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Studies on drying characteristics, nutritional composition and sensory evaluation of moringa leaves powder

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Abstract
Moringa is an important food that is well-known for its part in the natural nutrition of the tropics. The powdered moringa is dried using several methods. We gathered fresh moringa leaf samples and gave them a water wash. Following that, the leaves were distributed in a single layer with a tray load of 0.714 kg/m² and in a double layer with a tray load of 1.56 kg/m². Powdered moringa leaves were made using a variety of drying techniques, including sun drying and tray drying. At 45, 50, and 55 °C, tray drying was carried out. Moisture content, moisture ratio, drying time, drying ratio, and rehydration ratio were the observed statistics. Additionally, a sensory and nutritional examination of the powder was conducted. According to the results, the Initial Moisture Content (IMC) was observed to be 392.28 (%db), 391.75 (%db), 392.14 (%db), and 392.92 (%db), and the Final Moisture Content (FMC) to be 4.82, 4.76, 4.56 (%db), and 4.17 (%db), with drying times 375 minutes, 255 minutes, 225 minutes, and 525 minutes respectively in single layer. IMC were 392.33 (% db), 391.64 (% db), 392.53 (% db), and 392.23 (% db); FMC were 4.62 (% db), 4.47 (% db), 4.23 (% db), and 4.72 (% db), with drying times in double layers of 524 min, 285 min, 255 min, and 615 min, respectively. In the sensory evaluation the highest scores for taste, aroma, texture, colour, and overall acceptability were 6.7, 6.92, 7, 7.07, and 6.63. The powders moisture content, crude fibre, protein, ash, vitamin C, calcium, and iron content were found to be 4.38 (% wb), 22.95%, 16.97%, 22.64%, 3.29%, 137.76%, and 1.66 ppm, respectively.

Keywords: *Moringa oleifera* leaves, tray drying, sun drying, nutritional, sensory

Introduction
From the Moringaceae family, *Moringa oleifera* is the most widely cultivated plant. Due to its nutritional and therapeutic benefits, *Moringa oleifera* is frequently referred to as a "miracle plant" in various cultures. Due to the high protein content of *Moringa oleifera* leaves, many medical professionals, shamans, nutritionists, and community leaders utilize them to cure various ailments and undernutrition. The moringa tree, often known as the miracle tree, is a rich natural supply of the vitamins, minerals, carbohydrates, and digestible proteins that are essential for people of all ages. (Fahey *et al.*, 2005) [2]. Moringa is an effective remedy for malnutrition and has variety of essential phyto-chemicals in its leaves, pods and seeds. In fact, moringa is said to provide 7 times more vitamin C than oranges, 10 times more vitamin A than carrots, 17 times more calcium than milk, 9 times more protein than yoghurt, 15 times more potassium than bananas and 25 times more iron than spinach (Rockwood *et al.*, 2013) [5].
Malnutrition, particularly in young children and nursing moms, has been combated by using moringa leaves. Approximately 14% of the protein, 40% of the calcium, 23% of the iron, and nearly all of the vitamin A needs for a child aged 1-3 are met by one level tablespoon (8 g) of leaf powder. During pregnancy and breast-feeding, six rounded spoonfuls of leaf powder will provide virtually all of a woman's daily iron and calcium requirements. (Fuglie and Lowell, 2001) [3].
Drying means removing moisture from products, and it is very important for preserving agricultural foods. It works by using heat to evaporate water from the product. However, drying can change food quality, such as causing color changes, loss of aroma, texture changes, and reduced nutrition. Using higher temperatures can dry the product faster, but it may damage the quality and use more energy.

Drying is a simple way to preserve moringa leaves so they can be stored and used anytime. It removes moisture from the leaves through heat and evaporation, which helps prevent spoilage. This study focuses on two drying methods-sun drying and tray drying-to see which one produces better quality moringa leaf powder.

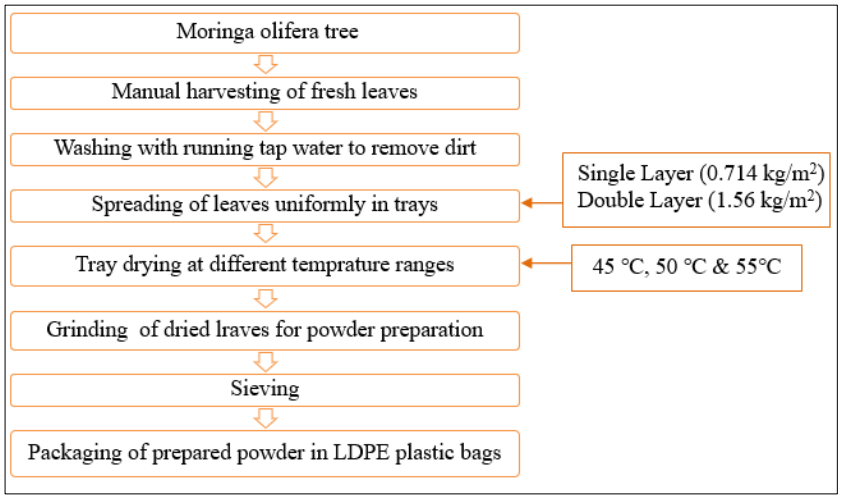
Materials and Methods

Collection Of Raw Materials

Moringa leaves were collected from local area of Dediapada and CAET college campus. Specific selection criteria for green leaves were applied basis on dark green color, variety, maturity indices and uncut leaves. It was ensured that the green leaves are not contaminated, partially yellowish leaves. Collected leaves are washed in running tap water till the removal of dirt generally present on the surface of the leaves.

- **Experimental design:** Experimental design for drying is shown in Table 1.
- **Treatment Details:** Treatment details of the drying are shown in Table 2.
- **Treatment Combinations:** Table 3 lists various treatment combinations with temperature, tray load, and sample code.

Experimental Procedure



Drying methods

Tray drying

Using a tray dryer with the capacity to dry leaves, the fresh samples were washed thoroughly with ordinary water until they were free of dust and rodents. About 250 g of leaves were spread on the tray in a single layer and 500 g were spread on the tray in a double layer. The drying was carried out at 45, 50 and 55 °C. The weight of the moringa leaves samples were recorded at regular intervals using a digital weighing balance until they were

Sun drying

For the sun-drying procedure, precisely weigh 250 g and 500 g of moringa leaves. With this technique, the fresh moringa leaves are cleaned, let to air dry for a short time, and then placed on filter paper. Tray with filter paper should be positioned somewhere with enough natural light.

Observations

Drying time

The total amount of time needed to remove all of the moisture from the sample was used to calculate the drying time (min) needed for the tray drying procedure of *Moringa oleifera* leaves.

Moisture content

The amount of moisture removed from leaves was measured at intervals of 5 minutes for the first 25 minutes, 10 minutes for the next 50 minutes, 15 minutes for the following hour, and then every 30 minutes for the following hour until the drying process was complete. (Mishra *et al.* 2020) [4].

$$\text{MC (\%wb)} = \frac{W_w - W_d}{W_w} \times 100$$

Where, Ww = Wet weight of the moringa leaf sample; Wd = Dry weight of the moringa leaf sample

Drying rate

For calculating the drying rate (DR), the following equation was used.

$$\text{Rate of Drying} = \frac{dM}{dt} = \frac{M_{t+dt} - M_t}{dt}$$

Where, Mt = moisture content at time t; M (t+dt) = denotes moisture content at t + dt; dt = time difference between two successive drying times

Rehydration ratio

Rehydrating ratio dried moringa leaves were rehydrated by soaking in warm water (about 60°C) and then allowing them to cool to room temperature, dried moringa leaves were rehydrated. After soaking in water for 20 minutes with samples of dried moringa leaves, filter paper was used to remove the water. A weight was then applied to the samples of rehydrated moringa leaves. The rehydration ratio was calculated as follows. (Champaneri *et al.* 2020) [1].

$$\text{Rehydration ratio} = \frac{W_r}{W_d}$$

Where, Wr = Rehydrated weight in g; Wd = Dehydrated weight in g

Proximate analysis

Dried powder's nutritional composition was discovered at NAU, Navsari's Centre of Excellence Post Harvest Technology. Proximate analysis which evaluates the moisture content (%wb), protein (%), carbs (%), vitamin C, ash content (%) and fibre content. The mineral content of powder was evaluated their calcium content and the iron concentration was also examined.

Estimation of Moisture Content

Moisture content of the samples was determined according to the gravimetric methods of AOAC (1995). Exactly 5 g of test sample was measured into crucibles that have been earlier washed, dried in an oven at a temperature of 70-80 °C for 2 h and weighed. The samples were dried in the oven at 105 °C for 4 h. This was cooled in desiccators and weighed. It was returned to the oven for further drying, cooling and weighing at 30 min intervals repeatedly until a constant weight is obtained.

$$\% \text{ Moisture Content} = \frac{W_2 - W_3}{W_2 - W_1}$$

Where, W1 = Initial weight of empty crucible; W2 = Weight of crucible + sample before drying; W3 = Weight of crucible + sample after drying

Estimation of Ascorbic Acid (Vitamin C) Content

Pipette out 5 ml of the working standard solution into a 100 ml of conical flask. Add 10 ml of 4% oxalic acid and titrate against the dye (V1 ml). End point is the appearance of pink colour which persists for a few min. The amount of dye consumed is equivalent to the amount of ascorbic acid. Extract the sample (0.5-5 g depending on the sample) in 4% oxalic acid and make up to a known volume (100 ml) and centrifuge. Pipette out 5 ml of this supernatant, add 10 ml of 4% oxalic acid and titrate against the dye (V2 ml).

$$\text{Amount of ascorbic acid (mg/100 ml sample)} = \frac{0.5 \text{ mg} \times V_2 \text{ ml} \times 100 \text{ ml} \times 100}{V_1 \text{ ml} \times 5 \text{ ml} \times \text{Wt. of the sample}}$$

Estimation of Protein Content

Extraction of protein from sample

1. Grind 0.5 g of the sample with water in mortar and pestle.
2. Centrifuge and use the supernatant.

Estimation of protein from sample

1. Pipette out 0.2, 0.4, 0.6, 0.8 and 1.0 ml of working standard solution in series of test tubes.
2. Pipette out 0.1 and 0.2 ml of sample extract into other test tubes.
3. Make up volume to 1 ml with water. A tube with 1 ml of water will serve as blank.
4. Add 5 ml of solution-C mix well and incubate for 10 ml at room temperature.
5. Add 0.5 ml of FCR, mix well and incubate for 30 min in dark.
6. Read the absorbance at 660 nm against blank.

Calculation

Draw a standard graph, calculate the amount of protein in the sample and express the results as mg/g or mg/100 g sample or percentage.

Estimation of Total Carbohydrates Content

Weigh 100 mg of the sample into a boiling tube. Hydrolyze by keeping it in boiling water for three hours with 5 ml of 2.5 N HCL and cool to room temperature. Neutralize it with solid sodium carbonate until the effervescence ceases. Make up the volume to 50 ml and centrifuge. Collect the supernatant and take 0.5 and 1ml aliquots for analysis. Prepare the standards by taking 0, 50, 100, 150, 200 ml of the glucose standard. '0' serves as a blank. Make up the volume to 1 ml in all the tubes including the sample tubes by adding distilled water and add 4 ml of Anthrone reagent. Heat for 8 min in a boiling water bath. Cool rapidly and read the green to dark green color at 630 nm. Draw a standard graph by plotting concentration of the standard on the X-axis versus absorbance on the Y-axis. From the graph calculate the amount of carbohydrate present in the sample tube.

$$\text{Carbohydrate present in 100 mg of the sample} = \frac{\text{mg of glucose} \times 100}{\text{volume of test sample}}$$

Estimation of Fat Content: Clean boiling flask (250 ml) was dried in an oven at 105°C-110°C for 30 min, allowed to cool in desiccators, and weighed. The flask was filled with 300 ml of petroleum ether. Five grams of the test sample was measured into a fat-free extraction thimble which has been dried in an oven and weighed. The extraction thimble was plugged with cotton wool and the weight taken again. The Soxhlet apparatus was assembled and allowed to reflux for 4-5 h. The thimble was removed and the flask kept briefly for escape of petroleum ether before drying at 105°C-110°C for 1 h. The flask was allowed to cool in desiccators and then the weight taken.

$$\%\text{Fat} = \frac{W_2 - W_3}{W_1} \times 100$$

Where, W1 = Weight of sample used; W2 = Weight of flask and oil extract; W3 = Weight of empty extraction flask

Estimation of Calcium Content: The equipment LAQUA twin Ca+2 was used to assess the calcium content. Open the light shield cover and place some drops of the standard solution (150 ppm and 2000 ppm) on the flat sensor taking care to cover the entire flat sensor. Close the light shield cover. When the read value meets the stability criteria, ☺ appears and the reading is locked. If the read value does not meet the stability criteria, ☺ disappears and the reading changes with time. Sample mixed with water and filters it by filter paper. Fill the sensor with the sample and when the smiley face appears, the measurement is complete. Clean the sensor thoroughly with water.

Estimation of Ash Content: An analytical balance was used to weigh a dried crucible dish and 5 gm of the sample was placed. Keep the silica dish in muffle furnace between 500-

600°C for 4-6 h. Take the weight of ash and determine the% ash by formula, as given in standard method.

$$\text{Ash Content (\%)} = \frac{\text{Weight of ash after ignition (finale weight)}}{\text{Initial weight of the sample used}} \times 100$$

Color analysis

Colour attributes of the *Moringa oleifera* leaves powder (L*, a* and b*) were performed using Sensegood Color Spectro Photographmeter. The color of the moringa leaves was determined after drying. A portable colorimeter was used to measure the CIE (the International Commission on Illumination) coordinates including L*, a* and b* values. The colorimeter was calibrated against a standard calibration photograph of a white surface and set to CIE. The chromaticity coordinate a* determines green when negative and red when positive, while the chromaticity coordinate b* measures blue when negative and yellow when positive.

Sensory evaluation

The sensory evaluation of the powder was carried out by panelists from the College of Agricultural Engineering and Technology, NAU, Dediapada. They evaluated the five major sensory characteristics of colour, texture, taste, aroma and overall acceptability using a 9-point hedonic score card, where 9 indicated "like extremely" and 1 indicated "dislike extremely."

Results and Discussions

Effect of drying temperature on moisture content

Figures 1 and 2 illustrate the impact on moisture content and drying time of a 0.714 kg/m² tray load with a single layer and a 1.56 kg/m² tray load with double-layer moringa leaves. At 45°C, 50°C, 55°C and sun drying (avg. temp. 34°C), the initial moisture content in a single layer was 392.33% db, 391.75% db, 392.14% db and 392.92% db and the final moisture content was 4.82% db, 4.76% db, 4.56% db and 4.17% db, respectively. The drying time for tray drying at given temperatures were found to be 375 minutes, 255 minutes, 225 minutes and 525 minutes, respectively. The initial moisture content in double layer was 392.33(% db), 391.75(% db), 392.14 (% db) and 392.92 (% db) and the final moisture content was 4.62 (% db), 4.47 (% db), 4.23 (% db) and 4.72 (% db) at 45°C, 50°C, 55°C and sun drying (avg. temp. 34°C). The drying time required was 525 min, 285 min, 255 min and 615 min.

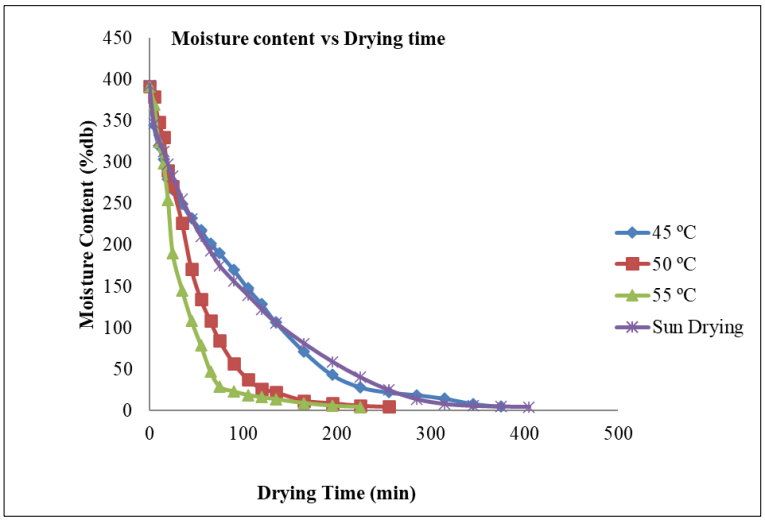


Fig 1: Variation in moisture content with drying time (single layer)

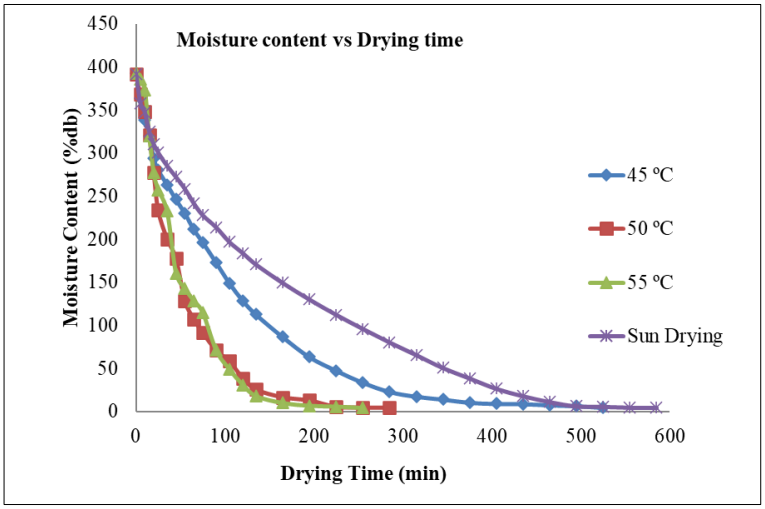


Fig 2: Variation in moisture content with drying time (double layer)

Effect of drying temperature on drying rate

Figures 3 and 4 illustrate how varying drying air temperatures affect the drying rates and drying times of moringa leaves. Figure 3 showed that the minimum drying rates were 0.048, 0.047, and 0.044 for tray drying and 0.042 g-w/g-dm-h for sun drying, while the highest drying rates were 3.923, 3.912, and 3.921 for tray drying and 3.929 g-water/g-dm-h for sun drying, respectively. The maximum drying rates were found to be 3.923, 3.916, and 3.925 for tray drying and 3.922 g-w/g-dm-h for sun drying, respectively, and 0.046, 0.045, and 0.042 for tray drying and 0.047 g-w/g-dm-h for sun drying, respectively, according to figure 4. For all three drying air temperatures (45, 50, and 55 °C) and single- and double-layer thicknesses, as well as sun drying (Control) in both thicknesses, the highest drying rates were discovered at the beginning of drying.

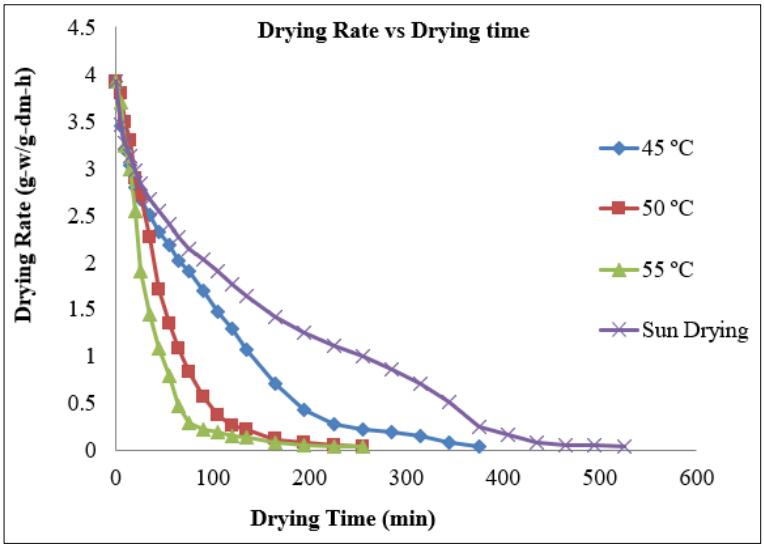


Fig 3: Variation in drying rate with drying time (single layer)

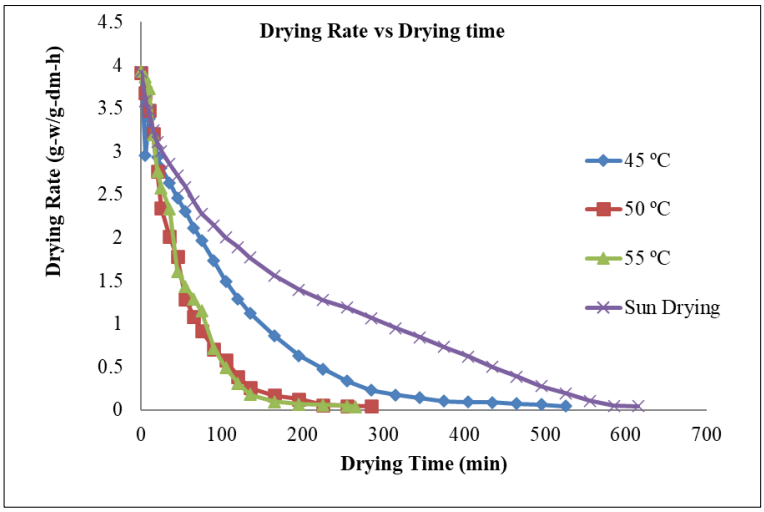


Fig 4: Variation in drying rate with drying time (double layer)

Effect on moisture ratio with drying time

It can be seen from the Figure 5 for single layer and Figure 6 for double layer. For tray drying the moisture ratio of moringa leaves decreased exponentially with drying time and varied from 1 to 0.01227, 1 to 0.01214 and 1 to 0.01113 for tray drying and 1 to 0.01060 for sun drying (Control) of moringa leaves in single layer at different drying air temperature and varied from 1 to 0.01178, 1 to 0.01142 and 1 to 0.01077 for tray drying and 1 to 0.01203 for sun drying (Control) of moringa leaves in double layer at different drying air temperature. From the figures, it was evident that moisture ratio of moringa leaves decreased with drying time in all the drying air temperatures.

Rehydration ratio: The data recorded on rehydration ratio as influenced by tray drying treatments was numerically presented in Table 4 and bar graph shows in figure 7. Initially maximum rehydration ratio was recorded in T_3 (3.74). However, the lowest rehydration ratio was recorded in treatment T_7 (2.88).

Nutritional analysis

The information gathered on nutrient compositions, as shown in Table 5. The maximum moisture content 4.68% was found for treatment T_4 and minimum 4.24% for treatment T6. Protein content of moringa leaves maximum found 25.53% for treatment T_5 and minimum found 21.05% for treatment T_3. The maximum carbohydrate was found 25.20% for treatment T5 and minimum carbohydrate was found 21.05% for treatment T_1. The maximum ash content was found 4.03% for treatment T_1 and minimum ash content was found 2.96% for treatment T_7.

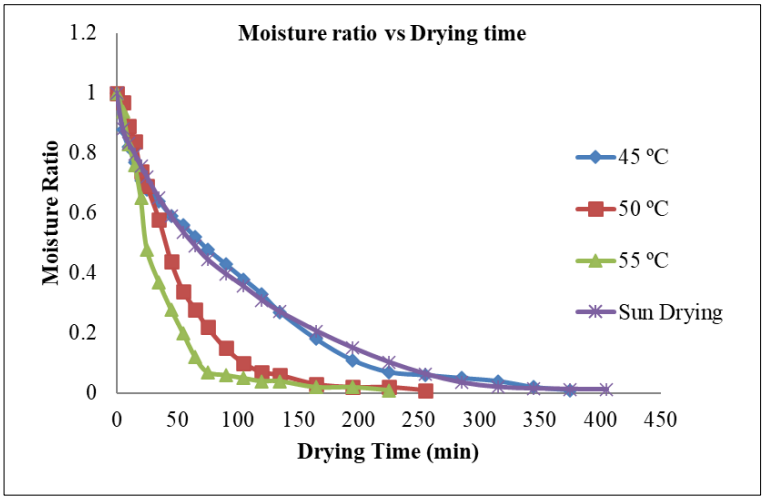


Fig 5: Variation in moisture ratio with drying time (single layer)

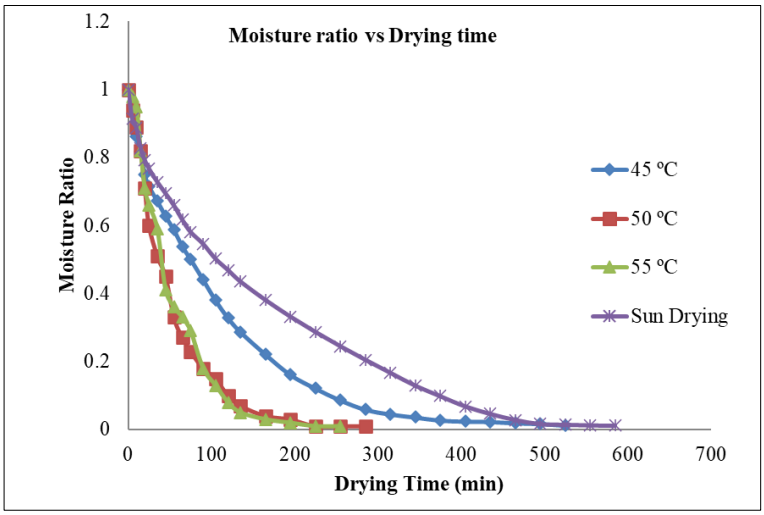


Fig 6: Variation in moisture ratio with drying time (double layer)

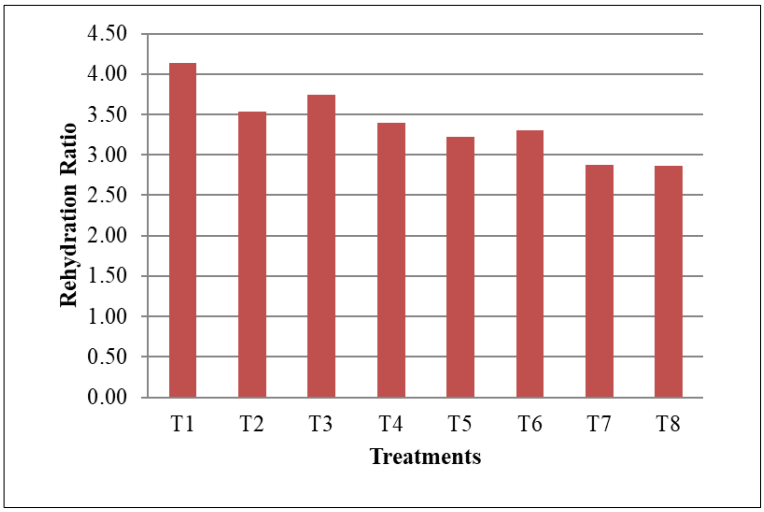


Fig 7: Rehydration ratio of *Moringa oleifera* leaves powder

Color analysis

The data of color analysis shown in Table 6. The color of the Moringa leaves was determined after drying including L*, a*, and b* values. The chromaticity coordinate a* determines green when negative and red when positive, while the chromaticity coordinate b* measures blue when negative and yellow when positive. Results of colour measurement values of dried moringa leaves powder as obtained for different treatments were recorded and presented in Table 4. Hunter colour in best value of powder is L*, a*, b* are 43.767, -13.14, and 33.467.

Sensory evaluation

Sensory acceptance based on a 9-point hedonic scale was conducted on *Moringa oleifera* powder products, in order to determine the most acceptable drying conditions. The effect

of different drying methods in different conditions on sensory evaluations of moringa powder. The greatest values of the sensory assessment scores for powder were 7.43, 7.50, 7, 7.60, and 7.03. All data shows in Table 7.

Table 1: Experimental design for moringa leaves powder

1.	Crop	:	*Moringa oleifera* Leaves (Drumstick)
2.	Experimental Design	:	Factorized Completely Randomized Design (F-CRD) Mathematical Modeling for drying behavior
3.	Number of Treatments	:	3×2 = 6 + 2 (Control) = 8
4.	Number of repetitions	:	3

Table 2: Treatment details for drying

Factor 1	:	Temperature of drying air (A) = 3
		A_1 = 45 °C
		A_2 = 50 °C
		A_3 = 55 °C
Factor 2	:	Tray load (L) = 2 Level
		L_1 = Single Layer (0.714 kg/m^2)
		L_2 = Double Layer (1.56 kg/m^2)
Control	:	Sun Drying

Table 3: Treatment combinations for powder preparation

Temperature	Tray Load	Sample Code
A_1 (45 °C)	L_1	T_1
	L_2	T_2
A_2 (50 °C)	L_3	T_3
	L_4	T_4
A_3 (55 °C)	L_5	T_5
	L_6	T_6
Sun Drying	L_7	T_7
	L_8	T_8

Table 4: rehydration ratio of dehydrated moringa leaves

Treatments	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8
Rehydration Ratio	4.14	3.54	3.74	3.40	3.22	3.30	2.88	2.86

Table 5: Physico-chemical composition of *Moringa oleifera* leaves powder

Treatments	Moisture Content (%wb)	Protein (%)	Carbo-hydrates (%)	Vitamin C -	Calcium (ppm)	Iron -	Ash Content (%)	Fiber (%)
T_1	4.44	21.49	21.87	116.02	1.55	0.66	4.03	20.06
T_2	4.51	22.81	21.05	135.12	1.77	0.69	3.30	16.22
T_3	4.41	21.05	23.90	145.55	1.45	0.69	3.60	16.18
T_4	4.68	24.48	22.69	145.96	1.80	0.68	3.04	19.33
T_5	4.32	25.53	25.20	105.62	1.61	0.65	3.58	16.52
T_6	4.24	22.39	22.30	134.41	1.56	0.73	3.27	15.79
T_7	4.28	23.49	23.20	140.39	1.71	0.72	2.96	17.41
T_8	4.34	22.48	23.90	146.42	1.81	0.62	3.27	17.62
Min	4.24	21.05	21.05	105.62	1.45	0.62	2.96	15.79
Max	4.68	25.53	25.20	146.42	1.81	0.73	4.03	20.06
Mean	4.38	22.64	22.95	137.76	1.66	0.68	3.29	16.97
S. Em	0.14	1.49	1.32	15.12	0.14	0.04	0.35	1.56
CD@5%	NS	1.05	NS	NS	0.22	0.06	NS	2.24
CV%	5.81	2.63	6.18	13.08	7.50	4.95	11.89	7.44

Table 6: Color Values of *Moringa oleifera* Leaves Powder after Drying

Treatments	L*	a*	b*	Whiteness Index
T_1	54.23	-13.14	33.46	-230.25
T_2	37.52	-5.46	21.56	-202.77
T_3	38.42	-6.023	20.61	-195.49
T_4	43.76	-8.64	19.36	-170.33
T_5	39.34	-5.52	25.61	-230.28
T_6	40.34	-6.80	25.86	-231.44
T_7	42.32	-6.24	24.18	-208.26
T_8	40.63	-8.87	26.05	-234.39
Min	37.52	-13.14	19.36	-234.39
Max	54.23	-5.46	33.46	-170.33

Mean	40.48	-6.52	24.9	-219.25
S. Em	5.311	2.59	4.40	22.82
CD@5%	1.85	0.93	1.69	1.745
CV%	2.54	-7.13	3.97	-0.473

Table 7: Sensory evaluation of *Moringa oleifera* leaves powder

Sr. No.	Treatments	Aroma	Color	Taste	Texture	Overall Acceptability
1	T_1	7.10	7.50	6.60	7.60	6.93
2	T_2	6.73	6.57	6.10	6.50	6.27
3	T_3	7.13	6.87	7.00	7.20	6.83
4	T_4	6.53	7.20	6.87	6.80	6.63
5	T_5	7.43	7.20	6.63	7.27	6.63
6	T_6	6.60	7.03	6.67	6.63	6.47
7	T_7	7.23	7.10	7.00	7.43	7.03
8	T_8	6.73	6.27	6.73	6.77	6.47
	Min	6.53	6.27	6.10	6.50	6.27
	Max	7.43	7.50	7.00	7.60	7.03
	Mean	6.92	7.07	6.70	7.00	6.63
	S. Em	0.33	0.39	0.29	0.40	0.26
	CD@5%	NS	NS	NS	0.688	NS
	CV%	5.53	8.82	5.09	5.65	5.40

Conclusion

The physico-chemical analysis of moringa leaves powder revealed that the protein, ash content, carbohydrates, fat, iron, fiber and calcium at significant level of powder.

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