Reema Kshetrimayum, 11:1
ISSN (Online): 2348-4098
ISSN (Print): 2395-4752

Drying Characteristics And Quality Attributes Of Conventional Hot Air Dried Chayote Slices (Sechium Edule Sw.)

Reema Kshetrimayum(Research Scholar) , Prof. M.K Chourasia
Dept of Food Engineering,
Bidhan Chandra krishiviswa vidyalaya, Nadia West Bengal, India,
reemaksh7@gmail.com
Ng. Joykumar Singh
Dept. of Food Technology
Central Agricultural University, Imphal, India, joyngang@gmail.com

Abstract- The present study was aimed to investigate drying of chayote (*Sechium edule Sw*.) slices in tray dryer at different temperatures, drying was conducted at 50°C, 60°C, 70°C , 80°C and 90°C at constant air velocity of 1.0, 1.5, 2 m/s in tray dryer; drying of slices was recorded for time interval of 10 min each till completely dried respectively. The analysed moisture data was fitted in three different drying mathematical models, i.e. Page's Model, Generalised Exponential Model and Logarithmic Model. Statistical analysis predicted that Page model was best-fitted model for describing drying characteristics of chayote slices.

Keyword - Dehydration (tray dryer), Moisture content, Color, Rehydration .

I. INTRODUCTION

The removal of moisture can be due to simultaneous heat and mass transfer. Purposely it is carried out to reduce water to the level at which microbial spoilage and deterioration reactions are greatly minimized .The dried product achieved will minimize transportation, storage, packaging cost and time. Chayote or squash (Sechium edule L.), is an edible fruit consumed as vegetable of a tropical perennial vine plant belonging to Cucurbitacae family and its physical characteristics are pale green, peer shape, mild flavor and crispy textures having a single seed. It is cultivated in various parts of India for its huge market demand in Manipur, chayote is available from the month of July to October, where it is locally called Daskhush. Chayote has been used in salads, cooked vegetables, fermented pickles, candy, juice. Chayote has very high moisture content of 88-92.5% on wet basis, which can lead to extensive postharvest losses caused by chemical and microbial deterioration (Lira-Saade 1996, Perez-Francisco et al. 2008). Fresh chayote cannot be stored for more than 6-7 days in ambient conditions, but shelf life can be extended through different processing methods such as fermentation, pickling, canning or cold storage freeze-drying.

Conventional methods such as hot air-drying have been applied severally in the processing and preservation of fruits and Vegetables. This method, however have been reported to impart certain undesirable physical and nutritional been reported to impart certain undesirable physical and nutritional characteristics to the finished dry product. As a result, pre- treatments have been applied prior to drying fruits and vegetables to control the objectionable changes in colour, texture (low porosity and low rehydration characteristics) and flavor that occurs (Grabowski et al, 2002; Aguilera et al. 2003; Jayaraman and Gupta, 2006; Aversa et al., 2010; Falade and Omojola, 2010). Blanching and osmotic dehydration are two common pre-treatments applied to food produce prior to drying (Senadeera et al., 2000; Sablani 2006).

Drying needs to be time and energy efficient without compromising on quality, therefore efforts should be made to reduce drying times and to decrease the temperatures used in the drying process (Adiletta et al., 2016). Mishra and Das (2015) analyzed the fruits of 10 accessions of Sechium Edule (Squash) for different physical parameters. The fruit weight, fruit length and fruit diameter in the collected samples ranged from 0.149 to 0.385kg, 10.1 to 12.8cm and 3.9 to 7.7cm, respectively. The variations in the collected samples were also evident in the colour of fruits as they had light green, yellowish green and dark colors. The fruit skin of the chayote fruits was either smooth in texture or had spines.

Studies on the nutritional characterization of Sechium edule (Jacq.) Swartz reported the total sugar content 2.74%, phenol 0.0048%, protein 0.94%, vitamin C 0.16%, carbohydrate 5.19%, iron 10.67ppm, manganese 3.61 ppm, zinc 1.39 ppm and calcium 27.89 ppm, indicating that the fruit Sechium edule (Jacq.) Swartz reported that the chayote is rich in phytochemical and lowered carbohydrate content used to prevent chronic disease, cardiovascular disease, high blood pressure and diabetes Greeshma (2016). However, the quality parameter of the variety available in Manipur has not been reported in previous researches. Hence, the present study was taken to analyse the drying characteristics and its quality of dried product.

II.MATERIALS AND METHODS

1. Experimental Procedure

11. Selection of raw materials

Good quality light green fresh chayote was purchased from local market in Manipur, damage and immature pieces of chayote was removed manually by visual inspection.

1.2 Chemical pre-treatment

After thoroughly washed the sliced chayote pieces were blanched with KMS and soaking the sample in boiling water for 10 minutes at 50^{0}C. The blanched with KMS samples were cooled immediately by keeping the under flowing water to prevent overcooking of the sample and drained to remove the excess water for blanched with KMS: citric acid (0.5:1% solution of potassium Meta bisulphate) sample.

Chayote
↓
Sorting
↓
Washing/Trimming
↓
Peeling
↓
Blanching in hot water (5min)
↓
Cutting slices
↓
Soaking with KMS: Citric acid in 0.5: 1% at (50^{0}C for 10 min.)
↓
Drying
↓
High velocity hot air dryer (6-10% dry basis)
↓
Tempering of dehydrated slices (10 minutes)
↓
Packaging (Normal 150 gauge polypropylene bag)
↓
Storage for 6 months

Quality testing at One month interval

Fig.1 Processing Flow chart for Dehydrated Chayote Slices.

2. Physicochemical Analysis

2.1 Initial moisture content

A standardization procedure of AOAC (1980) was followed to estimate the moisture content of food. The moisture content of the sample was computed using the following equations.

$$\text{Moisture content (wb)} = \frac{M_1 - M_2}{M_1} \times 100 \quad \text{..... (i)}$$

$$\text{Moisture content (db)} = \frac{M_1 - M_2}{M_2} \times 100 \quad \text{.....(ii)}$$

Where,

M.C. = moisture content of sample (% w.b. and d.b.)

M_1 = wt. of sample before drying (g)
M_2 = wt. of sample after drying (g)

Calculation:

M.C. = wt. of sample at any time - wt. of b.d material x 100
wt. of sample at anytime

Where,

Wt. of bone dried material = (initial weight of sample - initial M. C) / 100

2.2 Drying rate (DR):

Drying rate = Amount of moisture remove(g) Time taken (min) x total bone dried weight of sample (g)
Similarly, the drying rate was approximately proportional to the difference in moisture content between the product being dried and EMC at the drying air state.

D.R = (Mt + dt) –Mt
dt

Where,
Mt = moisture content at time t (% db)
Mt+dt = moisture content at time t+dt (%db)
dt = time of successive measurement (min)

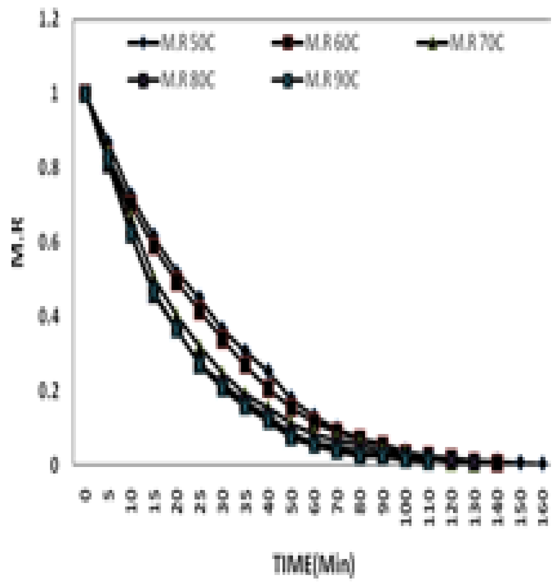

Figure 2 Effect of temperature on the moisture ratio of the chayote slice during drying at 50^{0}C , 60^{0}C, 70^{0}C, 80^{0}C, 90^{0}C, thickness 5mm & 1m/s air velocity.

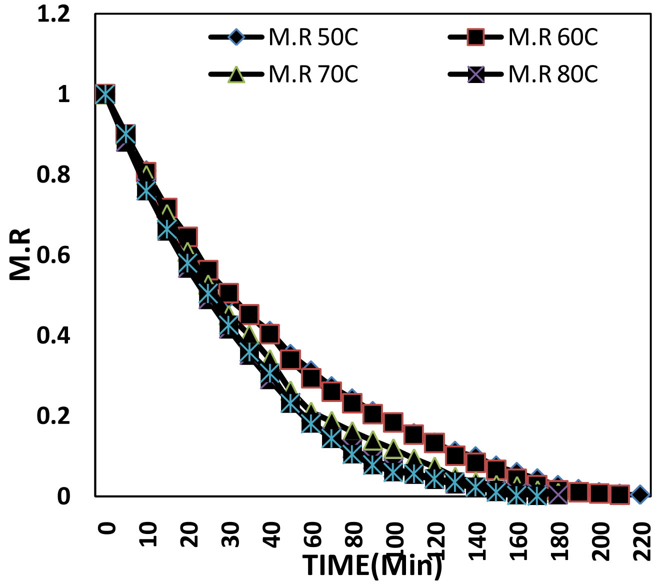

Figure 2. Effect of temperature on the moisture ratio of the chayote slice during drying at 50^{0}C ,60,70,80,90^{0}C, thickness 10mm & 1m/s air velocity.

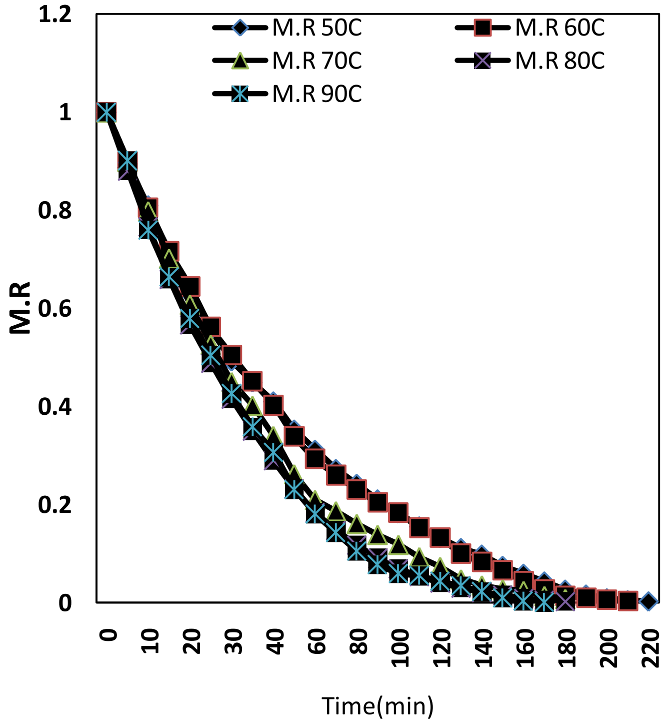

Figure 3 Effect of temperature on the moisture ratio of the chayote slice during drying at 50^{0}C,60^{0}C,70^{0}C,80^{0}C,90^{0}C, Thick ness 15mm & 1m/s air velocity.

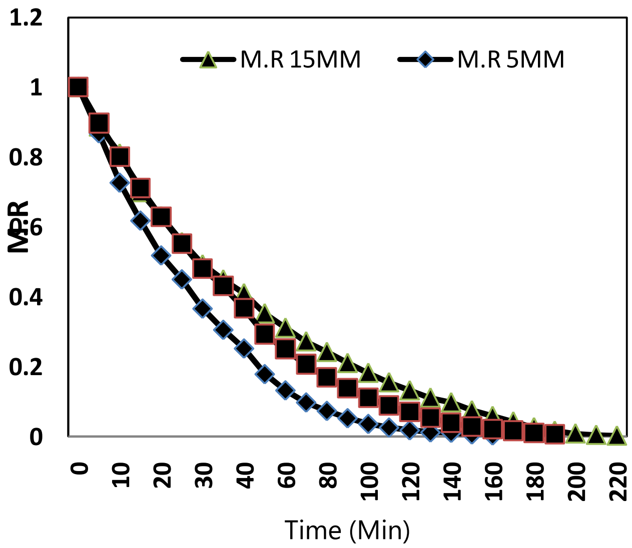

Figure 4 Effect of slice thickness on the moisture ratio of the chayote slice during drying at 50°C,5mm,10mm, 15mm (thickness)& 1m/s air velocity.

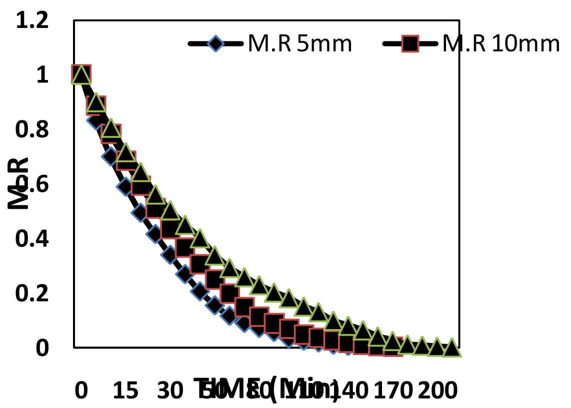

Figure 5 Effect of slice thickness on the moisture ratio of the chayote slice during drying 60°C, 5mm,10mm, 15mm & 1m/s air velocity.

Influence of drying temperature and slice thickness on drying time

The influence of the drying temperature on chayote at each of three sample thicknesses, namely 5, 10 and 15 mm, is shown in Figures 2.1 – 2.3, representing the moisture ratio versus drying time. It is clearly evident that the moisture ratio decreased continuously with drying time. At constant sample thickness, the increase in temperature reduced the drying time needed to reach moisture content of about 5-7 % wet basis. This was due to the increased energy of water molecules when the temperature was increased, as the evaporation of water molecules from the sample occurs more quickly.

The change in moisture content of sample versus drying time, for various sample thicknesses at a drying temperature of 50 & 60 °C, is shown in Figure 2.4-2.5. It was also found that greater sample thickness required a longer drying time due to the increased distance travelled by moisture to the surface. Similar trends were also observed at drying temperatures of 70,80, and 90 °C. Drying times for reducing moisture content from an final moisture content of 5-7 % (wb) for all experiments are given in Table 1. The time used to reduce the moisture ratio to the given level was as expected; that is, the reduction of moisture ratio of the sample depended on both the drying temperature and the thickness of the chayote slices, being highest at 50°C for drying chayote slices 15mm thick, and lowest at 90 °C for drying chayote slices 5 mm thick.

Figure 6 Chayote after blanching with KMS & Citric acid.

Table 1 Drying time (min) for drying to reach the final moisture content of 5-7 % (wb) at different temperatures and slice thicknesses.) Sample thickness (mm) 1m/s, 1.5m/s, 2m/s

Temp°C / slice thickness	1m/s			1.5m/s			2m/s		
	5mm	10mm	15mm	5mm	10mm	15mm	5mm	10mm	
50	150	190	220	150	170	220	140	160	210
60	140	170	210	140	160	200	130	140	190
70	130	160	180	120	150	180	120	130	180
80	130	140	180	120	130	170	110	120	170
90	110	140	170	100	130	170	100	120	160

Table 2. Equilibrium Moisture Content of Chayote

Independent variable T, °C	V, m/s	Blanched and treated sample (0.5 cm-slices (d.b)%	Blanched and treated sample(1.0 cm-slices) (d.b)%	Blanched and treated sample(1.5 cm-slices) (d.b)%
50	1.0	4.20	3.59	4.01
60	1.0	3.40	3.51	3.60
70	1.0	3.38	3.35	2.97
80	1.0	3.20	3.27	2.95
90	1.0	3.00	3.20	2.89

The equilibrium moisture content of chayote at air drying temperatures; 50, 60, 70, 80 and 90°C and air velocities; 1.0, 1.5 and 2.0 m/s in Table 2, were estimated by analyzing the moisture loss data using Henderson and Pabis (1961) technique. The estimated equilibrium moisture content values varied from 4.20 to 2.89% (d.b.) over the temperature range of 50-90°C. This apparently indicated that pretreatments had certain improvement in drying rate of chayote. As expected, the equilibrium moisture content decreased with increase in drying temperature in the present study. Similar observations were reported by previous research worker; Lidoo (2008) for thin layer drying of brinjal slices, Pandey and Aich (1989) on Mushroom with EMC varying from 5.6 and 4.93% (d.b.) within temperature range of 40⁰ to 50°C.

III.RESULTS AND DISCUSSION

Experiments were conducted to study the tray drying characteristics of chayote slices at different temperature. Chayote samples were packed in HDPE bags and stored at room temperature. Studies on quality were based on physicochemical characteristics (i.e., moisture content, drying rate, rehydration ratio, moisture ratio, ash content) which were determined for fresh samples. The results of the study are presented and discussed in following section.

1.Tray Drying Characteristics

Chayote slices were dehydrated in Tray dryer at 50⁰C 60⁰C, 70⁰C, 80⁰C,90⁰C to final equilibrium moisture content. The initial average moisture content of chayote slices was 540 % (db). The relationship between moisture content, drying time. The moisture content decreased very rapidly during the initial stage of drying, as there was fast removal of moisture from the surface of the Product. Decrease in drying rate with respect to time suggests a decreased drying rate with the decrease in moisture content. The drying rate was calculated using equation as discussed in earlier.

Effect of Pre-treatment and tray dryer on moisture content of chayote during drying process.

After pretreatments the samples were subjected to drying at various processing conditions; drying temperatures of 50⁰**C**, 60⁰**C**, 70⁰**C**, 80⁰**C** and 90°C and air velocity of 1.0, 1.5, and 2.0 m/s for slices sizes of 0.5, 1.0 and 1.5 cm. It can be seen that initially moisture removal of chayote slices was fast up to 30 min. As the drying progressed, the moisture removal decreased with time. It is typical drying behavior for agricultural materials reported by many research workers (S. R. Sharma 2005 for cauliflower, Gazor and Saeid, 2005 for pistachio). It was also observed that increase in the drying temperature caused an increase in drying rate, thus the drying time was decreased. With drying, the time taken to reduce the initial moisture content about 540 % d.b. to final 5-7% d.b. varied between 90 and 150 min for 0.5 cm-slices, 100 to 190 min for 1.0 cm-slices and 120 to 220 min for 1.5 cm–slices for blanched and treated sample, it ranged between 100 and 170 min for 0.5 cm- slices, 120 and 200 min for 1.0 cm-slices and 140 and 240 min for 1.5 cm-slices respectively in the temperature range of 50-90°C.

These moisture contents were different from each other and ranged from 88 to 92.5 % (w.b.) for blanched and chemical treated samples of chayote in potassium metabisulphite and citric acid solution. The drying time varied in the entire range from 90 to 220 min in blanched plus chemical treated sample of chayote. Consequently, the effect of air temperature has been reflected in drying rate. At higher temperature more than 90°C, the dried product was partially lost its fresh product characteristics (Mulet et al., 1987). Similar results were reported by Prabhanjan et al. (1995) and Ozdemir and Devres (1999). Dried chayote slices could be stored in sealed polythene package for more than six months without much deterioration to it is quality.

Specific energy consumption in drying of chayote slices for the pretreated samples varied from 3.296 to 8.270 kWh/kg of product in the drying air temperature ranging between 50⁰C and 90°C. Empirical model namely Page's, Generalized

Exponential and Logarithmic models were fitted in the drying data. The empirical models were analyzed for best prediction of moisture ratio.

The best models were selected on the basis of maximum coefficient of determination (R^2) and standard error (SEE). After optimum drying conditions were selected, the dried samples were packed by one types of packaging methods namely normal packaging in polypropylene bags and kept under ambient temperature for storage studies. The packed samples were reopened at each month interval during the period of storage to evaluate the quality in terms of rehydration properties, textural properties, and extent of browning, proximate compositions. The data of different responses obtained at each month interval during the period of storage was optimized using multiple responses package, to evaluate the drying and storage behavior simultaneously. The microbial analysis was also done for selected samples at each month of storage to evaluate the quality of packed samples in terms of microbial load. The variables for storage namely pretreatment, packaging methods and storage periods were analyzed statistically for their significance by using three factors ANOVA applied to the three replications.

IV.QUALITY ATTRIBUTES

1.Rehydration Characteristics

The rehydration behavior was analyzed in terms of the ability of the dried chayote slices to regain the original product characteristics. This is expressed in the form of rehydration ratio (RR), coefficient of rehydration (CR) and moisture content (MC) in rehydrated samples. Rehydration kinetics was studied for a period of 15 min for 0.5 cm-slice, 20 min for 1.0 cm-slice and 25 min for 1.5 cm-slice chayote at 100^0C temperature. The average rehydration ratio varied between 3.361 to 4.096, 3.357 to 3.604 and 2.991 to 3.588 for 0.5, 1.0 and 1.5 cm-slice respectively for blanched and treated sample respectively. It was lower in the case of 1.5 cm-slice. This is attributed to more shrinkage of dried material. The maximum value of rehydration ratio (4.096) was found in blanched and treated sample of 0.5cm slice dried at 90°C air temperature and 2.0 m/s air velocity. Coefficient of rehydration (CR) ranged between 0.331 to 0.662, 0.550 to 0.601 and 0.296 to 0.604 for 0.5, 1.0 and 1.5cm-slice, respectively for blanched and treated sample.

Table 3 Rehydration Ratio for blanched and treated sample in thickness (cm)& air velocity(m/s).

Coefficient of Rehydration		(COR)		
Thickness (cm)	Velocity, m/s	R1	R2	R3
0.5	1	0.554	0.551	0.547
0.5	1.5	0.568	0.571	0.565
0.5	2	0.596	0.599	0.592
1.0	1	0.550	0.556	0.553
1.0	1.5	0.552	0.559	0.555
1.0	2	0.554	0.561	0.557
1.5	1.0	0.563	0.568	0.605
1.5	1.5	0.572	0.593	0.566
1.5	2	0.296	0.604	0.575

Table no. 4, Coefficient of Rehydration ratio for blanched and treated sample in thickness (cm)& air velocity(m/s).

Rehydration Ratio		(RR)		
Thickness (cm)	Velocity, m/s	R1	R2	R3
0.5	1	3.877	3.900	3.924
0.5	1.5	3.942	3.966	3.990
0.5	2	4.047	4.072	4.096
1.0	1	3.355	3.314	3.335
1.0	1.5	3.319	3.360	3.340
1.0	2	3.333	3.373	3.353
1.5	1	2.992	3.010	3.028
1.5	1.5	2.991	3.009	3.027
1.5	2	3.080	3.099	3.117

2. Color Lightness (L*)

Chayote is often found discoloured after processing due to the presence of phenolic compounds which give rise to coloured quinonic compounds leading to a dull colour as reported by Arslan, D., & Özcan, M. M. (2011) . It was observed that the values of lightness (L*) were ranged between 64.71 and 76.56 for dried blanched and treated sample. The recorded data for lightness (L*) for each set of experiment were analyzed for three factors ANOVA for colour (L*) lightness, as shown in Table 4.

It can also be clearly seen that the single terms such as air temperature and cube size are the important terms affecting the colour (L*) at 1% significance level as the value F_t . The effect of air velocity was not significant at 5% significant level. In terms of redness, it was found that the redness of pretreated samples was not significantly different among all the samples due to probably to the leaching out of the soluble pigments during blanching and immersion in KMS and citric solution. After subsequent drying the changes of redness of dried chayote were observed. All dried chayote slices were obviously redder than fresh and pretreated chayotes.

Table 5,ANOVA for Full Model of Lightness (L*) for Different Pretreatments

Pretreatments	Source	DF	SS	F	P	R^2,%
Blanched and Treated Samples	Regression	9	0.02335	1.54	0.154	17.5
	Error	65	0.10972			
	Total	74	0.13307			

V.CONCLUSION

In the present study of drying of chayote in the mechanical dryer, the constant drying rate period did not exist and drying of chayote took place in falling rate period. Falling rate drying curve was divided into two periods. During first falling rate period, the rate of drying decreased very rapidly up to about 300% (d.b.) moisture content or 30 min time. During falling rate period, the drying rate decreased gradually then it decreased very slowly. Coefficient of rehydration (CR) ranged between 0.331 to 0.662, 0.550 to 0.601 and 0.296 to 0.604 for 0.5, 1.0 and 1.5 cm-Slice, respectively for blanched and treated sample. The coefficient of rehydration increased with increase in temperature for all the sizes under study.

Drying can be one of the methods to increase shelf life of chayote. Drying as a preservation method has many advantages such as much extended shelf life, lower weight and sometimes volume, relatively cheaper packaging, storage at ambient conditions, ease of handling and transportation. The chayote fruit is a rich source of carbohydrates, fats, proteins, minerals and vitamin A and vitamin C. Chayote is mainly used for human consumption. As it is soft in nature as compared to other fruits, it has been used for children's food, juices, sauces and pasta dishes. It gives positive results while preparing jams and other sweet products. In India, fruit and roots are not only consumed as human food but also used as fodder.

Acknowledgements

This work was supported by Department of Food Process Engineering, College of Food Technology, CAU, Manipur.

REFERENCE

[1]. Adiletta et al., (2016). Drying characteristics and quality of grape under physical pretreatment. J. Food Eng. (172), 9-18.

[2]. Aguilera, J.M, Chiralt, A., Fito, P. (2003). Food dehydration and product structure. Trends in Food Science and Technology, 14, 432-437.

[3]. Arslan, D., & Özcan, M. M. (2011). Dehydration of red bell-pepper (Capsicum annuum L.): change in drying behavior, color and antioxidant content. Food and Bioproducts Processing, 89(4), 504-513

[4]. Aversa, M., Curcio, S., Calabrò, V., Iorio, G. (2010). Experimental Evaluation of quality parameters during drying of carrot samples. Food and Bioprocess Technology, (5), 118–129.

[5]. Falade, K.O., Omojola, B.S. (2010). Effect of processing methods on physical, chemical, rheological, and sensory properties of okra (Abelmoschus esculentus). Food and Bioprocess Technology. (3)387–394.

[6]. Grabowski, S., Marcotte, M., Poirier, M., Kudra, T. (2002). Drying characteristics of osmotically pretreated cranberries, energy and quality aspects. Drying Technology, 20, 1989-2004

[7]. Greeshma P. K. (2016). Preliminary phytochemical and nutritional profiles of an underutilized vegetable Sechium edule (Jacq.) Swartz. South Indian Journal Of Biological Sciences; 2(1); 207-212.

[8]. Gonzalez-Martinez, C., Chafer, M., Xue, K. Chiralt, A. (2006). Effect of the osmotic pretreatment on the convective air drying kinetics of pear var Blanquilla. International Journal of Food Properties, 9, 541 – 549.

[9]. Haas, G. J., and Prescott, H. E. (1972). On rehydration and respiration of dry and partially dried vegetables. J. Food Sci. 39: 681-684.

[10]. Hamid Reza Gazor & Saeid Minaei .Influence of Temperature and Air Velocity on Drying Time and Quality Parameters of Pistachio (Pistacia vera L.), Drying Technology: An International Journal, 23:12, 2463-2475.

[11]. Henderson, S. M., and Pabis, S. (1961). Grain drying theory. Temperature effect on drying

coefficient. J. Agril. Engng. Research 6(3): 169-174.

[12]. Jayaraman, K.S and Gupta D.K. (2006). Dehydration of fruits and vegetables-Recent developments in principles and Techniques. Drying Technol. 24 (10-12):1487-1494.

[13]. Lidoo, C. K. (2008). Thin-layer drying characteristics of brinjal slices, J. Food Sci. Technology 45(5):423-425.

[14]. Mishra, L. K., and Das, P. (2015). Nutritional Evaluation of Squash (Sechium edule) Germplasms Collected from Garo Hills of Meghalaya-North East India. International Journal of Agriculture, Environment and Biotechnology, 8(4), 971.

[15]. Mulet, A.; Berna, A.; Borras, M. and Pinaga, F. 1987. Effect of flow rate on carrot drying. Drying Technology 5(2): 245-258.

[16]. Ozdemir, M. and Devres, Y. O. 1999. The thin layer drying characteristics of hazelnuts during roasting. J. of Food Engineering 42: 225-233.

[17]. Pandey, T. and Aich, (1989). Equilibrium MC of dehydrated mushroom (Pleurotus sajor caju). J. of Food Sci. and Technology 26(2):108-109.

[18]. Prabhanjan, D. G.; Ramaswamy, H. S. and Raghavan, G. S. V. 1995. Microwave-assisted convective air drying of thin layer carrots. Journal of Food Engineering 25: 283-293.

[19]. Sablani, S.S. (2006). Drying fruits and vegetables: retention of nutritional/410 functional quality. Drying Technology, 24, 123 – 135.

[20]. Senadeera, W., Bhandari, B., Young, G., Wijesinghe, B. (2000). Physical property changes of fruits and vegetables during hot air drying. In: Mujumdar, A. S. (ed) Drying technology in agriculture and food sciences, Enfield Science Publishers, pp. 159 – 161.