Physico-chemical and Functional Properties of Drumstick leaf powder

Abstract:

The study was conducted to analysis of physico-chemical properties of drumstick leaf powder. Drumstick leaf were dried in a convective hot air dryer at 30ºC, 40ºC and 50ºC. The air velocity inside the dryer was 2-3 m/s, the drying process takes 6 hrs, 27hrs, and 19 hrs time to dry the product at 30 ºC, 40 ºC, and 50 ºC. Drying rate increased with increase in air temperature. The experimental drying data of drumstick were applied to six Moisture ratio models, namely, the Newton model, modified Page model, Henderson and Pabis, Logarithmic, Two term and Exponential Model was found to be the best for explaining the drying characteristics of drumstick leaf. The effective moisture diffusivity varied from 3.651 $\times 10^{-11}$, 4.503$\times 10^{-11}$ and to 7.343$\times 10^{-11}$ over the temperature range studied, with activation energy of 28.281 kJ/mol for drying of drumstick leaf. The drumstick leaf powder contains moisture 10.85 to 15.56 %, protein 22.88 to 23.979 %, fat 1.80 to 2.42 %, fibre 11.53 to 12.16 %, ash 3.69 to 4.93 %, carbohydrate 40.94 to 849.25% The flour had average water absorption capacity (3.081to 4.22l g/cc), bulk density (3.081 to 0.445 g/cc) were recorded.

Keywords: drumstick leaf powder, effective moisture diffusivity, activation energy, Physico chemical and functional properties.

1. Introduction:

Drumstick *(Moringa oieifera)*, known as miracle tree and native plant to the southern foothills of the Himalaya India, and is grown in tropical and subtropical countries and is well known for its health benefits. Leaves, flower and the fruits (popularly known as drumstick) are being used in traditional food preparation (Vanajakshi *et al.*, 2015). It is the most widely cultivated species of *Moringaceae* family. Commonly it is known as in English–moringa or drumstick tree or horseradish tree, in hindi-*sahjan*, in latin- *moringa oleifera*, in Sanskrit -*surajana*, in nepali - *sajiwan* or *swejan* etc. It is useful not only for human beings but also for animal and also in various industrial application

(Patel *et al.*, 2010). Yield of leaves is approximately 55.73-15.73 tone's per hectare (Foidl *et al*., 2007). World Annual drumstick leaf production range from 25-32 ton per hectare (Zheng *et al*., 2016). The leaves contain 7.5 mg water, 6.7 mg protein, 1.7 mg fat, 14.3 mg total carbohydrate, 0.9 mg Fibre, 2.0 mg ash, 440 mg Calcium, 70 mg

Phosphorous, 7 mg Iron, 110 mg Copper, 5.1 mg, 11.300 mg vitamin A, 120 mg vitamin B, 0.8 mg nicotinic acid, 220 mg ascorbic acid and 7.4 mg tocopherol per100 mg (Fahey, 2005). Leaves of *M. Oleifera* possess: 4 time more calcium and two times more protein than milk, 7 times more vitamin C than oranges, 3 times more potassium and iron than banana and spinach respectively and 4 times more vitamin A than carrots (Thurber 2009). People generally use for stomach complaints, cancer, gastric ulcers, skin diseases, lowering blood sugar, increasing bone density, nervous condition, diabetes, fatigue, increase lactation, hay fever, cramps, headaches, sore gums; to strengthen the eyes and the brain, liver, gall digestive, respiratory and immune system and as a blood cleaner and blood builder (Patel *et al*., 2010). *M. Oleifera* leaves as fortificant in food product such as bread, biscuits, cereal porridge, cake, yoghurts and chees has been reported to improve their sensory properties and shelf life with consequent boosting of consumer endogenous antioxidant ability to scavenge free radicals and reduce health related disease (Oyeyinka and Oyeyinka, 2016). Dried Moringa powder can be consumed in raw form or can be added to various value added food product for nutritent fortification viz. biscuit (1%), butter milk (3%), weaning food (10%), soup (10%), cheese (2%) (Otoluwa *et al*., 2014). To prepare powder of Moringa oleifera by applying drying technique. Drying was done at 60°C to minimize the drying losses. Results obtained from cabinet dried sample were better than other and had highest nutrient retention followed by shadow, sun and oven dried sample (Satwase *et al*., 2013).

Various Mathematical Models have been fitted to the experimental data was observed in the literature for drumdtick leaves (Potisate and Phoungchandang, 2015); (Premi et al., 2010); (Ali *et al*., 2014), jute leaves (Famurewa and Akinmuyisitan, 2014). Present study is aimed to study the drying characteristics of drumstick leaf at varied temperature. Various Mathematical Model were fitted to experimental data on the moisture ratio with respect to time. The nutritional and physical qualities (moisture content, protein, fat, fiber, carbohydrate, ash) and functional properties (colour, water absorption, bulk density) of the drumstick leaf powder were also been determined.

2. Material and Methods

Drumstick leaves were procured from the farmers field at Roha. The leaves were washed with tap water to remove dirt, dust after removing surface water with the blotting paper, these were dried at 30 ºC, 40 ºC, and 50 ºC in a convective hot air dryer.

2.2 Drying of drumstick leaf

2.2.1 Convective hot air drying

Convective hot air drying of drumstick leaf was performed at Department of Post-Harvest Engineering, Post Graduate Institute of Post-Harvest Management, Killa-Roha. The drying was carried out in the convective hot air dryer (Make M/s. Aditi Associates, India; Model: ATD-124) having capacity of 5 kw. There were nine numbers of trays inside the convective hot air dryer. The size of the tray was 81cm x 41cm x 3.4 cm. The leaf were spread on the tray in single layer. The mesh (square) size of the tray was 1x1 mm. The temperature of the drying was 30ºC, 40ºC and 50ºC. The weight loss with respect to the time was recorded from trays at different location in the convective hot air dryer. The moisture content with respect to the time was calculated from drying data. The drying data includes initial moisture content; weight loss, average moisture content with respect the time, drying rates, moisture ratios, and final moisture content of drumstick leaf was recorded. Three replications were taken for each experiment.

2.2.2 Drying rate

The drying rate of drumstick leaf was calculated on dry basis using following formula (Chakraverty, 2005).

$$R=\frac{W_r}{T\times W_d}\times 100 \quad \ldots(1)$$

Where,

R = Drying rate (g/min)

W_r = Amount of moisture removed (g)

T = Time taken (min)

W_d = Total bone-dry weight of sample (g)

2.2.3 Moisture ratio

The moisture ratio of drumstick leaf was calculated on dry basis using following formula (Chakraverty 2005).

$$Moisture\ ratio = \frac{M-M_e}{M_o-M_e} \quad \ldots (2)$$

Where,

MR = Moisture ratio

M_0 = Initial moisture content, %(db)

M_e = Equilibrium moisture content, % (db)

M =Moisture content at any time θ, %(db)

The root mean square error was for the best fit of the model was determined for equation (3).

$$\mathrm{RMSE} = \left[\frac{1}{N}\sum_{i=1}^{n}(MR_{exp} - MR_{pre})^2\right]^{1/2} \quad \ldots(3)$$

Where,

MR_{exp}= experimental moisture ratio

MR_{pre}= predicted moisture.

N and n = number of observations, number of constant (Togrul and Pehlivan, 2004).

2.2.4 Drying model

Moisture Content (% db) versus drying time (min) and drying rate (g of water removed / 100 g bone dry material / min) with respect to moisture content was determined for drying of drumstick leaf. Moisture ratio versus drying time (min) was also determined from the experimental data.

Table 1 Mathematical model tested with the moisture ratio of drumstick leaf

Sr.No	Model name	Equation	Reference
1	Newton	MR = exp (-kt)	Westerman *et al.*, (1973)
2	Modified Page	MR=exp (- $(kt)^n$)	Yaldiz *et al.*, (2001)
3	Henderson and Pabis	MR = a.exp (-kt)	Henderson and Pabis, (1961)
4	Logarithmic	MR= a.exp(-kt) + C	Zhu and Shen., (2014)

5	Two term	MR=aexp(-k_0t)+bexp(-k_1t)	Henderson, (1974)
6	Exponential	MR = exp (-kt)	Liu and Bakker-Arkema, (1997)

Various mathematical models listed in Table.1 were tested on the experimental data on moisture ratio versus drying time in minute of drumstick leaf with convective hot air drying the moisture ratio determines the unaccomplished moisture change defined as the ratio of free water still to be removed, at time t over the initial total free water (Henderson and Pabis, 1961)

2.2.5 Correlation regration coefficient and error analysis

The goodness of fit of the tested mathematical models to the experimental data was evaluated with the correlation coefficient (r^2), chi-square (χ^2) the equation (4). The higher the r^2 value and lower the chi-square (χ^2) equation (4) and lower value of RMSE values, the better is the goodness of fit (Ozdemir *et al*, 1999; Wang *et al.*, 2007). According to Wang *et al.*, (2007) reduced chi-square (χ^2) and root mean square error (RMSE) can be calculated as follows.

$$\chi^2 = \frac{\sum_{i=1}^{N}\left(MR_{exp,i} - MR_{pre,i}\right)^2}{N - Z} \quad \ldots (4)$$

Where,

$MR_{exp,i}$ = is the i^{th} experimental moisture ratio,

$MR_{pre,i}$= is the i^{th} predicted moisture ratio ,

N = is the number of observations, and

Z = is the number of constant.

The non-linear regression analysis was performed by using the statistical software SAS 6.5

2.2.6 Effective moisture diffusivity

The Fick's second law can be used to describe the drying process of drumstick leaf. In general series solution of Fick's second law in spherical co-ordinates on drumstick leaf with spherical with radious 28.6 mm. Effective diffusivity of drumstick leaf can be calculated by using Fick's second law of diffusion equation (Doymaz and Pala, 2003) given equation (5)

$$MR=\frac{6}{\pi^2}\sum_{n=1}^{\infty}\frac{1}{n^2}exp(-t\ \frac{n^2.\pi^2\ D_{eff}}{R^2}) \quad \ldots(5)$$

Where,

R^2 = equivalent radius of drumstick leaf to be dried, m (for drumstick leaves R= 0.2 mm)

n= positive integer

D_{eff} = effective diffusivity, (m^2/s)

t= time, min

For long drying times, equation (6) can be simplified in straight line equation. The effective diffusivity determined using the method of slopes as discussed by (Ojediran and Raji, 2010)

$$Ln(MR)=\frac{-6\times t\times D_{eff}}{R^2} \quad \ldots(6)$$

The effective diffusivity can be determined from the slope of equation (7) (Sacilik, 2007)

$$\text{Effective diffusivity } (D_{eff}) = \frac{R^2K}{\pi^2} \quad \ldots(7)$$

2.2.7 Activation energy

The effect of temperature dependence of the effective moisture diffusivity is generally described using Arrhenius type relationship to obtained better agreement by Suarez *et. al.*, (1980) and Roberts *et al.,* (2008).

$$D_{eff} = D_o exp\left(-\frac{Ea}{RT}\right) \quad \ldots(8)$$

Where,

D_o = diffusivity constant or Arrhenius pre- exponential factor (m^2 /s),

Ea = activation energy (kJ/ mol),

R = universal gas constant (kJ/ mol K),

T = air temperature (°K).

The pre exponential factor of the Arrhenius equation and corresponding activation energies were determined by using the data of effective moisture diffusivities and absolute air temperature.

2.3 Sample preparation

The dried drumstick leaves were ground into powder of size 4.885×10^{-5}mm in mixer were used .

2.3 Physico chemical analysis of drumstick leaf flour

2.3.1. Moisture content

The moisture content of the sample drumstick leaf flour prepared by dried seed at 30, 40 and 50^0C determined by AOAC (2010). 15 g of the drumstick leaf flour was taken for in to each three different moisture boxes. The initial weight of moisture box was recorded. The samples were exposed to 105˚C ± 1˚C for 24 hr. in a hot air oven (Make M/s: Aditi Associate, Mumbai. Model: ALO-136). The final weight was recorded. The moisture content of the sample were determined by equation (9)

$$\text{Moisture content \% (db)} = \frac{W_1 - W_2}{W_2} \times 100 \quad \ldots(9)$$

Where,

W_1= weight of sample before drying, g

W_2= weight of sample after drying, g

2.3.2. Protein

Protein content in the sample drumstick leaf flour prepared by dried seed at 30, 40 and 50^0C was determined by a micro-Kjeldahl distillation method (AOAC, 1990). The samples were digested by heating with concentrated sulphuric acid (H_2SO_4) in the presence of digestion mixture, potassium sulphate (K_2SO_4) and copper sulphate (C_uSO4). The mixture was made alkaline with 40% NaOH. Ammonium sulphate thus formed. Released ammonia which was collected in 4% boric acid solution and titrated again with standard HCL. The per cent nitrogen content of the sample was calculated by the equation (10).

$$\text{\% (N)} = 1.4 \times (\text{ml HCl} - \text{ml blank}) \times \text{Conc. of } \frac{HCL}{Weight} \text{ of sample (g)} \quad \ldots (10)$$

% Protein = % N × Factor (6.25).

2.3.3 Fat (%)

Fat contain of sample drumstick leaf flour prepared by dried leaf at 30, 40 and 50^0C was determined using soxhlet fat extraction system (AOAC, 2010). In this method, initially weight of empty flask was weighed. 2g of sample drumstick leaf flour was wrapped in filter paper and was kept in siphoning tube and condenser was fixed above it and siphoned for 9 to 12 times with the petroleum ether in soxhlet apparatus. After removing assembly, evaporation of petroleum ether was allowed by heating round bottom flask. Residue reminder at the bottom of the flask and was reweighed with flask. The quantity of residue was determined as fat content of drumstick leaf flour. Fat content was calculated by using equation (11)

$$\% \text{ Fat} = \frac{final\ weight(g) - Initial\ weight(g)}{weight\ of\ sample(g)} \times 100 \quad \ldots (11)$$

2.3.4 Fiber (%)

Fiber contain of sample drumstick leaf flour prepared by dried leaf at 30, 40 and 50^{0}C was determined using about 2 – 5 g of moisture and fat free sample was weighed into a 500 ml beaker and a 200 ml of boiling 0.25 N sulphuric acid was added to the mixture and boiled for 30 min keeping the volume constant by addition of water at frequent intervals. The mixture was filtered through a muslin cloth and then transferred to the same beaker and 200 ml of boiling 0.31 N (1.25 %) NaOH was added. After boiling for 30 min, the mixture was filtered through muslin cloth. The residue was washed with hot water till it is free from alkali, followed by washing with alcohol and ether. It was then transferred to crucible, dried overnight at 80ºC to 100ºC and weighed. The crucible was heated in muffle furnace at 525ºC for 2 – 3 hrs, cooled and weighed again. The difference in the weights represented the weight of crude fibre, Rangana (1986).

$$\text{Crude Fiber} \left(\frac{\text{g}}{\text{100g}}\right) = \frac{100 - (\text{Moisture+Fat}) \times \text{Weight of Fiber weight}}{\text{Weight of sample taken (Moisture+Fat free sample)}} \times 100 \quad \ldots (12)$$

2.3.5 Ash (%)

Ash content of sample drumstick leaf flour prepared by dried leaf at 30, 40 and 50^{0}C was calculated using muffle furnace. 5 gram of drumstick leaf flour prepared by dried seed at 30, 40 and 50^{0}C was taken in crucible. Weight of crucible and flour was recorded and kept in muffle furnace at 525 ºC for 4 -5 hrs till constant weight was achieved. The crucible was cooled in desiccators and final weight of ash and crucible was recorded. Ash content was calculated by using equation (13).

$$\text{Ash content (\%)} = \frac{(W_2 - W_1)}{(Weight\ of\ sample)} \times 100 \quad \ldots (13)$$

Where,

W_2= weight of crucible + ash,

W_1= weight of empty crucible

2.3.6 Carbohydrates (%)

The carbohydrate content of drumstick leaf flour prepared by dried leaf at 30, 40 and 50^{0}C were calculated from protein, fat, fiber, ash and moisture content (Adegunwa *et al*., 2012)

Carbohydrates = 100 – (protein+ fat+ fiber+ ash+ moisture content) … (14)

2. 3.7 Water absorption capacity

Water absorption of samples drumstick leaf flour prepared by dried leaf at 30, 40 and 50^0C was determined using the method of Sosulski (1962) with slight modifications. The 3 g sample was dispersed in 25ml of distilled water and placed in pre weighed centrifuge tubes. The dispersions was stirred occasionally. After a holding period of 30 min, the dispersions were centrifuged at 5000 rpm for 25 min. The supernatant was removed and the pellet was dried at 50ºC for 25 min which was cooled and weighed. The water absorption capacity was expressed as grams of water retained in the material. The experiment was repeated for three times and average reading was reported. The water absorption capacity calculated using equation (15).

$$\text{WAC} = \frac{W_2 - W_1}{W_0} \times 100 \quad \ldots(15)$$

Where,

W_0 = The weight of sample, (g)

W_1 = The weight of centrifuge tube plus sample, (g)

W_2 = The weight of centrifuge tube plus sediments

2.3.8 Bulk density (g/cc)

Bulk density was evaluated by 10 ml measuring cylinder bound on the weight and volume of sample of drumstick leaf powder were poured into a graduated cylinder, gently tapped ten times and filled to 10 ml results were expressed as g/ml (Mandge *et al.,* 2014).

$$\text{Bulk density (g/ml)} = \frac{Wt.\ of\ Cylinder + Sample\ (g) - Wt. of\ empty\ Cylinder\ (g)}{Volume\ of\ Sample\ filled\ (ml)} \quad \ldots(17)$$

2.3.9 Colour

Colour of drumstick leaf flour at 30ºC, 40ºC, and 50°C was measured by using Konica Minolta colour Reader. (Make: Minolta Camera Co. Ltd. Japan Model: (R-10). The colour of the drumstick leaf flour was measured in dark room. Drumstick leaf flour at 30ºC, 40ºC, and 50°C was placed on white surface and placing colour reader on the flour sample in a Petri dish and the colour was measured in L, a, b were reported. Where L value indicates degree of lightness or darkness, 'a' value indicates redness or greenness and 'b' value indicates the yellowness or blueness

Sample A
Convective hot air drying
drumstick at 30⁰C

Sample B
convective hot air drying
drumstick at 40⁰C

Sample C
Convective hot air drying
drumstick at 50⁰C

Plate. 1 Powders of drumstick leaf dried by convective hot air drying

3. Result and Discussion:

3.1. Convective hot air drying of drumstick leaf .

Fig. 1 shows moisture content (db) % with respect to time (min) of drumstick leaf dried by convective hot air dryer. The drumstick leaf were dried from average initial moisture content of 312.122% (db) to 3.718% (db) at 30 ºC; 278.677 % (db) to 4.947 % (db) at 40 ºC; 244.048 to 1.121% (db) at 50 ºC respectively. It took around 12 hrs, 9hrs, and 7 hrs time to dry the product at 30 ºC, 40 ºC, and 50 ºC. fig. 2 shows the drying rate (g of water removes / 100 g bone dry material / min) w.r.t time. The initial drying rate of drumstick leaf was 0.0322g, of water removed /100 g of bone dry matter per minute and decrease up to the 0.0063 g of water removed/ 100g of bone dry matter per minute at 30 ºC;0.435 g of water removed /100 g of bone dry matter per minute and decreases up to the 0.008 g of dry matter at 40 ºC; 0.054 g of water removed /100 g of bone dry matter per min and decreases up to the 0.011 g of water removed / 100 g of dry matter at 50 ºC.

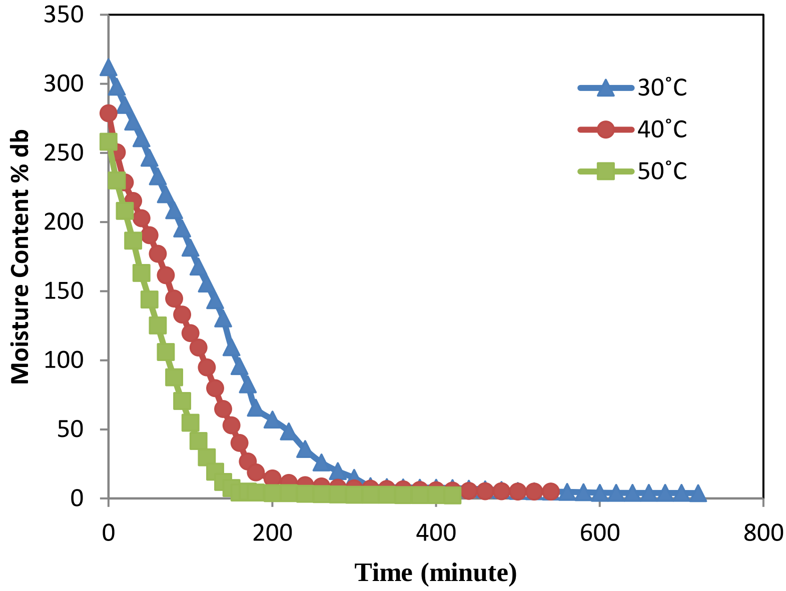

Fig. 1 Moisture content % (db) versus time (min) by convective hot air drying at different temperature for drumstick leaf

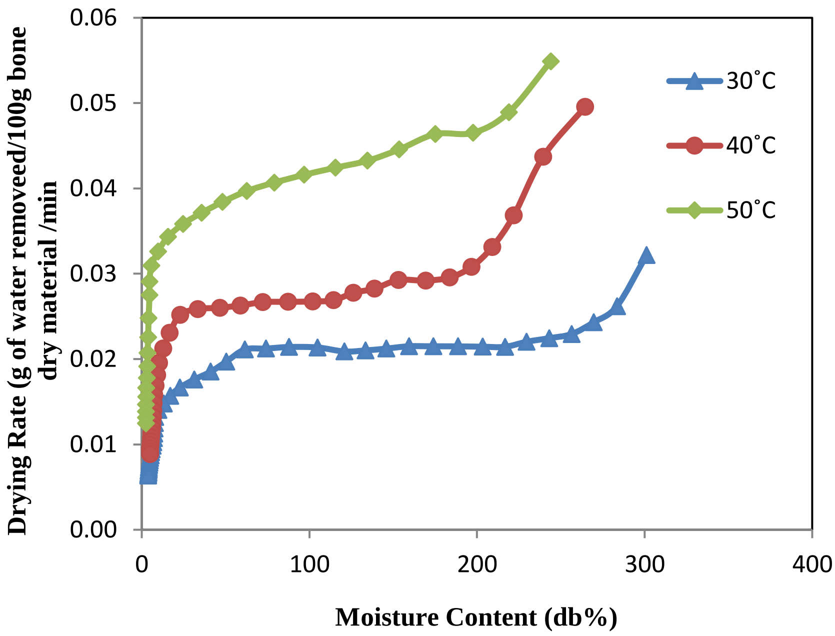

Fig. 2 Drying rate (g water removed/100 g of bone dry material/min) versus moisture content % (db) of drumstick leaf dried by convective hot air drying method at different drying temperature.

From Fig. 2 it was observed that the drying took place in falling rate period. As the temperature of drying increases from 30 °C, 40 °C and 50 °C the drying rate also increases. Moisture removal inside the drumstick leaf at 50°C was higher and faster than the other investigated temperature. Migration of surface moisture and evaporation rate from the surface to the air decreases with decrease of the moisture in the drumstick leaf. The shorter time of drying was observed at higher temperature thus increased drying rate.

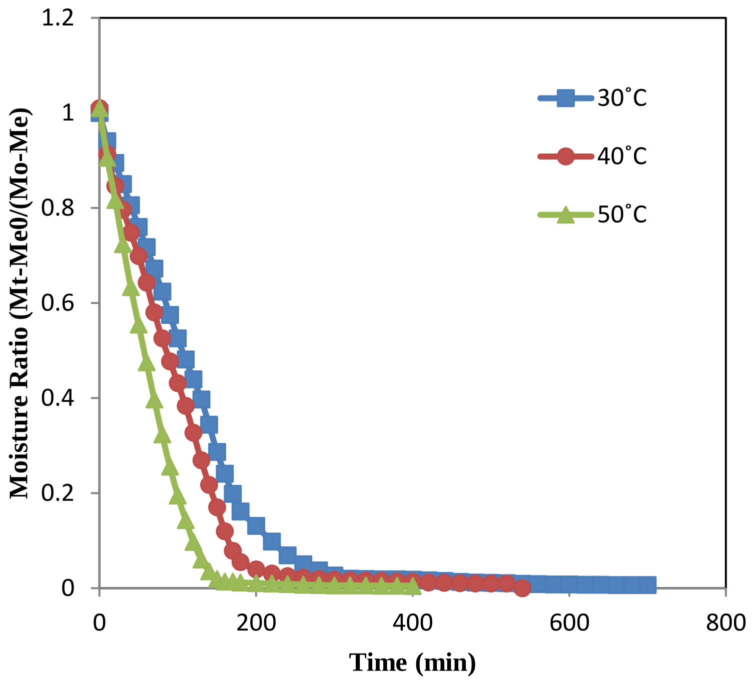

Fig.3. Variation in moisture ratio with respect to time, min for drumstick leaf during convective hot air drying.

Fig. 3 shows variation in moisture ratio with respect to time in minute. During the drying experiment moisture ratio decreases from 1 to 6.49×10^{-3}, 1 to $3.61\text{x}10^{-4}$ and 1 to $5.11\text{x}10^{-3}$ at the drying temperature of 30°C, 40°C and 50°C respectively. The results obtained were in agreements with those reported by Premi *et al.*, (2012).

3.2 Evaluation of thin layer drying model of drumstick leaf dried by convective hot air drying.

The Table 2(a), 2(b) and 2(c) shows the model parameters of various model fitted to the experimental data for Newton model, Modified Page model, Henderson and Pabis, Logarithmic, Two term, Exponential at 30°C, 40°C and 50°C by convective hot air drying of drumstick leaf. Among the models fitted to the experimental data at 30°C, 40°C and 50°C the Modified Page model was well fitted to the experimental data with $R^2 \geq 0.988$; MSE$\leq$ 0.0796 and chi square (χ^2) $\geq$ 0.6590 Non-Linear regression analysis was done according to the three thin layer models for moisture ratio data.

Table 2(a), 2(b), and 2(c) shows the statistical regression results of the different models, including the drying model coefficients and comparison criteria used to evaluate goodness of the fit including the R^2, and RMSE of drumstick leaf at different temperature. In all cases R^2 values for the models were greater than 0.988 indicating model is well fitted. The model parameter i.e. 'k' was 0.0077, 0.0094 and 0.0140 at 30°C, 40°C and 50°C respectively. Value 'n' was 1.540, 1.5996 and 1.567, for the 30°C, 40°C and 50°C respectively. The 'k' value increases with in-crease in temperature from 30°C to 50°C.

Table 2 Model parameters, R^2, RMSE and Chi squre values of drumstick leaf dried by Convective hot air drying at 30 ⁰C, 40 ⁰C, 50 ⁰C,

Table 2 (a)Convective hot air drying at 30⁰C temperature.

Sr.No	**Model name**	**Model Parameters**	**R^2**	**MSE**	**χ^2**
1	Newton	k=0.0086	0.96547	0.3579	15.7501
2	Modified Page	k=0.0077 n=1.5406	0.99631	0.0448	1.9266
3	Henderson and Pabis	a= 1.3151 k=0.0104	0.97768	0.16624	7.1486
4	Logarithmic	a= 1.3157 b=0.0104	0.97768	0.16624	7.1486
5	Two term	a=1.3151 k_0=0.0104 b=3.3064 k_1=156.9549	0.97768	0.16624	7.1486
6	Exponential	k= 0.0086	0.9654	0.3579	15.7501

Table 2 (b)Convective hot air drying at 40⁰C temperature.

Sr.No	**Model name**	**Model Parameters**	**R^2**	**MSE**	**χ^2**
1	Newton	k=0.010842	0.95136	0.3804	13.3170
2	Modified Page	k=0.0094 n=1.5996	0.9889	0.0796	2.6980
3	Henderson and Pabis	a= 1.31463 k=0.013051	0.9626	0.2264	7.7001
4	Logarithmic	a= 1.3146 b=0.0130	0.9626	0.2264	7.7001
5	Two term	a=1.3146442 k_0=0.0130517	0.9626	0.2264	7.7001

		b=406.6891103 k_1=10.6285380			
6	Exponential	*k*= 0.0108	0.9513	0.3804	13.3170

Table 2 (c)Convective hot air drying at 50°C temperature.

Sr.No	**Model name**	**Model Parameters**	**R^2**	**MSE**	**χ^2**
1	Newton	*k*=0.0166	0.9552	0.2259	6.5521
2	Modified Page	*K*=0.0140472 *n*=1.5670	0.9942	0.0235	0.6590
3	Henderson and Pabis	a= 1.3593406 k= 0.0200854	0.97768	0.1147	3.2133
4	Logarithmic	a= 1.3593438 b= 0.0200854	0.96834 67	0.1147	3.2133
5	Two term	a=1.3593369 k_0=0.0200853 b=8.5855514 k_1=130.896675 7	0.9683	0.1147	3.2133
6	Exponential	*k*= 0.0166	0.9552	0.2259	6.5521

3.3 Effective moisture diffusivity of drumstick leaf dried by convective hot air drying

Fig.4 shows Ln (MR) versus time (minute) for convective hot air drying of drumstick leaf dried at 30°C, 40°C and 50°C respectively. The graph shows the straight line curve. The straight line equation y= mx+c where the m is the slope of line. Effective diffusivity (D_{eff}) at time for jackfruit seeds which was calculated by Eq (6). Table 3 shows the effective diffusivity of drumstick leaf dried at 30°C, 40°C and 50°C. The diffusivity values were in the range of 3.65126×10^{-11} to 7.3431×10^{-11} for all the temperature. As the temperature increases the diffusivity value increases from 3.65126×10^{-11}, 4.50323×10^{-11} and 7.3431×10^{-11} at 30°C, 40°C and 50°C respectively. The effective diffusivity used to explain the mechanism of moisture movement during drying.

It was observed that D_{eff} values increased greatly with increase in drying temperature and thickness. When samples are dried at higher temperature, increased heating energy would increase the activity of the water molecules leading to higher moisture diffusivity (Xiao *et al*., 2010). The values obtained of effective diffusivity from this study was 3.65126×10^{-11}, 4.50323×10^{-11} and 7.3431×10^{-11} during the drying temperature of 30°C, 40°C and 50°C respectively. The values of D_{eff} obtained from this study lies within the general range of for drying of drumstick leaf was 2.40- 3.04×10^{-9} to 3.21- 3.89×10^{-9} m^2/s reported by Premi *et al*., (2010) dried at 50, 60, 70, 80^{0}C, D_{eff} for drumstick leaf drying was 3.17×10^{-11} to 1.75×10^{-10} and 3.64×10^{-11} to 1.71×10^{-10} m^2 /s respectively, reported by Potisate and Phoungchandang, (2015). D_{eff} for drumstick leaf 4.70- 7.60×10^{-9} to 1.20- 1.50×10^{-8} m^2/s reported by premi *et al*., (2012).

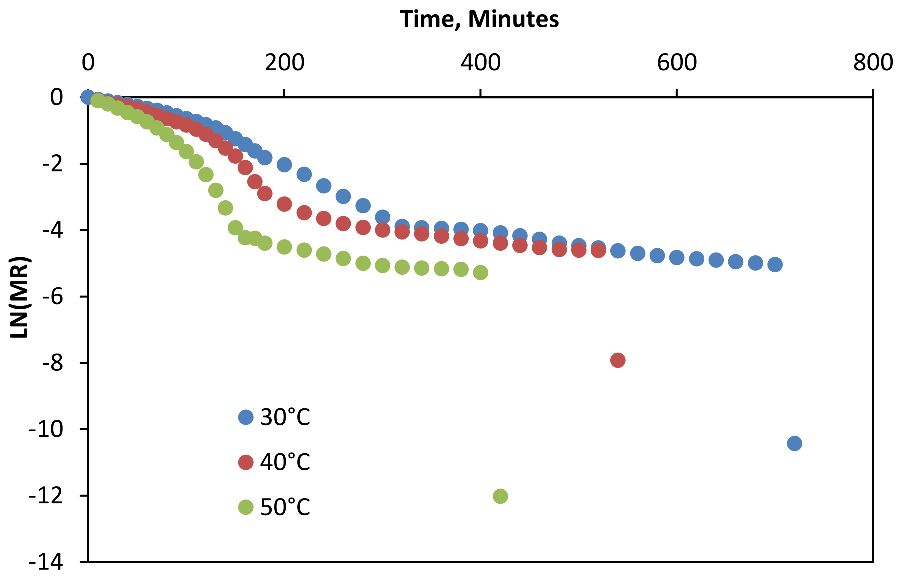

Fig. 4 Ln(MR) vs Time, Minutes of Drum Stick Leaf Powder

3.4 Activation energy for drumstick leaf dried by convective hot air drying

Fig. 5 shows the Ln (D_{eff}) vs 1/T_{abs} for dried drumstick leaf at 30 ºC, 40 ºC, and 50 ºC. The activation energy was calculated by plotting of Ln (D_{eff}) vs. reciprocal of absolute temperature showed straight line in the range of air temperature studied. The activation energy (Ea) for moisture diffusion calculated from the slope of straight lines graphs are given in Table (3) The activation energy for moisture diffusion was found to be 28.281 kJ/mole. The energy of activation (Ea) are reported in the literature, 5.54kJ/mole for okra (Dadali *et. al*., 2007); 12.28 kJ/mol for mint leaves (Ozbek *et al.*, 2007), 55.841kJ/mol for the drumstick leaf which was reported by (Potisate, and Phoungchandang 2015); 32.74 kJ/mol for drumstick leaf (Premi *et al*., 2012).

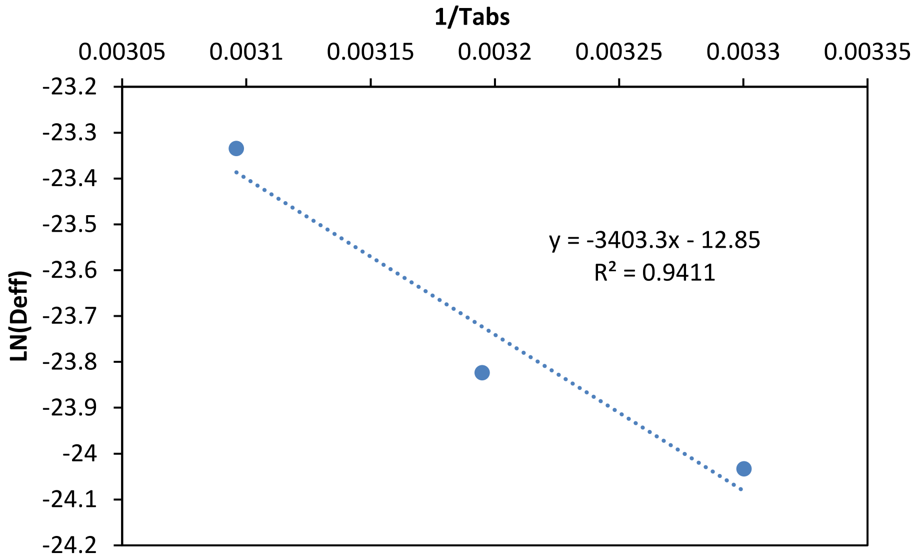

Fig.5 Ln(Deff) versus 1/Tabs for the Drumstick Leaf drying

Fig. 5 Ln D_{eff} vs 1/ T_{abs} of drumstick leaf drying by convective hot air drying method

Table 3 Values of effective diffusivity and activation energy of drumstick leaf at different temperature.

Temperature	D_{eff}(m²/s)	Ea (kJ/mole)
30 ºC	3.65126×10^{-11}	**28.281**
40 ºC	4.50323×10^{-11}	
50 ºC	7.3431×10^{-11}	

The results indicated a linear relationship between (Ln D_{eff}) and (1/T_{abs}) as plotted in Figure 5 for drumstick leaf dried by convective drying at 30 ºC, 40 ºC and 50 ºC. The diffusivity constant or pre- exponential factor of Arrhenius equation (D_o) and activation of energy (Ea) calculated from the linear regression are 2.447 m^2/s and 28.281kJ/mol for drumstick leaf.

3.5 Physico chemical and Functional Properties of drumstick leaf powder:

Table 4 shows the physico-chemical and functional properties of drumstick flour such as Moisture (%), Protein (%), Fat(%), Fibre(%), Carbohydrates (%), Ash (%), Water absorption capacity(g/ml), Bulk density(g/ml), Colour (L*), (a*), (b*). for drumstick leaf flour dried at 30 ºC, 40 ºC and 50 ºC respectively.

Table 4 Physico - chemical and functional properties of drumstick leaf powder

Sr.no	Parameter	Fresh Drumstick leaf	Drumstick leaf flour			SE± at P≤0.05	CD at P≤0.05
			30ºC	40ºC	50ºC		
a)	Moisture (wb %)	71.98±0.123	15.56±0.84	12.17±0.572	10.85±0.466	1.590	4.548
b)	Protein (%)	10.36±1.253	23.979±0.71	22.97±1.037	22.88±1.165	2.427	6.944
c)	Fat (%)	1.36 ±0.551	2.42±0.59	1.89±0.547	1.80±0.447	1.307	3.740
d)	Fibre(%)	0.86 ±0.058	12.168±0.055	11.91±0.021	11.53±0.395	0.692	1.979
e)	Ash(%)	1.86±0.058	4.93±1.059	4.00±0.894	3.69±0.34	2.019	5.777
f)	Carbohydrate (%)	13.55 ±1.087	40.94±2.162	47.03±2.068	49.25±1.844	4.970	14.768
g)	Water absorption capacity (g/cc)		4.22±0.540	3.74±0.329	3.08±0.24	0.957	2.739
h)	Bulk density (g/cc)		0.445±0.023	0.446±0.033	0.416 ±0.025	0.067	0.193
i)	Colour L*		48.43±0.008	49.40±0.008	50.81±0.021	0.038	0.109
	a *		-15.04±0.018	-15.48±0.032	-17.23± 0.018	0.058	0.166
	b *		24.82±0.051	25.45 ±0.155	30.16±0.021	0.232	0.665

3.5.1 Moisture (%)

Table 4 (a) shows moisture content of fresh drumstick leaf and drumstick leaf dried at 30ºC, 40ºC and 50ºC. Moisture content for drumstick leaf was 71.98±0.123% (wb) and the moisture content varied for drumstick leaf powder in the range was 10.85-15.56% and average was 15.56±0.84, 12.17±0.572, 10.85±0.466 at drying temperature 30ºC, 40ºC, 50ºC respectively. The moisture content of fresh drumstick leaf reported in the literature was 70.12 to 75.45 by Agbogidi and Ilondu (2012). The results of moisture content of drumstick leaf powder are obtained by Alakali *et al*., (2015) reported that moisture content 10.33 % and 15.01% respectively.

3.5.2 Protein (%)

Table 4 (b) shows that Protein content of fresh drumstick leaf and drumstick leaf powder. Protein content for drumstick leaf was 10.36±1.253% and protein content varied for drumstick leaf powder ranged was 11.70 – 11.93 % at 30 ºC, 40ºC and 50ºC respectively. The protein content of drumstick leaf powder was 22.88-23.97% and average was 23.97±0.71, 22.97±1.037, 22.88±1.165 at drying temperature 30ºC, 40ºC and 50ºC respectively. The protein content of fresh drumstick leaf reported in the literature was 6.7-10.98 by Satwase *et al*., (2013). The highest protein content was observed at 30ºC drying temperature of drumstick leaf powder. The protein content decreases with increase in drying temperature from 40ºC to 50ºC. The decrease in protein was significant at $p \leq 0.05$. The protein content of drumstick leaf powder reported in literature was 20.97-24.31% reported by Isitua *et al.*, (2014) and Gatade *et al*., (2013).

3.5.3. Fat (%)

Table 4 (c) shows that Fat content of fresh drumstick leaf and drumstick leaf powder. Fat content for fresh drumstick leaf was 1.36 ±0.551%. Fat content varied for drumstick leaf powder 1.010 to 3.456 %. The average fat content of drumstick leaf powder was 2.42±0.59, 2.42±0.5 and 1.89±0.547 at drying temperature 30 ºC, 40 ºC and 50ºC. Fat content was highest at drying temperature at 30ºC of drumstick leaf powder. The decrease in fat was significant at $p \leq 0.05$. The fat content of fresh drumstick leaf reported in the literature was 1.5 to 1.7 by Gopalakrishnan (2016), Satwase *et al*., (2013). Similar results of fat content of drumstick leaf powder reported by Alkali *et al*., (2015) ranged 2.67 to 2.47 and by Agbogidi and Ilondu (2012) reported 2.3% of fat for drumstick leaf powder.

3.5.4 Fibre (%)

Table 4 (d) shows that fibre content of fresh drumstick leaf and drumstick leaf powder . Fibre content of fresh drumstick leaf was 0.86 ±0.058 % and fibre content for drumstick leaf powder was observed in the range of 11.123-12.180%, the average fiber content was observed, 12.168±0.055, 11.91±0.021 and11.53±0.395 at 30ºC, 40ºC and 50ºC respectively. The decrease in fibre was significant at $p \leq 0.05$. The fibre content of fresh drumstick leaf reported in the literature was 0.9% by Satwase *et al*., (2013).The fiber content of drumstick leaf powder was 10.987 to 15.141 % reported by Gopalakrishnan (2016), Isitua *et al.*, (2014) and Alkali *et al*., (2015).

3.5.5. Ash (%)

Table 4(e) shows that the ash content of fresh drumstick leaf and drumstick leaf powder. Ash content for fresh drumstick leaf was 1.86±0.058 %. The ash content varied for drumstick leaf powder was observed in the range of 3.487 – 4.487 %. The average ash content was 4.93±1.059, 4.00±0.894 and 4.00±0.894 at 30ºC, 40ºC, and 50ºC. Highest ash content was observed in 30ºC of drumstick leaf powder . The ash content decrease with the increase in temperature from 30ºC to 50ºC. The decrease in ash content was significant at p≤0.05. The ash content of fresh drumstick leaf reported in the literature was 2% Satwase *et al*., (2013). The ash content of drumstick leaf powder was 4.55 to 4.70% Alkali *et al*., (2015).

3.5.6. Carbohydrates (%)

Table 4 (f) shows that the carbohydrate content of fresh drumstick leaf and drumstick leaf powder. Carbohydrate content for drumstick leaf was 13.55 ±1.087 and carbohydrate content varied for drumstick leaf powder ranged was 40.94 –49.25%. The average carbohydrates content was 40.94±2.162, 47.032±2.068 and 49.25±1.844 at 30^0, 40^0 and 50^0C respectively. Highest carbohydrate content observed at 30ºC of drumstick leaf powder. The carbohydrates content increases with increase in temperature from 30ºC to 50ºC. The increase in carbohydrates was significant at p≤0.05. The carbohydrate content of fresh drumstick leaf reported in the literature was 14.3%,12.05% by Fahey, (2016), Agbogidi and Ilondu (2012). The carbohydrates from the drumstick leaf powder was 32.57%, 44.55% reported by Alkali *et al*., (2015), Satwase *et al*., (2013).

3.5.7 Water absorption capacity (g/cc)

Table 4 (h) shows that the Water absorption capacity of drumstick leaf powder. Water absorption capacity of drumstick leaf powder ranged was 3.082 – 4.221 g/cc and average water absorption capacity of drumstick leaf powder was 4.22±0.540, 3.74±0.329, 3.08±0.24 g/ml at 30^0C, 40^0C and 50^0C drying temperature. The highest water absorption capacity was observed at 30^0C drying temperature and lowest water absorption capacity was observed at 50^0C drying temperature. The water absorption capacity was significant at p≤0.05. Sing and Prasad (2013) reported the water absorption capacity of drumstick leaf powder 3.9 g/cc.

3.5.9 Bulk density (g/cc)

Table 4 (f)shows that the bulk density for drumstick leaf powder. Bulk density varied for drumstick leaf powder was in the range of 0.445±0.023, 0.446±0.033 and 0.416 ±0.025g/cc for 30˚C, 40˚C and 50˚C respectively. Highest bulk density was observed at 40˚C of drumstick leaf powder. Okoye *et al*.,(2013) reported the 0.32 g/cc value of drumstick leaf powder .

3.5.10 Colour

Table 4(g) shows the colour for the drumstick leaf powder dried at 30, 40 and 50˚C. L, ‘a’ and ‘b’. value for drumstick leaf powder colour L values was 48.43 to 50.80 at 30^0C,40^0C,50^0C and average was 48.43±0.008, 49.40±0.008, 50.81±0.021, respectively. The L values increases with drying air temperature from 40^0C to 50^0C.The drying air temperature had significant influence of L value of colour on drumstick leaf powder at p≤0.05. ‘a’ value for drumstick leaf powder 30˚C, 40˚C and 50˚C was in the range of -15.50 to -17.20 and decreases with increase in temperature from 40^0C to 50^0C and average ‘a’ value was -15.04±0.018, -15.48±0.032 and -17.23±0.018 at 30˚C, 40˚C and 50˚C respectively. The ‘a’ value had significant influence of ‘a’ value of colour on drumstick leaf powder at p≤0.05. The ‘b’ value for drumstick leaf powder at 30˚C, 40˚C and 50˚C was in the range of 24.48 to 30.17 and average was 24.82±0.051, 25.45 ±0.155 and 30.16±0.021 at 30˚C, 40˚C and 50˚C respectively. The ‘b’ value had significant influence of ‘b’ value of colour on drumstick leaf powder at p≤0.05. Singh and Prasad, (2013) reported the colour values L, ‘a’ and ‘b’ of drumstick leaf powder was 43.87 to 57.67, -15.73 to -16.19, 21.82 to 22.5 respectively.

Conclusion:

The drumstick leaf were dried from average initial moisture content of 312.122% (db) to 3.718% (db) at 30 ºC; 278.677 % (db) to 4.947 % (db) at 40 ºC; 244.048 to 1.121% (db) at 50 ºC respectively. It took around 12 hrs, 9hrs, and 7 hrs time to dry the product at 30 ºC, 40 ºC, and 50 ºC respectively. The modified Page model was well fitted to the drying data at 30, 40, 50ºC respectively. The drying of drumstick leaf occurred in the falling rate period. The effective diffusivity values greatly increased with increasing drying air temperature, i.e. 3.651×10^{-11}, 4.503×10^{-11} and to 7.343×10^{11} m^2/s at 30, 40, and 50ºC respectively. The activation energy for moisture diffusion was found to be, 28.281 kJ/mol. The drumstick leaf powder obtained at 30ºC had better physico-chemical and functional properties than the samples obtained at other different temperatures selected for the study. Drumstick leaf at 30ºC contains, moisture 15.56%, protein 23.97%, and fat 2.42 %, fibre 12.16 % carbohydrate 40.94 %, ash 4.93 %. The powder had average of water absorption capacity at 30ºC (4.2g/cc), bulk density (0.44g/cc).

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