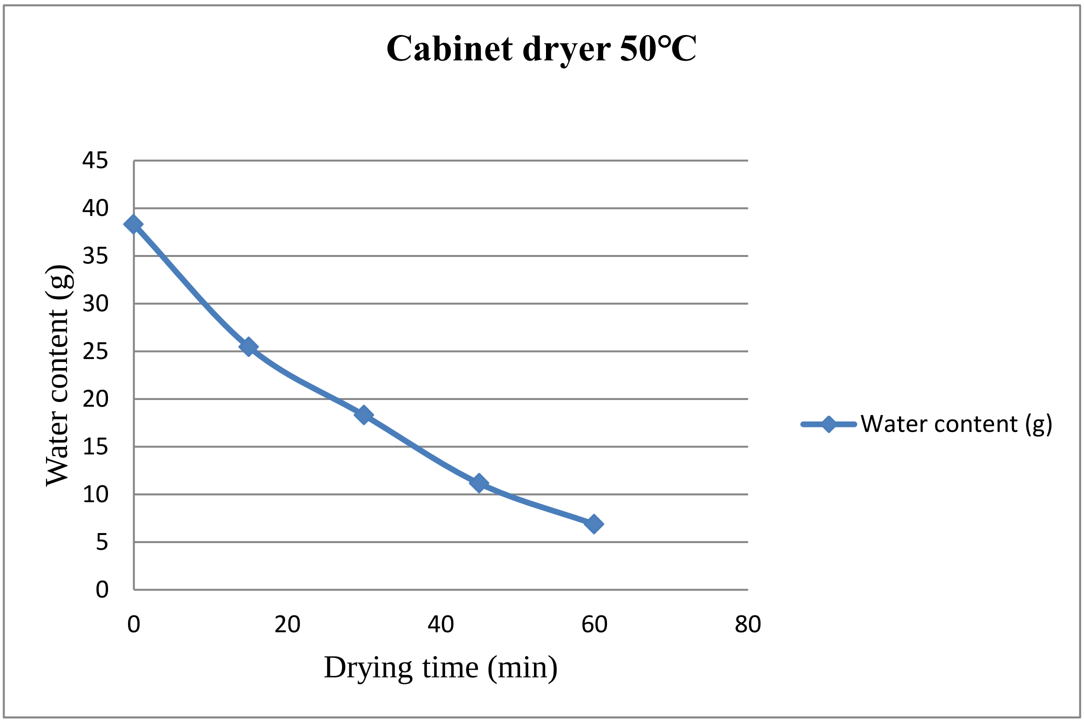

Fig.4.01. Drying curve for Cabinet dryer 50℃

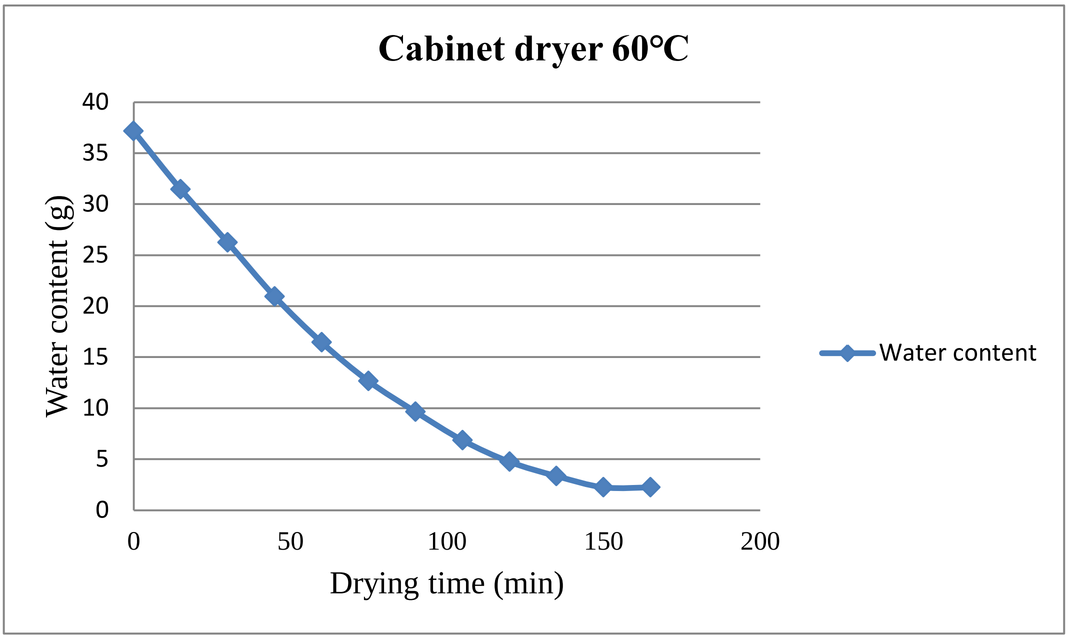

Fig 4.02. Drying curve for Cabinet dryer 60℃

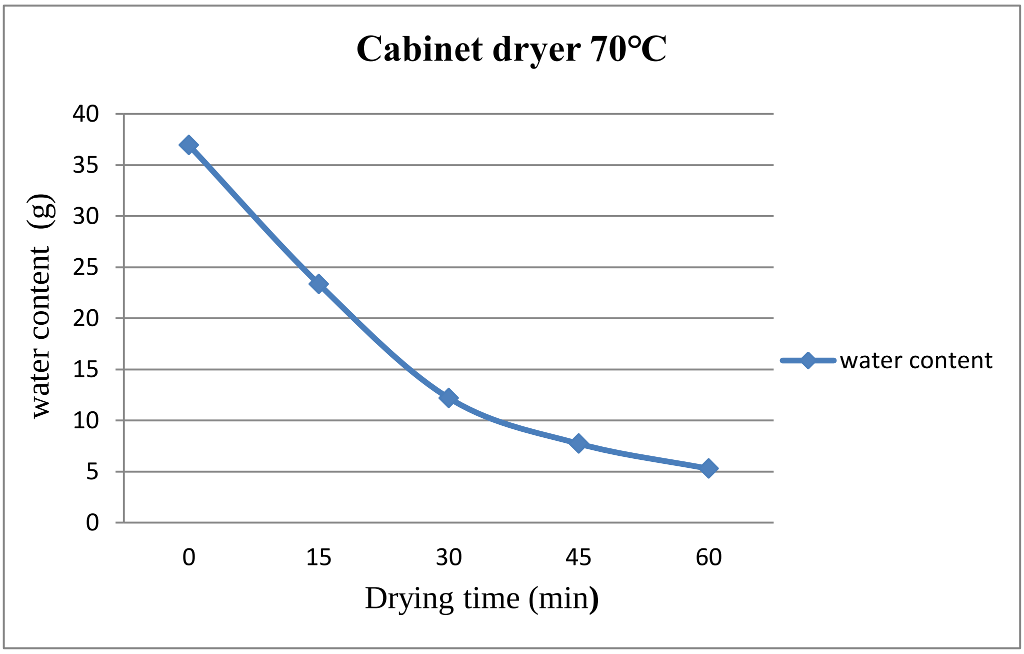

Fig 4.03. Drying curve for Cabinet dryer 70℃

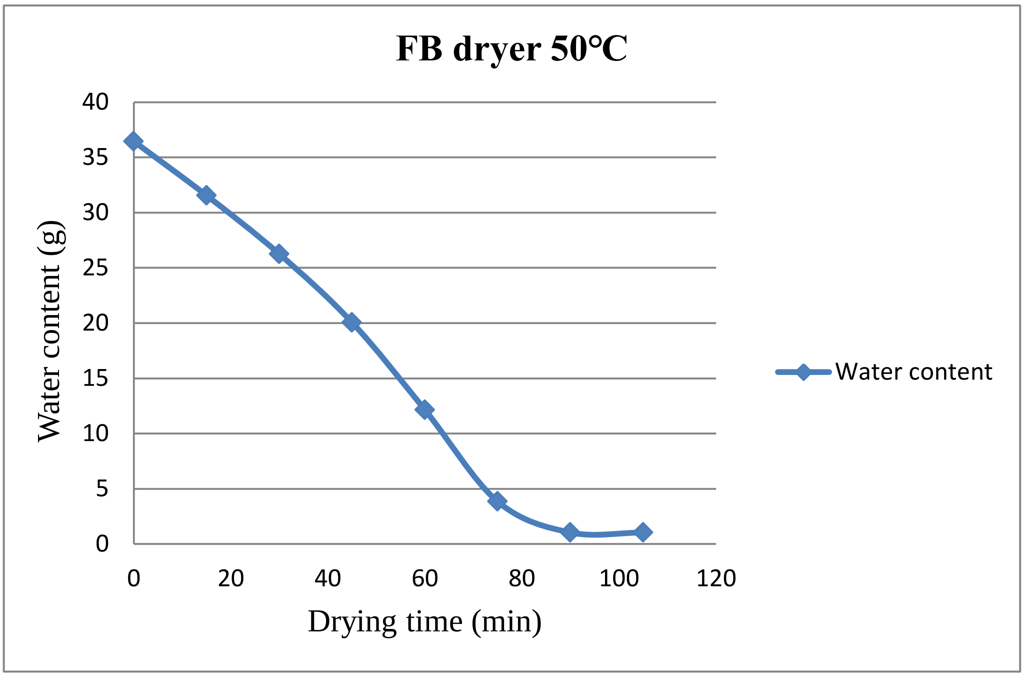

Fig.4.04. Drying curve for fluidized bed dryer 50℃

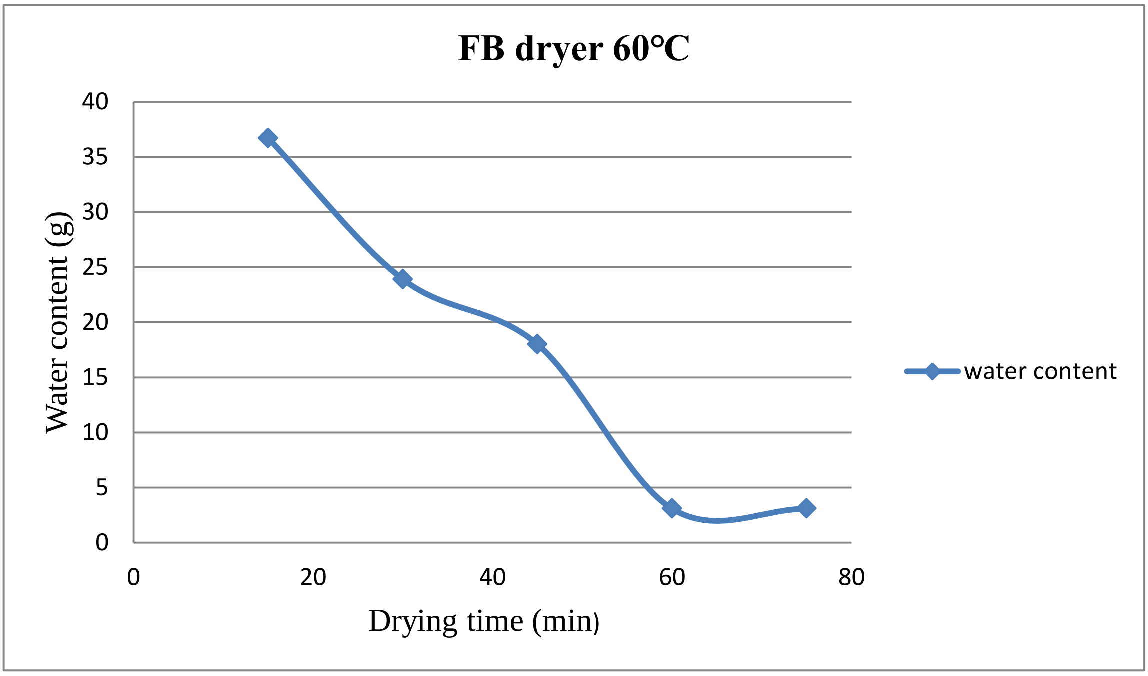

Fig.4.05. Drying curve for fluidized bed dryer 60℃

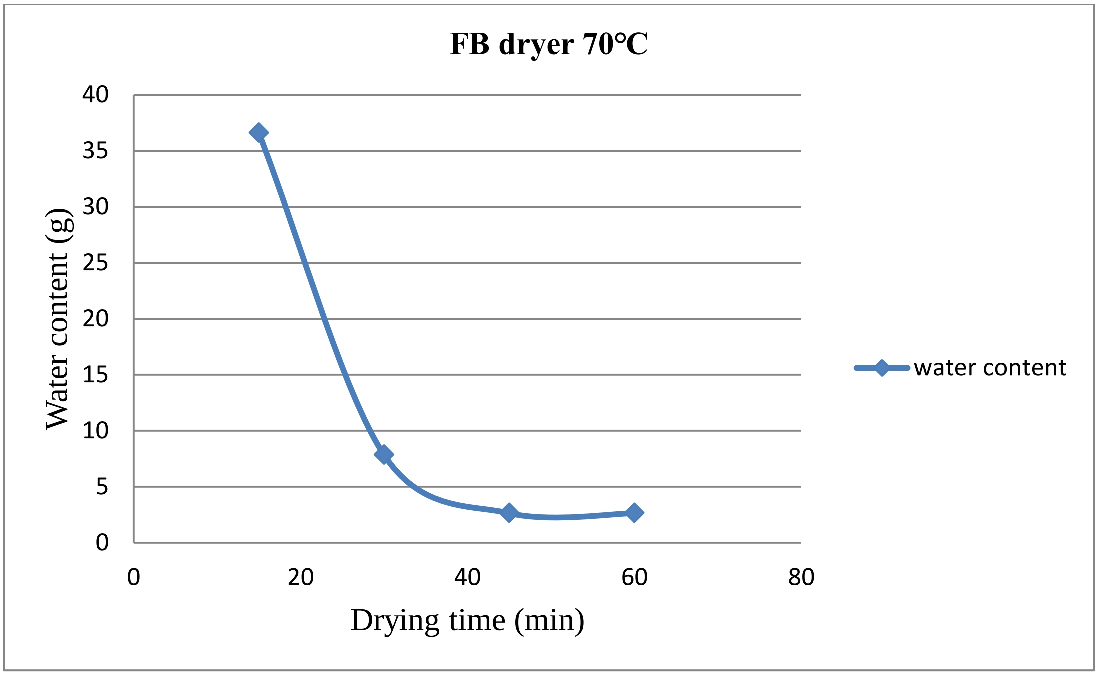

Fig.4.06. Drying curve for fluidized bed dryer 70℃

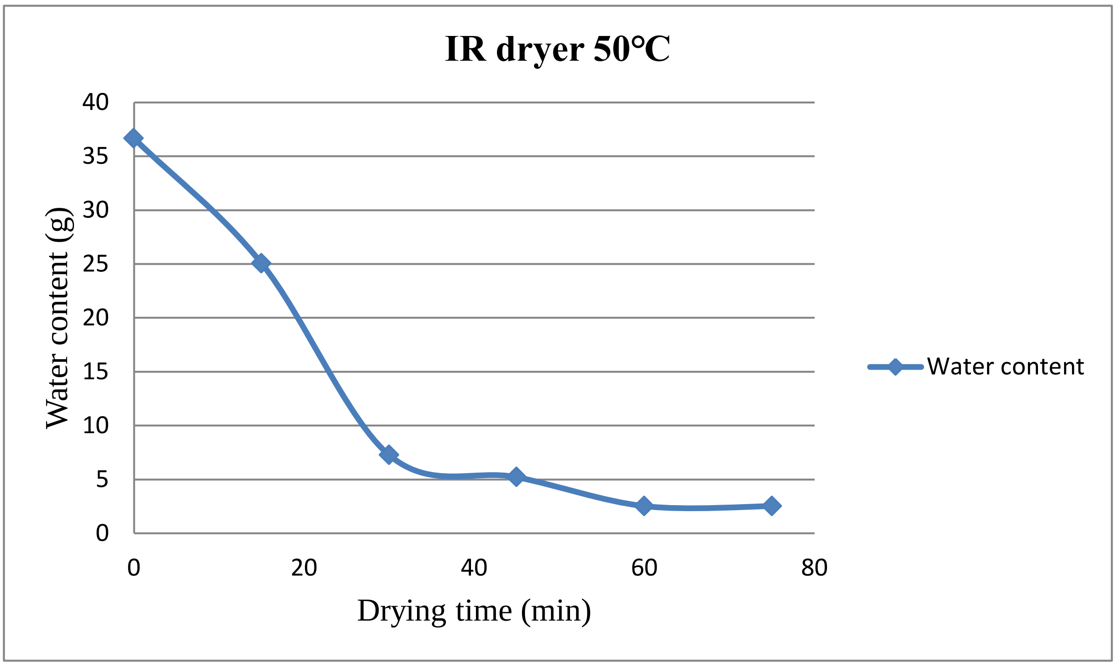

Fig.4.07. Drying curve for IR dryer 50℃

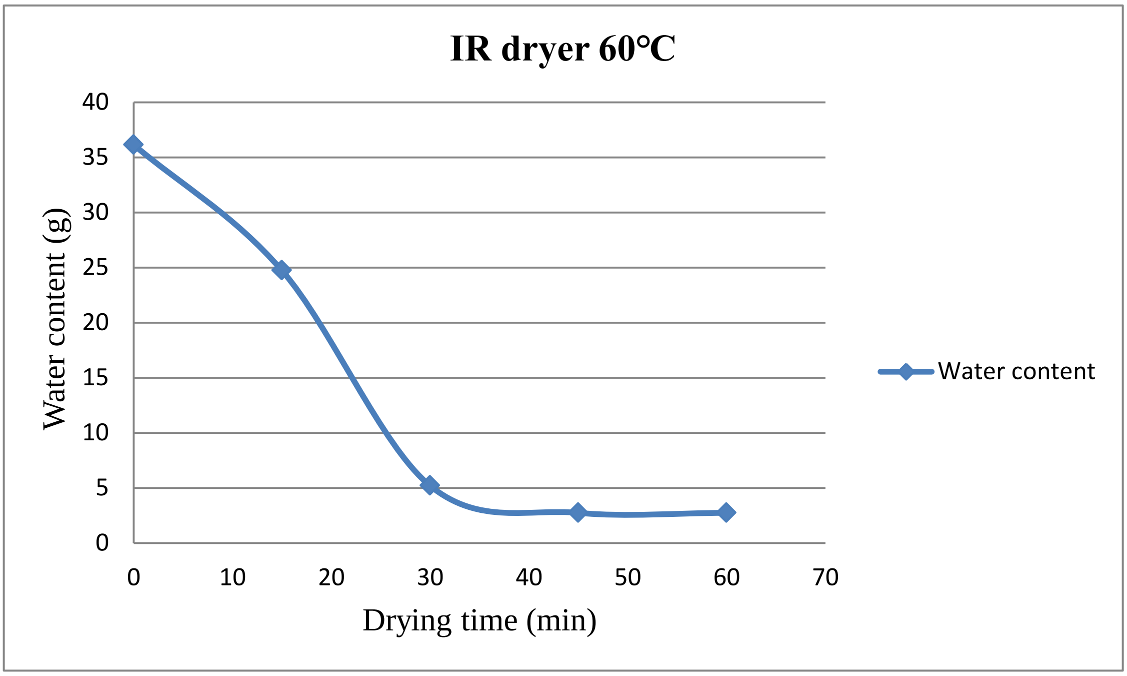

Fig.4.08. Drying curve for IR dryer 60℃

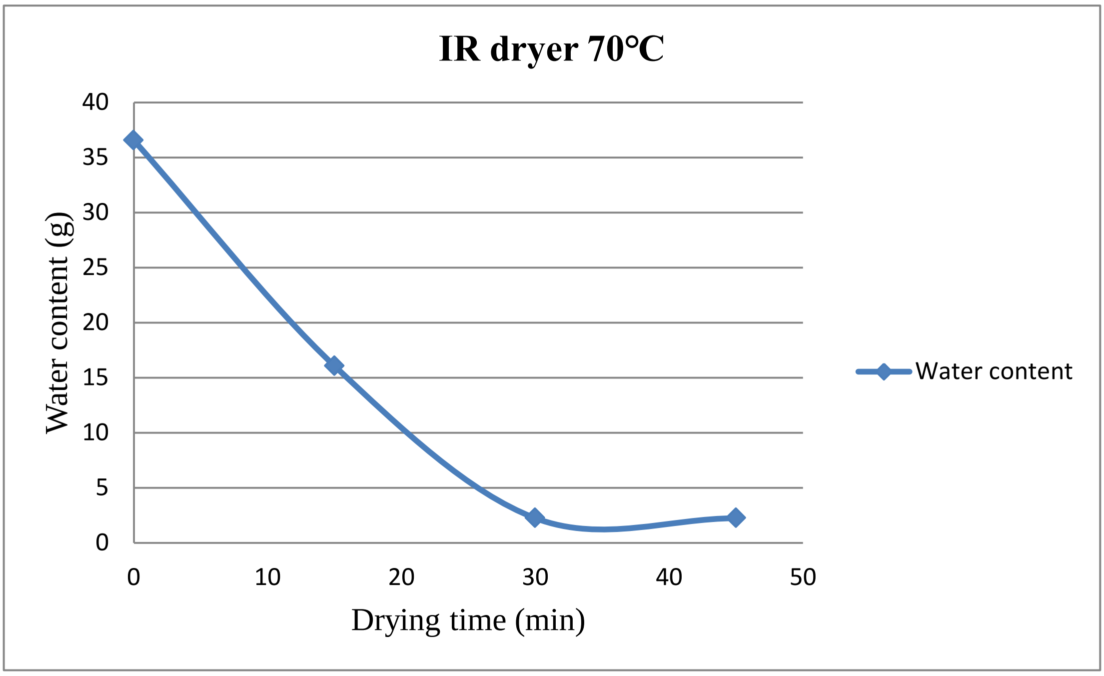

Fig.4.09. Drying curve for IR dryer 70℃

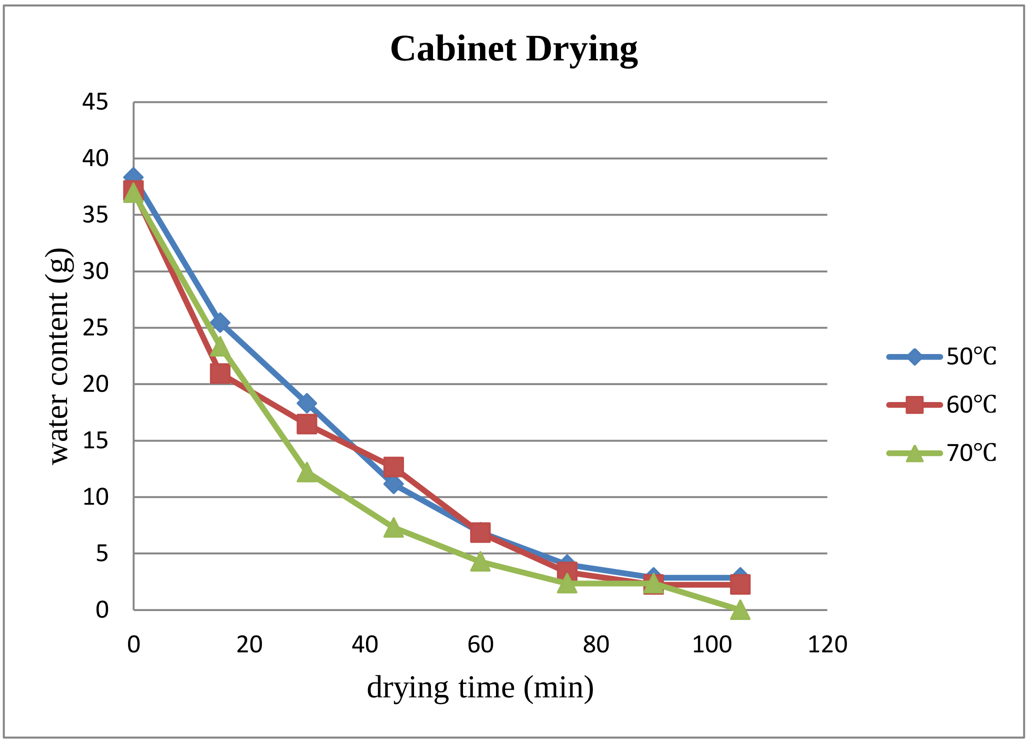

Fig.4.10. Drying curve for Cabinet dryer

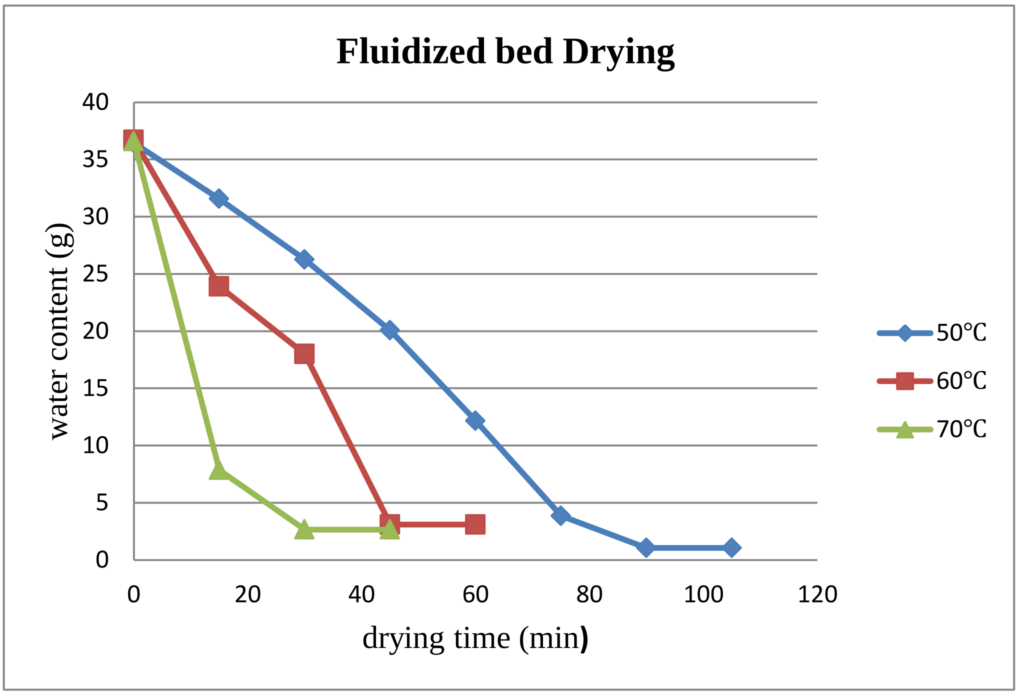

Fig.4.11. Drying curve for fluidized bed dryer

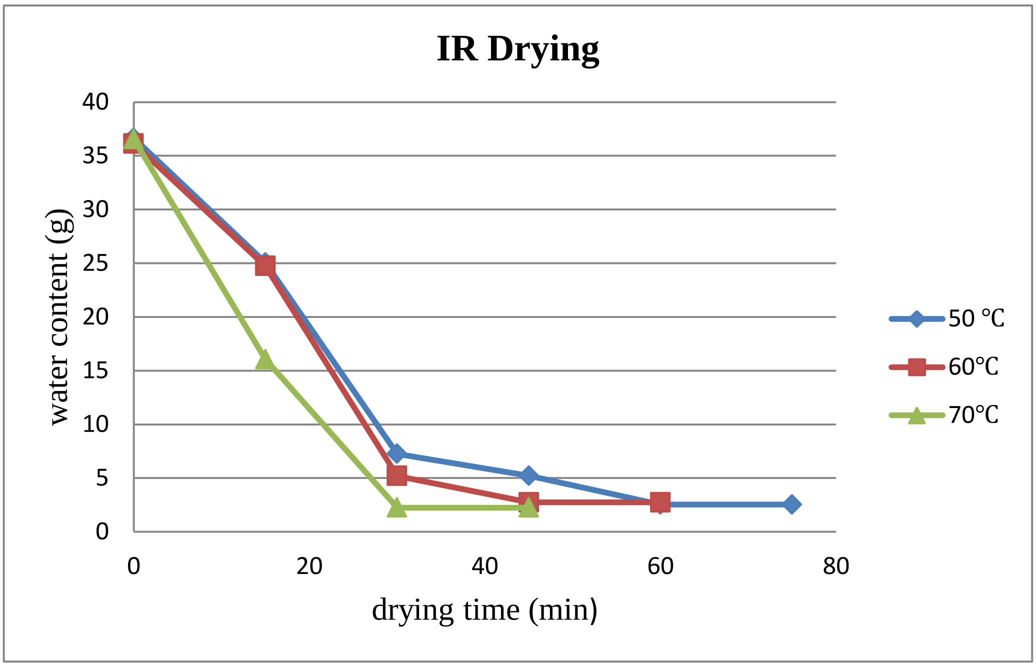

Fig.4.12. Drying curve for IR dryer

The drying rate as a function of moisture content at different drying air temperature for Moringa leaves with treatment in different dryer is shown in Figure , 4.10, 4.11, and 4.12. It can be seen that initially the drying rate was more and subsequently it reduced with drying time. It can also be seen that they follow typical drying rate curves. These drying rates continuously decreased with respect to time.

Drying curves (Figure 4.10, 4.11, and 4.12) were experimentally obtained by plotting the moisture content versus drying time. A considerable time period is required to achieve complete drying and to reach equilibrium moisture content (EMC). At initial stage of the drying process, the moisture contents of Moringa leaves were high due to the availability of free moisture samples at the initial stage. The moisture contents of leaves were decreasing with increasing temperature. This finding agreed with work of Seremet *et al.*, (2016), who also found that drying removes the water from the food and consequently inhibits the development of microorganisms, improves food preserving as well as proper storage. The drying curves agreed with the theory of drying (I. Doymaz *et al.*, 2006). Initially, sensible heat was transferred from to the fresh leave and the moisture was removed from the leave. The rate of evaporation increased during this period. Then, the moisture kept being removed from the saturated leaves surface.

During this period, the rate of evaporation was the highest and it changed very little as the moisture content was reduced. As illustrated in Figures 4.10, 4.11, and 4.12, the actual drying rate was seen to fluctuate within this period; it could be attributed to the phase transition of water from the leave surface to the surrounding air. The falling rate period coincided with the last stage of drying. The material surface in the falling rate period was no longer saturated with water and the drying rate was controlled by diffusion of moisture from the interior of solid to the surface as cited by L.M. Diamante *et al.*, 1993.

4.4 Ash

Sample	Ash content(g)
Fresh leaf	0.065
Cabinet	0.2
Fluidised bed	0.15
Infrared	0.19

Table.4.10. Ash content in dried Moringa leaves

Ash content represents the total mineral present in the sample. After the analysis it was found that cabinet dryer and infrared had the highest value of ash content (0.2 g & 0.19 g).

The ash content in Moringa leaves is high, which means that inorganic elements are substantial in the plant (McClements *et al.*, 2009). The percentage of ash content was much lower in fresh leaves than dried leaves.

4.5 Color characteristics

Colour of product is an important parameter that will be valued during product marketing. Colour of the Moringa leaves was measured by Hunter lab colour flex meter. L*, a*, and b* values of fresh Moringa leaves were 38.73, -8.95 and 18.15. The lightness values decreased as temperature increased and leaves colour became dark green. The change in lightness value of Moringa leaves possibly because of chlorophyll degradation. The decrease in L* value when dried for all drying temperatures which is possibly due to drying time and drying temperature (Rudra *et al.,* 2008). The lower a*/b* and higher L* values are preferred in dried food products (Doymaz et al., 2006).

The L* value is high for Infrared dried moringa leaves at drying temperature 60℃ and the a*/b* value is also lower for moringa leaves dried in Infrared dryer at 60℃. Therefore IR dried Moringa leaves showed better color quality compared to fresh leaf.

The color of green vegetables is mainly determined by the chlorophyll pigments available in plant materials, which to catch the energy from the sun light. In most cases, color changes are reflected in the chemical, biochemical and microbiological reactions. The natural green colour of leaves is due to mixture of chlorphyll which is directly related to magnesium. During drying, the magnesium molecules are changed to pyropheophytin and pheophytin (Buchaillot *et al.,* 2009). Therefore, at higher temperatures greenness is reduced. Visually, dark green colour of the leaves seemed as dull green-yellow due to degradation of chlorophyll.

Indicators of fresh and dried leaves of linden at 50, 60, and 70 is presented in Table 4.10. The L*, a*, and b* values mentioned in the Table 4.10, represent lightness (L*), greenness (a*), and yellowness (b*) of linden leaves respectively.

Sample	Temperature (°**C)**	L* value	a* value	b* value
Fresh leaves	Room temp	38.73	-8.95	18.15
Cabinet	50	33.79	-4.0	17.53
	60	29.12	-4.25	13.33
	70	27.37	-0.78	13.75
Fluidized	50	33.62	-0.78	17.79
	60	31.56	-5.31	18.56
	70	35.17	-6.04	21.91
IR	50	38.12	-9.56	24.34
	60	40.36	-10.21	22.17
	70	39.57	-9.93	21.29

Table 4.11. Colour characteristics of Moringa leaves at different temperature.

SUMMARY AND CONCLUSION

CHAPTER 5

SUMMARY AND CONCLUSION

Moringa Oleifera belonging to the family of Moringaceae is an effective remedy for malnutrition. All parts of *M. Oleifera* tree is said to have useful assets that can help humankind. The Moringa plant has found a great deal of economic, nutritional and medicinal use globally as all its parts contain good sources of proteins, vitamins and minerals and carotenoids. Moringa tree is rich in nutrients such as minerals, fibre and proteins that can play essential role in human nutritional consumption. *M. Oleifera* is often referred as a panacea and can be used to cure more than 300 diseases. Moringa is an ideal crop for sustainable food production that thrives as the climate changes. Every part of *M. Oleifera* is a storehouse of important nutrients and anti-nutrients. The leaves of *M. Oleifera* are rich in minerals like calcium, potassium, zinc, magnesium, iron and copper. Vitamins like beta-carotene of vitamin A, vitamin B such as folic acid, pyridoxine and nicotinic acid, vitamin C, D and E also present in *M. Oleifera*. Phytochemicals such as tannins, sterols, terpenoids, flavonoids, saponins, anthraquinones, alkaloids and reducing sugar present along with anti-cancerous agents like glucosinolates, isothiocyanates, gly-coside compounds and glycerol-1-9-octadecanoate. Moringa leaves also have a low calorific value and can be used in the diet of the obese.

One of the best ways of utilization of these leaves is to dry them first and then incorporate them into various food products. Leaves particularly when dried are easy to handle and store as they have a very good shelf life. Also, after drying, the nutrients are more concentrated, thereby making them even richer and more valuable. The drying operation is a very ancient practice for food preservation, but instead of being abandoned presently it continues very important industrial process of treatment for diversified food products. Much innovation and technological advancements have led to better drying processes, more efficient in energetic terms and allowing a better preservation of the organoleptic and nutritional qualities.

The work started with the harvesting of fresh Moringa leaf which was both young and old. It was dried using various drying methods like cabinet, IR and fluidized bed drying methods. M. Oleifera leaves were dried at 50, 60, and 70°C temperature, the drying rate decreased continuously throughout the drying period. Constant rate period was absent and the drying process of moringa leaves took place in falling rate period. Drying time decreased considerably with increased temperature. The quality parameters like carbohydrate, sterol and flavonoid was done. Standard protocols were used for qualitative analysis of samples and the presence of carbohydrate, sterols and flavonoids were found out in all the dried samples. Engineering properties like colour, and proximate analysis (ash content) for various samples were measured. The color was measured using Hunter lab colour flex meter.

The ash content was seen high for cabinet dryer and infrared dryer with a value of 0.2 g and 0.19 g**.** The ash content represent the minerals in the moringa leaves. As the moringa leaves is rich source of minerals indicate that these minerals are preserved more in the drying of cabinet and infrared dryer. Infrared dried Moringa leaves at 60℃ showed better colour quality compared to fresh leaf with higher L* and lower a*/b values (L*=40.36, a*=-10.21, b*=22.17). To select the best drying method, different criteria such as plant species, cost, and final color of dried plant, and the time of drying should be considered.

Since the use of Moringa leaves and its products have been increasing during the past decades, selecting the best drying method in respect to qualitative and nutritional characteristics of this product is very important. The application of infrared radiation reduced the total electrical energy consumption of the drying process, and the increase in air temperature led to a proportional increase in energy consumption. Time taken for drying the Moringa leaves in infrared was found to be lower than fluidized bed and tray drier. Thus, the product dried in infrared was at a much better quality than the other driers. The rate of drying and the quality and time of drying is much more efficient in infrared drying when compared to tray and fluidized bed drying. The product is less deteriorated in infrared dryer than tray and fluidized bed dryers. Thus, for drying Moringa leaves infrared dryer is much more economic and efficient and it requires less adaptation time when compared to other dryers.

The use of infrared radiation was effective to increase the air and grain temperature, thus, providing lower drying time and energy consumption and higher drying rate. The drying temperature can be in the range 50°C - 65°C. The higher temperatures and longer drying time lead to more color damage. The advantages of infrared drying over other methods are clear and it is one of the better promising alternative method of drying among the tray drying and fluidized bed dryer.

RECOMMENDATION AND FUTURE PERSPECTIVE

CHAPTER 6

RECOMMENDATION AND FUTURE PERSPECTIVE

Recommendations of this study are:

- Moringa Leaf collection is suitable to be done in the morning.
- Moringa leaves from any variety of the plant can be used.
- The separation and cleaning of the leaves has to done carefully to avoid any extraneous matter.
- Care should be taken when Moringa leaves are dried in dryers working on the principle of convection heat because the leaves being lightweight can be flown away.
- Glass or plastic containers can be used as a low cost method for storage of moringa leaves during the study period.

Future perspectives of this study are:

.

- Moringa Leaf can be used for the preparation of Moringa Leaf Tea Powder which is healthier than other Tea powders.
- The drying method found out is cost effective and retains most of constituents in the leaf as compared to the others.
- The Dried Moringa leaves or powdered moringa leaves can be stored for a longer period of time and have excellent exporting potential .
- The Optimum drying method can be used in the production of Moringa leaves commercially.
- It is also found out that the different parts of the Moringa plant other than the leaves are rich in proteins, vitamins and minerals and present different pharmacological and biotechnical potential.

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CHAPTER 7

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APPENDIX

APPENDIX

COST ESTIMATION

• COST ANALYSIS OF CABINET DRYING

Capacity of the cabinet dryer =10-15kg

Working hour for Moringa leaves dry = 4 hrs

Cost of cabinet dryer (C) =Rs. 50000/-

Life span of the unit (n) = 15 Years

Annual usage (A) = 300 Days

Interest rate (i) = 11% per annum

I. Fixed cost per year

Fixed cost of the cabinet dryer (C) $= \frac{\mathbf{i(i+1)^n}}{\mathbf{(i+1)^n+1}} \times \mathbf{c}$

$$= \frac{0.11(0.11+1)^{15}}{(0.11+1)^{15}+1} \times 50000$$

= **Rs.4549/-**

II. Variable cost per year

(a) Repair and maintenance of solar cabinet dryer = 2 % of initial cost of the cabinet dryer

=50000 *(2/100)

=Rs.1000/-

(b) Cost of energy

Energy requirement of cabinet dryer =5 kWh/10 h

Energy requirement

2 fan = 80 w/h

3 light = 120 w/h = 1.4 KWh/10h

2 Exhaust = 80 w/h

Total energy requirement = 6.4KWh/10h

Electricity charges = Rs. 5.85 / kWh

Electricity consumption charges = No. of days x Energy/day x Rate

=300×6.4x 5.85

=Rs.11232/-

(c) Cost of raw material

Cost of moringa leaves = Rs.80/ kg

Total quantity of moringa leaves required per day = 20 kg

Cost of moringa leaves used per year =80×20×300

= Rs 4,80,000/-

Total variable cost for Drying of moringa leaf = a+b+c

=1000+11232+480000

=Rs492232/-

Total cost for the dried moringa leaf per year (m) = Total fixed cost + Total variable cost

= 4549+492232

= Rs496781/-

Production of dried moringa leaf per day = 6Kg

Total production of dried moringa leaf/ year (n) = 6× 300

= Rs.1,800/-

Cost of production of one kg of MLP/ year $= \frac{m}{n}$

$= \frac{496781}{3000}$

= **Rs.166/ kg**

- **COST ANALYSIS OF IR DRYER**

Capacity of the IR dryer = 0.5 kg/hr

Working hour for drying Moringa leaves = 3 h

Cost of IR dryer (B) = Rs. 25,000/-

Life span of the unit (n) = 15 Years

Annual usage (A) = 300 Days

Interest rate (i) = 11% per annum

I. Fixed cost per year

Fixed cost of the IR dryer (B) $= \frac{\mathbf{i(i+1)^n}}{\mathbf{(i+1)^n+1}} \times \mathbf{B}$

$= \frac{0.11(0.11+1)^{15}}{(0.11+1)^{15}+1} \times 25{,}000$

= Rs.2275/-

II. Variable cost per year

a) Repair and maintenance of IR dryer = 2 % of initial cost of the IR dryer

= 25,000 × 2 100

= Rs. 500/-

b) Cost of energy

Energy requirement of IR dryer = 2 KWh/10 h

Energy requirement of grinder = 5 KWh/10h

Energy requirement

2 fan = 80 w/h

3 light = 120 w/h = 1.4 KWh/10h

2 Exhaust = 80 w/h

Total energy requirement = 8.4KWh/10h

Electricity charges = Rs. 5.85 / kWh

Electricity consumption charges = No. of days x Energy/day x Rate

= 300×8.4x 5.85

= Rs.14,742 /-

c) Cost of raw material

Cost of moringa leaves = Rs.80/Kg

Total quantity of moringa leaves required per day = 1.33Kg

Cost of moringa leaves used per year = 80×1.33×300

= Rs.32,000/-

Total variable cost for Drying of moringa leaf **= a+b+c**

= 500+14,742+32,000

= Rs. 47,242/-

Total cost for the dried moringa leaf per year (m) = Total fixed cost + Total variable cost

=2275+47,242

=Rs.49,517/-

Production of dried moringa leaf per day = 0.399Kg

Total production of dried moringa leaf/ year (n) = 0.399× 300

= 119.7kg

Cost of production of one kg of dried moringa leaf/ year $=\frac{m}{n}$

$=\frac{49,517}{119.7}$

= Rs.414 /Kg

STUDY ON DRYING KINETICS OF MORINGA LEAVES USING

CABINET, FLUIDIZED BED AND INFRARED DRYER

BY,

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ABSTRACT

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In

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Faculty of Agricultural Engineering and Technology

Kerala Agricultural University

Department of Processing and Food Engineering

KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

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ABSTRACT

Moringa Oleifera leaves are familiar to all, but unknowing that this leaves contain quite a lot of nutrient value which are useful for human body function. This plant's leaves contain verities of antioxidant which inhabit & fight against free radical to cell of human body for preventing cancer. Moringa leaves need to dry for use through diversified use. Storage and processing quality depend on better dry. The absence of knowledge about the proper drying method which could be used in the production of Moringa leaves creates a challenge in its processing. The purpose of this study is to identify and examine performance of different types of dryer to dry *Moringa Oleifera* leaves by performing quantitative and qualitative analysis of Moringa leaves. For Moringa dried leaves apply three common type of dryer i.e. cabinet dryer, fluidized bed dryer and infrared dryer. This study was conducted to introduce the uses of *Moringa Oleifera* leaves as ingredient of functional foods. Through this study the ration of time and moisture loss by several dryer are mentioned. Most of the dryer for temperature range 50°C to 70°C. Optimum amount of moisture content increase shelf life, prevent loss of nutrition and protect form microbial spoilage. The quality parameters like carbohydrate, sterol and flavonoid were done. Engineering properties like color, and proximate analysis (ash content) for various samples were measured. The ash content was found to be higher in both cabinet and infrared dryer. And the color of the dried moringa was best in moringa leaves dried in infrared dryer at 60 ℃. In terms of ash content the cabinet and infrared dryer are found preferable than fluidized bed dryer. In terms of color characteristics the moringa leaves dried at 60℃ in infrared dryer is preferable than others. It can be concluded that moringa is better dried at 60°C. From our study, we found that the infrared drying has many advantages over other methods and it is one of the better promising alternative method of drying among the tray drying and fluidized bed dryer for the production of dried Moringa leaves.