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RESEARCH PAPER

Effect of Osmo-microwave Vacuum Drying Kinetic of Pineapple Cubes and their Quality Evaluation

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ABSTRACT

Drying of pineapple by microwave-vacuum (MW-V) with osmotic dehydration (OD) as a pretreatment was studied. The effect of sugar concentration (40, 50, and 60 Brix), soaking temperature 30, 45, 60 °C and magnetron ON/OFF time-15s/30s, 20s/30s, 25s/30s of the microwave vacuum dryer on TSS, pH, acidity, reducing sugar, non-reducing sugar and total sugar was evaluated. After the osmotic treatment, the moisture content of fruits and vegetable are usually reduced by 316.24-399.25(%db) from initial moisture content. The Hendersons and Pabis Model was well fitted to the experimental data $r^2 \geq 0.9464$. The effective diffusion coefficients for water and solute diffusion were determined, considering pineapple as slab of thickness 1 cm. The effective diffusion coefficients for water as well as solute were empirically correlated with sugar concentration, soaking temperature and magnetron ON/OFF time. The effective diffusivity was in the range of 2.91×10^{-7} to $7.58 \times 10^{-7} m^2/s$. The activation energy for pineapple cubes, which was estimated by using Arrehenius equation was in the range 13.79 to 94.77 kJ/mole. Overall score of sensory characteristics ranged from 6.3 to 8.7 for all magnetron ON/OFF time i.e. 15s/30s, 20s/30s, 25s/30s ON/OFF time of the magnetron. The quality characteristics of dried pineapple cubes i.e. TSS, pH, acidity, reducing sugar, non-reducing sugar, total sugar were significant at $p \leq 0.05$. Osmo-microwave vacuum dried pineapple cubes indicated that the best sample could be prepared at cubes soaked in at 60°B sugar concentration at 60°C soaking temperature and dried at 20 sec on time of magnetron and 30 sec off time of the magnetron resulted best sensory scores and the nutritional analysis indicated that the pineapple cubes dried at these condition have TSS 32.37%, p^H 4.44%, acidity 0.605%, reducing sugar 21.87%, non-reducing sugar 46.08% and total sugar 67.96% etc.

Keywords: Pineapple, osmotic dehydration, microwave vacuum, osmo-microwave vacuum drying rate, nutritional analysis, sensory analysis

Microwave vacuum drying the heat needed for drying is generated by the absorption of electromagnetic radiation by the water in the substance to be dried. The microwave radiation is transformed into kinetic energy, which makes water molecule vibrate intensively, leading to rapid increase in temperature and consequently efficient water evaporation. If the sample thickness is kept small then the warming up will be homogeneous, with only small temperature gradient generated across the sample. The vacuum produced in the dryer lowers the vapor pressure of the liquid, thus the combination of vacuum and microwave energy results in quick drying at low

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temperature (Musa and Farid, 2002). The advantage of microwave drying system was first reported by Mc Donnell Company (Gardner and butler 1982). Vacuum pressure range from 3.4 to 6.6 k Pa. was used for the dryer to vaporize free water at temperature of 26- 52 °C. The evaporated water from the product in the microwave vacuum drying system is usually removed by condensing using a cooling system, fed with water (Sanga *et al.* 2000).

It is a sub atmospheric drying, water evaporation takes place at lower temperature under vacuum, and hence the product processing temperature can be significantly lower, offering higher product quality. The microwave vacuum drying was first used for concentration of citrus juice (Decareau and Peterson, 1986). In the food industry, microwave vacuum drying is used for drying of pastas, powders, concentrated fruit juices, tea powder and enzymes (Schiffmann, 1995). Microwave vacuum-drying can provide a significant advantage in this falling rate period for two reasons: this region may be reduced because more moisture is lost in the constant rate period; and the in situ evaporation of water that occurs in microwave vacuum-drying is much more rapid than diffusion of liquid water that occurs during air-drying.

Microwave assisted vacuum drying, or microwave vaccum drying (MVD), is a technology that not only has the advantages of microwave heating (rapid heating, high efficiency, good controllability and sanitation) (Zang, *et al.* 2000), but also lowers the boiling point of water caused by vacuum environment, thus improving the energy efficiency and decreasing the formation of burned spots in the surface of the final product. Furthermore this new processing technology can increase the expansion ratio and improve the texture of the finished producs (Zhang *et al.* 2007). Drouzas and Schubert (1996) reported that the temperature of banana slices during microwave vacuum drying was always greater than the boiling point of water at the chamber pressure, an effect attributed to the presence of dissolved solids in the water, which causes an increase in the boiling point.

Microwave vacuum drying of banana slices was investigated experimentally by Drouzas and Schubert (1996). The structure of dried products was of excellent quality as examined by taste, aroma, smell and rehydration tests. Song *et al.* (2009) experimented with microwave vacuum drying of potato slices. The test materials were placed on a rotating tray to allow uniform exposure to the microwave field. The higher drying rates were obtained with higher microwave power and lower vacuum level. Despite these information on various fruits and vegetables, there is scanly information available either in terms of drying kinetics or quality of pineapple cubes undergoing osmo-microwave vacuum drying technique.

THEORETICAL CONSIDERATIONS

Osmotic dehydration

1. Water loss (W_L)

Water loss is the quantity of water lost by pineapple cubes during osmotic processing. The water loss (WL) is defined as the net weight loss of the fruit on initial weight basis and was be estimated by equation (1) (Lenart and Flink 1984; Shi *et al.* 1995; Silveira *et al.* 1996 and Kaleemullah *et al.* 2002).

$$W_L = \frac{W_i.X_i - W_\theta.X_\theta}{W_i} \quad ...(1)$$

Where,

W_θ = mass of cube after time θ, g

W_i = initial mass of cube, g

X_θ = water content as a fraction of mass of cube at time θ.

X_i = water content as a fraction of initial mass of cube, fraction

2. Solid gain

The solids from the osmotic solution get added to the samples during osmotic dehydration. The loss of water from the sample takes place in osmotic dehydration consequently it increases the solid content. The solid gain is the net uptake of solids by the pineapple cubes on initial weight basis (Lenart and Flink (1984); Shi *et al.* 1995; Silveira *et al.* 1996 and Kaleemullah *et al.* 2002) The solid gain was calculated using expression (2).

$$SG = \frac{W_\theta(1-X_\theta)-W_i(1-X_i)}{W_i}\times 100 \quad \ldots(2)$$

Where,

SG = solid gain (g per 100 g mass of sample).

W_θ = mass of slices after time θ, *g*

W_i = initial mass of slices, *g*

X_θ = water content as a fraction of mass of slices at time θ.

X_i = water content as a fraction of initial mass of slices, fraction

3. Mass reduction

The overall exchange in the solid and liquid of the sample do affect the final weight of the sample. The mass reduction (MR) can be defined as the net weight loss of the fruit on initial weight basis (Silveira *et al.* 1996).

$$MR = \frac{W_i - W_\theta}{W_i} \quad \ldots(3)$$

Where,

W_θ = mass of slices after time θ, *g*

W_i = initial mass of slices, *g*

MR = Mass reduction

4. Drying Characteristics

Moisture Content (% db) versus drying time (min) and drying rate (kg of water removed/kg of dry matter/h) with respect to moisture content (%db) was determined for drying of pineapple cubes. Moisture ratio versus drying time (min) was also determined from the experimental data of pineapple cubes.

Drying rate

The moisture content data recorded during experiments were analyzed to determine the moisture lost from the sample of pineapple cubes in particular time interval. The drying rate of sample was calculated by following mass balance equation (Brooker *et al.* 1974).

$$R = \frac{\text{WML (kg)}}{\text{Time interval (min)} \times \text{DM (kg)}} \quad \ldots(4)$$

Where,

R = Drying rate at time θ

WML = Initial weight of sample – Weight of sample after time θ

DM = Dry matter of the sample, g

1. Moisture Ratio

By comparing the phenomenon that drying takes place in falling rate period, with Newton's law of cooling, the drying rate is proportional to the difference in moisture content between the material being dried and equilibrium moisture content at the drying air condition as given in equation (5),

$$MR = \frac{M - M_e}{M_0 - M_e} \quad \ldots(5)$$

Where, MR = Dimensionless moisture ratio,

M = Moisture content at time t (% db),

M_0 = Initial moisture content (% db),

M_e = Equilibrium moisture content (% db).

2. Evalution of the model

In most of the studies carried on drying, diffusion was generally accepted to be the main mechanism during the transport of the moisture to the surface to be evaporated. The solution of ficks equation, with the assumption of moisture migeration being by diffusion negligible shrinkage, constant diffusion coefficients and temperature and for a slab (Crank, 1975; Pala *et al.* 1996);

$$MR = \frac{M-M_e}{M_0-M_e} = \sum_{n=1}^{n=r} \frac{8}{(2n-1)\pi^2} \exp\left(-\frac{D_{eff}(2n-1)^2\pi^2.t}{(4L)^2}\right) \ldots(6)$$

Where,

M_0 = Initial moisture content (%db)

M_e = Equilibrium moisture content (%db)

L = Half thickness of slab

n = Positive integer

The Henderson and Pabis model is first solution of Ficks second law (Henderson and Pabis, 1961, Ozdemir and Devres, 1999)

$$MR = \frac{M - M_e}{M_0 - M_e} = \frac{8}{\pi^2} \exp\left(-\frac{\pi^2 D_{eff}\, t}{4L^2}\right) \qquad \ldots(7)$$

Equation (7) can be written in a more simplified form as;

$$\frac{M - M_e}{M_0 - M_e} = k.\exp(-ct) \qquad \ldots(8)$$

Where,

k = constant

c = Drying constant

D_{eff} = Effective moisture transfer diffusion coefficient, m^2/s

3. Calculation of moisture diffusivity

The plot of ln MR versus time gives a straight line with a slope of;

$$\text{Slope} = \frac{\pi^2.D_{eff}}{4L^2} \qquad \ldots(9)$$

4. Activation energy for microwave vacuum drying:

Activation energy (Ea) was calculated using Arrhenius equation (s). The logarithm of D_{eff} versus a reciprocal of microwave power (P) was plotted which resulted in a linear relationship between ($ln\ D_{eff}$) and (1/P). The activation energy of diffusion was estimated by using following equation (Gökçe Dadalı *et al.* 2011)

$$k = k_0 \exp\left(-\frac{E_a.m}{P}\right) \qquad \ldots(10)$$

Where,

k = drying rate constant obtained by using Page's model (min^{-1}),

k_0 = preexponential constant (min^{-1}),

E_a = activation energy (kJ/mol),

P = microwave power level (W),

m = mass of raw sample (g).

Activation for microwave vacuum drying ON time of 2 kw of magnetron for 15 sec means 500.00 w, 2 kw magnetron ON for 20 sec means 666.66 w and 2 kw magnetron ON for 25 sec means 833.33 w.

MATERIAL AND METHODS

Osmotic dehydration of pineapple cubes

Ripe pineapple fruits of Gaint Kew variety were procured from the local market. Fully ripe, medium sized fruits, with soluble solid content from 12 ± 1^0Brix, were used in these experiments. The fruits were washed, hand peeled, cut into cubes of size 10 mm × 10 mm × 10 mm. Pineapple cubes (2 kg) were imersed in beakers containing sugar solution 40, 50, 60^0Brix, the solution were maintained at 30, 45, 60°C respectively in hot water bath. The syrup to fruit ratio was 2:l (w/w) to limit the concentration changes due to uptake of water and loss of solute to the cubes. Osmotic dehydration done at 3 levels of sugar syrup concentrations and 3 levels of soaking temperatures at 40, 50, 60 ^{0}Brix and at 30, 45, 60°C respectively. The experiments were repeated thrice, the total number of experiments were 27. The mass reduction w.r.t. time were recorded at each 10 minutes interval. The observations recorded were solid gain w.r.t. time, water loss w.r.t. time and mass reduction w.r.t. time. The observations were recorded till the constant reading was observed, it varied from 30 to 140 min for all the treatments. After expose sample to osmosis the surface moisture from the sample was removed by using tissue paper.

Microwave vacuum drying of osmotically dried pineapple cubes

(a) Experimental setup

Fully ripe, medium sized fruits of giant kew variety discussed in earlier section was used for the study.

The pineapple cubes were prepared of size 10 mm × 10 mm × 10 mm and loaded on the round plate (disc) of the microwave vacuum dryer. Microwave vacuum dryer (Make: M/S S. B. panchal & Co, Mumbai). The dryer is of the capacity 1 kg. around 600 g of pineapple cubes were loaded on the disc of the microwave vacuum dryer. There are two magnetrons of 1 kw capacity each which generated the microwaves. The vacuum was provided to produce the vacuum in the range of 3.0 to 6.0 kg/cm^2. The sample was exposed to 15s ON and 30s OFF time of magnetron, 20s ON and 30s OFF time of magnetron and 25s ON and 30s OFF time of magnetron to vary the power level. The sample was loaded on the disc of the sample loading chamber. The ON/OFF time of the magnetron was set by control panel of the microwave vacuum drying system. The vacuum level was achieved 4 kg/cm^2 then the drying process were carried out up to 15 min by maintaining 15s ON and 30s OFF; 20s ON and 30s OFF and 25s ON and 30s OFF. The weight loss of the sample was recorded. The weight loss was recorded till the constant reading was observed. The drying was continued till the constant weight was achieved. The Initial moisture content of the pineapple cubes was calculated by using hot air oven as per AOAC, 2010.

$$Moisture\ Content\ (db)\% = \frac{W_1 - W_2}{W_2} \times 100 \qquad \ldots(11)$$

Where,

W_1= weight of sample before drying, *g*

W_2 = weight of bone dried sample, *g*

The weight loss was recorded by an electronic balance (Make: M/s Contech Instruments, Navi Mumbai; Model: CT-3K1) with an accuracy of 0.001 g. The weight loss of the pineapple cubes were recorded at 15 min interval during progression of drying till the constant weight has achieved. The moisture content versus drying time, Drying rate versus moisture content and moisture ratio versus time was determine.

Quality evaluation of Osmo-microwave vacuum dried pineapple cubes

TSS, pH, acidity, reducing sugar, non-reducing sugar, total sugar, moisture content were determined by using standard procedures (Ranganna, 1986) at all three temperature 40, 50 and 60^{0}C and at magnetron ON/OFF time in sec 15s/30s, 20s/30s and 25s/30s of dried pineapple cubes. Three replications of each test were carried out at each temperature.

1. Total soluble solids (TSS)

The TSS of Osmo-convective and osmo-microwave vacuum dried pineapple cubes were measured by using digital refractometer (Make: Atago, Japan). The prism of the refractometer was cleaned with the help of distilled water and tissue paper. The distilled water was used to calibrate the Refractometer, the TSS of distilled water is zero and is known. This was used as standard for calibration. The Osmo-convective and osmo-microwave vacuum dried pineapple cubes were grounded and small quantity water was added to it. A drop of the sample was placed on the prism and the TSS of the sample was measured.

2. pH

pH was recorded by digital pH meter (Make: Hanna Instruments, Model: pH 211). The equipment was standardized by 4 and 7 pH standard solution. The pH of dried pineapple cubes was determined by adding 15 ml of distilled water to 5 g of ground pineapple powder.

3. Acidity

Acidity was determined by using titration method (Ranganna, 1986). 1g of ground dried pineapple powder was taken. 20 ml distilled water was added to it. Pipette out 1 ml of this sample in conical flask and 100 ml distilled water was added to it. 2-3 drops of phenolphthalein indicator was added to it. The solution was titrated with 0.1 N NaOH. End point is faint pink colour. Acidity was calculated by using equation,

$$\text{Total Acid, \%} = \frac{B.R.\times Normality \times Vol.madeup \times equivalent\ wt.of acid \times 100}{vol.of sample\ taken for estimation \times wt.of sample \times 1000} \quad \ldots(12)$$

4. Reducing Sugar

Reducing sugar was estimated by Fehling's method (Ranganna, 1986). The process was carried out in three steps. In first part, 5 g dried ground pineapple cube powder was added with 100ml distilled water. 2-3 drops of phenolphthalein indicator was added to it. This sample solution was titrated with 1 N NaOH. The end point was feint pink colour. It was filtered after addition of lead acetate and potassium oxalate solution. In second part, Fehling solution A, B and distilled water were taken in proportion 1:1:1 in a conical flask, and in the third part, titration of first part solution against second part solutions was carried out by using methylene blue indicator in boiling condition. Titration was continued until the end point of brick red colour appears. Reducing sugar was calculated by using formula;

Reducing Sugar, % =

$$\frac{\text{mg of invert sugar} \times \text{Dilution} \times 100}{\text{Titration} \times \text{Wt. or volume of sample} \times 100} \quad \ldots(13)$$

5. Non reducing sugar

Non reducing sugar was determined as per the Ranganna, 1986. In this method, part one solution of reducing sugar was used. 50 ml of this solution was neutralized with concentrated 20 N NaOH after overnight keeping with 1:1 HCL. By making 100 ml volume with distilled water, this solution was titrated with part two solutions i.e. first part and second part. In the third part same procedure was followed as discussed in reducing sugar. Total sugar was calculated by using equation,

Total Sugar, % =

$$\frac{\text{mg of invert sugar} \times \text{Dilution} \times 100}{\text{Titration} \times \text{Wt. or volume of sample} \times 100} \quad \ldots(14)$$

Non reducing sugar was calculated by using equation,

Non Reducing Sugar, % = Total sugar, % × 0.95 …(15)

6. Statistical analysis of quality characteristics of dried pineapple cubes

Statistical analysis of SE and CD values for quality characteristics of dried pineapple cubes like TSS, pH, acidity, Reducing sugar, Non-reducing sugar, total sugar were determined and was carried out by SAS 3.0. Recorded data were subjected to statistical analysis by "Analysis of variance" technique. ANOVA with replicated factor was done. The significant and non-significant treatment was judged with the help of F (variance ratio) table and t-test. The significant different between the means was tested against the critical difference at $p \leq 0.05$.

7. Sensory evaluation of osmo-microwave vacuum dried pineapple cubes

The sensory evaluation was carried out using trained taste panel consisting of students and staff from the College of Agricultural Engg. and Tech., Dapoli. The number of panelists who evaluated microwave vacuum dried pineapple cubes was 41 (22 female and 19 male). Samples were coded using random code A to AA (27 samples). Panelists were served with salted potato chips, water to break the monotony in taste of the dried pineapple cubes.

Mean sensory scores for quality attributes (colour, taste, texture, flavour) and overall acceptability were recorded in individual sheet and average scores are reported. The sensory method employed a nine-point hedonic scale used to assess colour, flavour, taste and texture: 9 (like extremely), 8 (like very much), 7 (like moderately), 6 (like slightly), 5 (neither like nor dislike), 4 (dislike slightly), 3 (dislike moderately), 2 (dislike very much), 1 (dislike extremely). These samples for each treatment were placed in the paper dish. These samples were organoleptically tested for different quality attributes like colour, texture, taste, flavour and overall acceptability.

8. Statistical analysis of sensory evaluation

ANOVA with replicated factor for sensory analysis was done. The significant and non-significant treatment was judged with the help of F (variance ratio) table and t-test. The significant different between the means was tested against the critical difference at $p \leq 0.05$.

9. Optimum product quality based on sensory score

Drying of pineapple cubes 3 levels of sugar concentration 40, 50, 60^{0}Brix, soaking temperature 3 levels at 30, 45, 60^{0}C, dried by microwave vacuum dryer magnetron ON/OFF time in sec 15s/30s, 20s/30s and 25s/30s were evaluated for better sensory scores and retention of nutritional quality characteristics (i.e. TSS, pH, acidity, Reducing sugar, Non-reducing sugar, total sugar), considering the all above properties the best treatment was decided.

RESULTS AND DISCUSSION

Osmotic Dehydration of pineapple cubes

The fully riped pineapple cubes (10 mm × 10 mm × 10 mm) were having initial moisture content (649.52%db). These cubes exposed at 40, 50 and 60^{0}B sugar solution and 30, 45 and 60^{0}C soaking temperatures.

1. Mass Reduction

Fig. 1 shows the typical average % mass reduction of pineapple cubes w.r.t. time (minutes) curve at soaking temperature 30, 45 and 60°C respectively at

Table 1: Mass reduction (%) with respect to time at varied sugar concentration

Soaking Temp	Mass reduction % at various sugar concentration					
	40°Brix	Time (min)	50°Brix	Time (min)	60°Brix	Time (min)
30°C	6.66	30	14.66	50	17.33	80
45°C	10.66	40	17.33	80	24.66	100
60°C	12.00	50	25.33	100	32.00	120

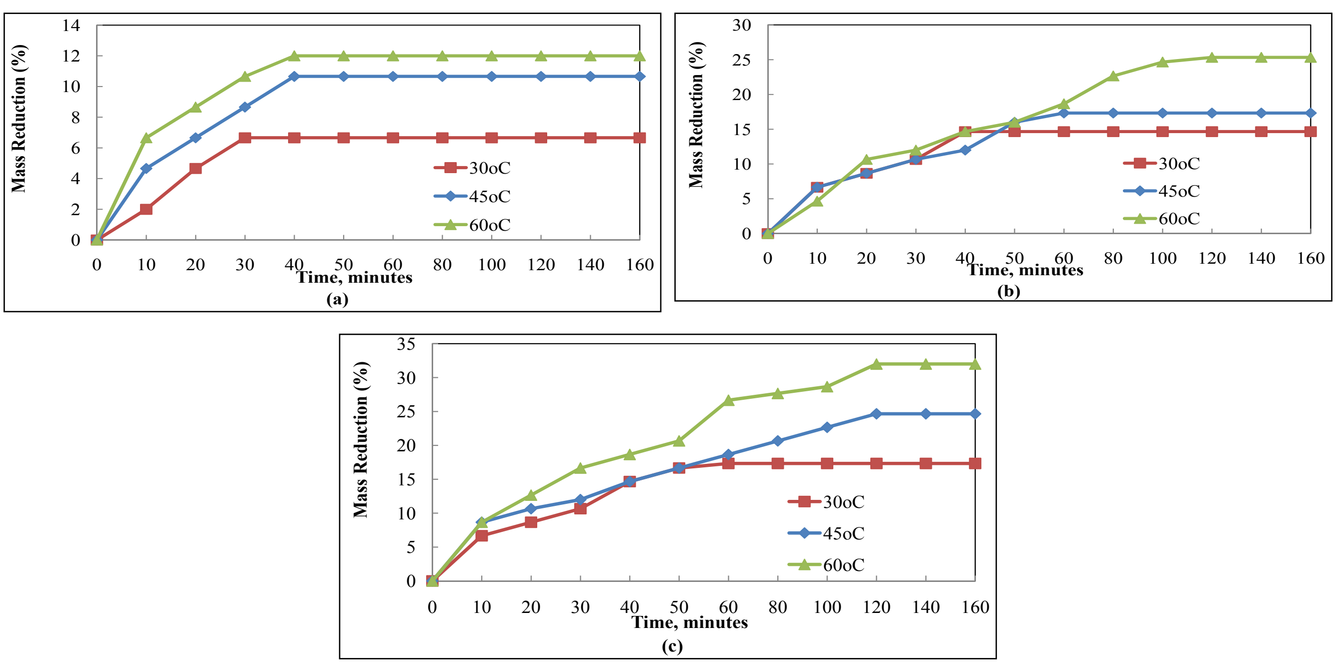


Fig. 1: Mass Reduction (%) versus time (min) at soaking temperature of pineapple cubes at 30, 45, 60°C in sugar concentration **(a)** 40°B; **(b)** 50°B; and **(c)** 60°B

40°B sugar concentration. As the soaking temperature increases from 30 to 60°C, the mass reduction (%) increases and it becomes stable reading, after which even the time of exposition increases the mass reduction (%) remains unchanged. The average % mass reduction at 40°B sugar concentration was 6.66, 10.66 and 12.00% at 30°C, 45°C and 60°C soaking temperature respectively. Similar type of behavior has been observed at 50°B and 60°B sugar concentration (trends not shown) at 30°C, 45°C and 60°C soaking temperature. Table 1 shows the peak mass reduction (%) with respect to soaking temperature (or) and time of soaking of pineapple cubes.

From Table 1 it is revealed that as the sugar concentration increases from 40°B to 60°B the mass reduction (%) increases from 6.66% to 17.33% at 30°C soaking temperature. Similarly as the 10.66% to 24.66% at 45°C soaking temperature and 12.00% to 32.00% at 60°C soaking temperature respectively. Filho *et al.* 2015 reported that mass reduction upto 26.38% at sugar concentration 50°B and soaking temperature 40°C in pineapple, Correa *et al.* 2014 reported that mass reduction in pineapple 7.4, 8.0 and 13.6 for varied sugar concentration 40, 50 and 60°B respectively. This increase in mass reduction (%) due to increase in soaking temperature. The increase in mass reduction (%) w.r.t to increase in sugar concentration.

2. Solid Gain

Fig. 2 represents the typical curve for solid gain (%) w. r. t. time in minutes of osmotic drying of pineapple cubes at 40°B sugar concentration and soaking temperature 30, 45 and 60°C. As the soaking temperature increases from 30°C, 45°C and 60°C, the solid gain (%) increases 5.6, 9.52 to 10.53% and it becomes stable solid gain (%), after which even the time of exposition increases the solid gain (%) remain unchanged. Similar type of behavior has been observed (trend not shown) at 50°B and 60°B sugar concentration. Table 2 shows the peak solid gain (%) w. r. t. soaking temperature at the time of soaking of the pineapple cubes.

From Table 2 it is reveled that as the sugar concentration increases from 40°B to 60°B the solid gain (%) increases from 5.6% to 14.32% at 30°C soaking temperature. Similarly at 45°C soaking temperature the solid gain (%) increases from 9.52% to 18.57% and for 60°C soaking temperature the solid gain (%) increases from 10.53% to 21.98% respectively. Solid gain (%) increases as the increases in soaking temperature from 30°C to 60°C at each sugar concentration i.e. 40°B, 50°B and 60°B respectively. Similar results have been observed for peas and blueberries products reported in the literature Ertekin and Cakaloz, (1996) and Nsonzi and Ramaswamy, (1998) for respectively. However a longer contact time of the samples with the sugar solution gives a higher solids gain and a higher moisture loss (Nieuwenhuijzen *et al*. 2001). Filho *et al.* 2015 reported that solid gain 7.31% at sugar concentration 50⁰B and soaking temperature 40⁰C in pineapple, Correa *et al.* 2014 reported that solid gain in pineapple 6.8, 5.4 and 8.9% for varied sugar concentration 40, 50 and 60°B respectively. Azuara *et al.* 1996 reported that solid gain in potato and apple 6.61 and 7.93 at 70°B sugar concentration solution. Sridevi and Genitha 2011 and Devi *et al.* 2012 reported that solid gain in pineapple was 8.57% at 30°C soaking temperature and 40°B sugar solution. Suresh kumar and Genitha, 2011 reported that solid gain in pineapple slices was 10.5% at 35°C soaking temperature and 50° Sugar concentration.

Table 2: Solid gain (%) with respect to time at varied sugar concentration

Soaking Temp	Solid gain % at varied sugar concentration					
	40°Brix	**Time (min)**	**50°Brix**	**Time (min)**	**60°Brix**	**Time (min)**
30°C	5.6	30	12.5	50	14.32	80
45°C	9.52	40	14.32	80	18.57	100
60°C	10.53	50	18.9	100	21.98	120

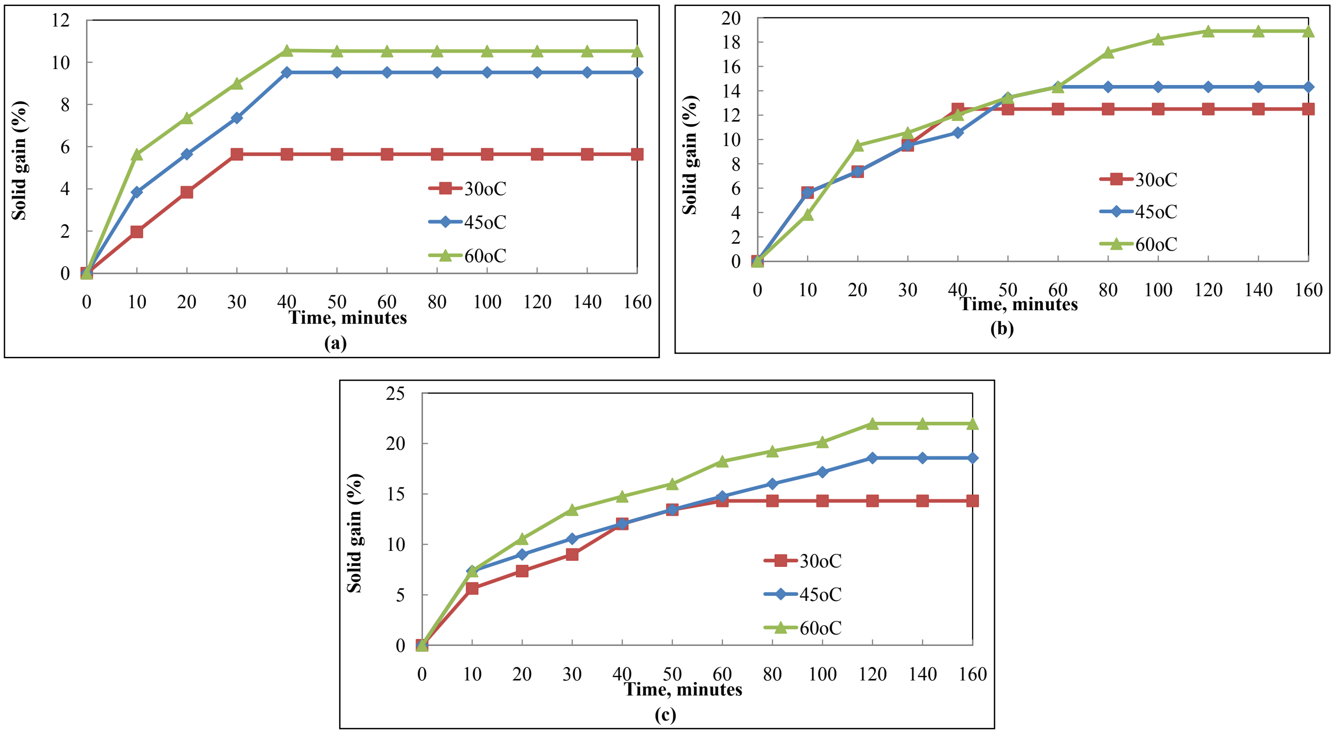


Fig. 2: Solid gain (%) versus time (min) at soaking temperature of pineapple cubes at 30, 45, 60°C in sugar concentration **(a)** 40°B; **(b)** 50°B; and **(c)** 60°B

3. Water Loss

Fig. 3 shows a typical curve of the average water loss (%) w. r. t. time in minutes of osmotic drying of pineapple cubes at 40°B sugar concentration and soaking temperature 30, 45 and 60°C. As the soaking temperature increases from 30°C, 45°C and 60°C, the water loss (%) increased from 10.83 to 18.76% and it becomes stable reading after which even the time of exposition increases the water loss (%) remain unchanged. The average water loss (%) was 10.83, 18.75 and 18.76 at 30°C, 45°C and 60°C soaking temperature respectively. Similar type of behaviour has been observed (trend not shown) at 50°B and 60°B sugar concentration at at 30°C, 45°C and 60°C soaking temperature. Table 3 shows the water loss (%) w. r. t. soaking temperature at the time of soaking of the pineapple cubes.

From Table 3 it is revealed that for a particular value of soaking temperature at 30°C the sugar concentration increases from 40°B to 60°B the water loss (%) increased from 10.83% to 29.34%. Similarly at 45°C soaking temperature the water loss (%) increased from 18.75% to 30.94% and for 60°C soaking temperature the water loss (%) increas from 18.76% to 49.46% respectively. Similarly for a particular value of sugar concentration °B as the soaking temperature increases from 30 to 60°C the water loss (%) increased. At 40°B it was 10.83 at 30°C and increased upto 18.76%; at 50⁰B sugar concentration the water loss (%) increased upto 25.21% and increased upto 40.86% at 60⁰B sugar concentration it was 29.34 to 49.46 respectively. Similar kind of results have been reported in the literature for other fruits and vegetable i.e. pea, pineapple, tomato, banana (Ertekin and Cakaloz, 1996; Hawkes and Flink, 1970; Karthanos *et al.*1995; Lazarides *et al.* 1995; Pokharkar and Prasad, 1998). The water loss (%) increased with increase in sugar concentration (⁰B), it may be due to increased osmotic pressure in the solution at higher

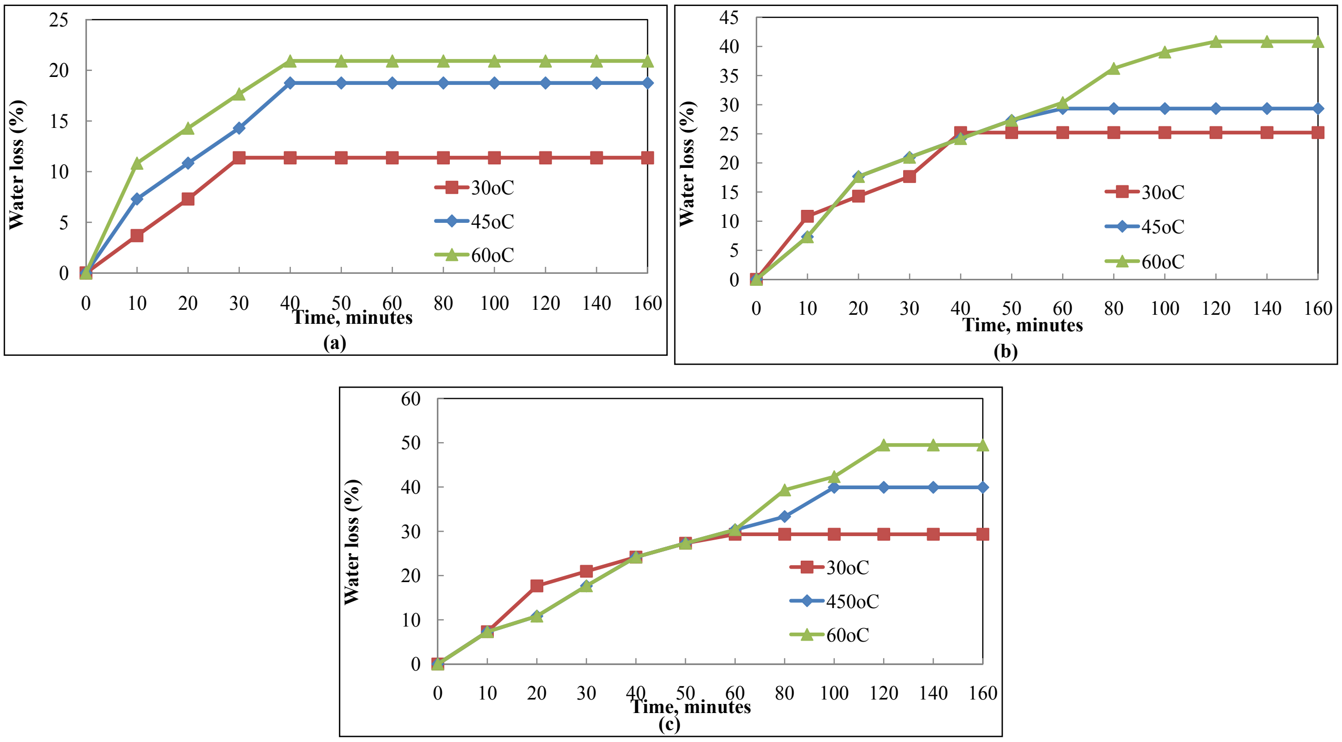


Fig. 3: Water loss (%) versus time (min) at soaking temperature of pineapple cubes at 30, 45, 60°C in sugar concentration **(a)** 40°B; **(b)** 50°B; and **(c)** 60°B

Table 3: Water loss (%) with respect to time at varied sugar concentration

Soaking Temp	Water loss % at varied sugar concentration					
	40°Brix	**Time (min)**	**50°Brix**	**Time (min)**	**60°Brix**	**Time (min)**
30°C	10.83	30	25.21	50	29.34	80
45°C	18.75	40	29.34	80	39.94	100
60°C	18.76	50	40.86	100	49.46	120

concentration, which increased the driving force for water transport. This is in agreement with (Pokharkar *et al.* 1998a; Pokharkar *et al.* 1998b; Nieuwenhuijzen *et al*. 2001). Filho *et al.* 2015 reported that water loss 26.37% at sugar concentration 50⁰B and soaking temperature 40⁰C in pineapple, Correa *et al.* 2014 reported that water loss in pineapple was 22.4% for at sugar concentration 50⁰B. Azuara *et al.* 1996 reported that water loss in potato and apple 69.50 and 70.63% at 70⁰B sugar concentration solution. Sridevi and Genitha and Devi *et al.* 2012 reported that water loss in pineapple 21.91% at 30⁰C soaking temperature and 40⁰B sugar solution. Suresh kumar and Genitha, 2011 reported that solid gain in pineapple slices 31.3% at 35⁰C soaking temperature and 50⁰Sugar concentration.

Osmotic drying characteristics of pineapple cubes

Fig. 4 shows the typical moisture content (%db) w.r.t. time (min) curve of pineapple cubes dried at soaking temperature 30, 45 and 60°C in sugar concentration 40⁰B. The drying was carried out from an initial moisture content 649.52(%db) to 399.83(%db), 316.55(%db) and 316.55(%db), it took around 40,

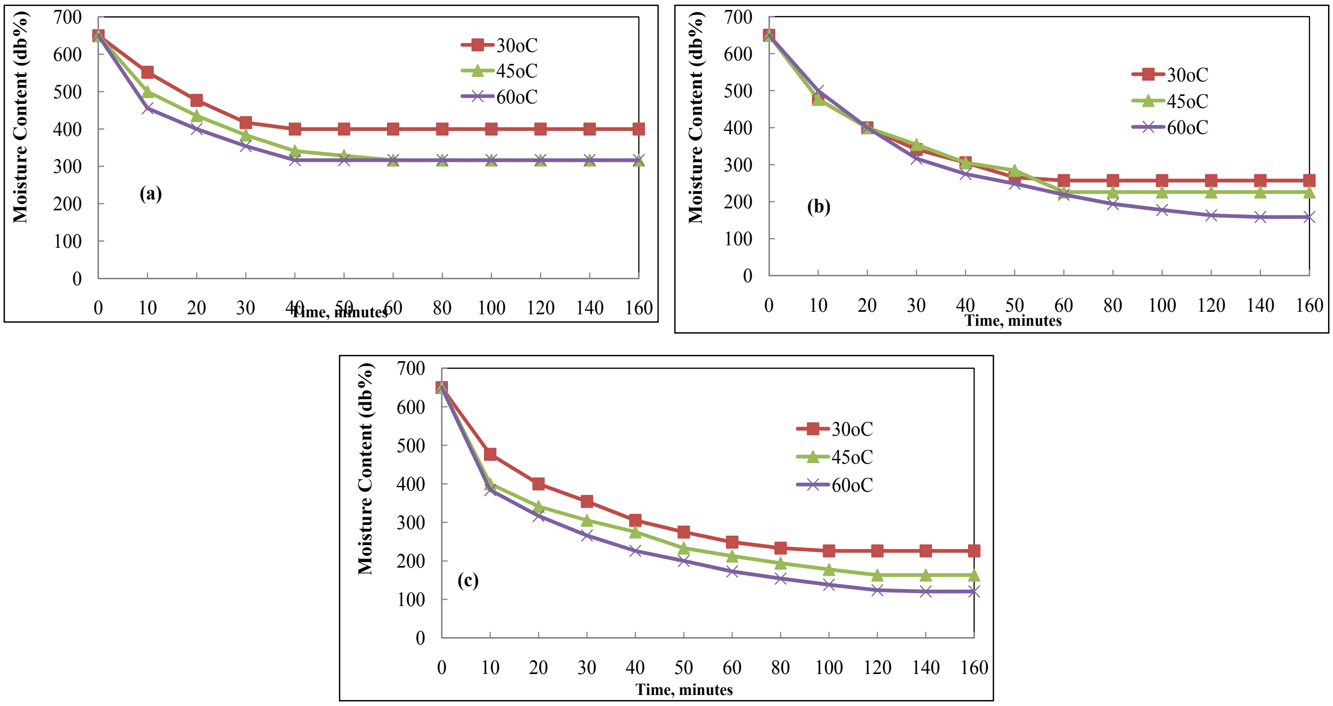


Fig. 4: Moisture content (%db) versus time (min) at soaking temperature of pineapple cubes at 30, 45, 60°C in sugar concentration **(a)** 40°B, **(b)** 50°B and **(c)** 60°B

Table 4: Final Moisture content (%db) with respect to time at varied sugar concentration and soaking temperature during osmotic drying of pineapple cubes

Soaking Temp	Final Moisture content (%db) at varied sugar concentration					
	40°Brix MC%(db)	Time (min)	50°Brix MC%(db)	Time (min)	60°Brix MC%(db)	Time (min)
30°C	399.83%	40	257.01%	60	226.01%	80
45°C	316.55%	50	225.94%	60	163.11%	120
60°C	316.55%	50	158.57%	120	120.55%	120

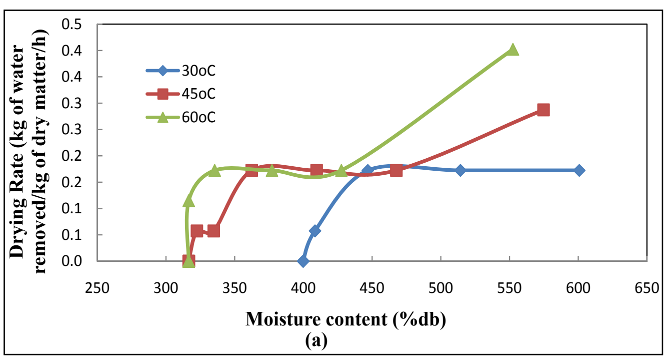
50 and 50 minutes to complete the drying process. Similar types of trends have been observed (trends not shown) at sugar concentration 50°B and 60°B for drying of the pineapple cubes at soaking temperature 30, 45 and 60°C. Table 4 shows the final moisture content achieved during osmotic drying of pineapple cubes at sugar concentration 40, 50 and 60°B and at soaking temperature 30, 45 and 60°C respectively. It took around 60, 60 and 120 minutes to dry the pineapple cubes from 649.52 (%db) to 257.01(%db), 225.94(%db), 158.57(%db) at 50°B sugar concentration and at 30, 45 and 60°C soaking temperature respectively. Also at 60⁰B sugar concentration the cubes were dried from 649.52(%db) to 226.01(%db), 163.11(%db) and 120.55(%db) at soaking temperature 30, 45 and 60°C, the time required for drying was 80, 120 and 120 minutes respectively. It can be clear from the Table 4 that for a particular value of soaking temperature as the sugar concentration increase the final moisture of the cubes was decreased resulting in increased in drying time. Also for a particular value of sugar concentration as soaking time increases the final moisture content of the cubes of the cubes decreases, resulting in drying time. After

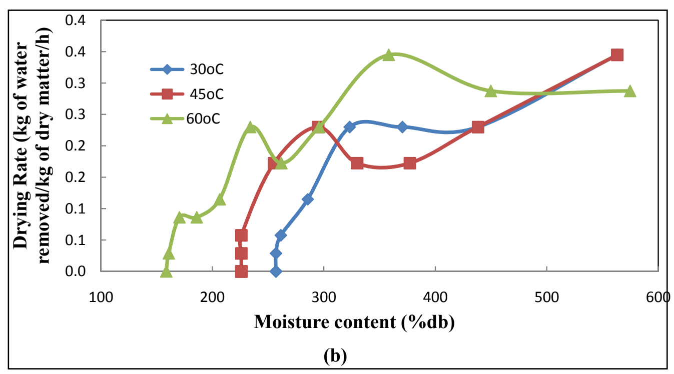
the osmotic treatment, the moisture content of fruits and vegetable are usually reduced by 30-50% (wet basis) (Yetenayat Bekele and Hosahalli Ramaswamy 2010). It is reported that up to 50% reduction in the fresh weight of fruits or vegetables can be achieved by osmotic dehydration (Rastogi and Raghavararo, 1997).

Fig. 5 shows the typical drying rate (kg of water removed/kg of dry matter/h) of osmotically drying pineapple cubes w.r.t. moisture content (%db) at soaking temperature 30, 45 and 60°C at 40°B sugar concentration. The drying rate decreases from 0.402 to 0, 0.287 to 0 and 0.1724 to 0 kg of water removed/kg of dry matter/h at soaking temperature 60, 45 and 30°C respectively. The higher rate of drying at higher soaking temperature may be due to the fact that the cell permeability increases and increases the rate of osmosis (Pokharkar, 1994). The driving forces have also been increased which may increased the rate of drying of pineapple cubes. Similar types of trends have been observed at sugar concentration 50°B and 60°B for drying of pineapple cubes at soaking temperature 30, 45 and 60°C. Table 5 shows the drying rate (kg of water removed/kg of dry matter/h)

Table 5: Drying Rate (kg of water removed/kg of dry matter/h) versus Moisture content (%db) at varied sugar concentration and soaking temperature during osmotic drying of pineapple cubes

Soaking Temp	Final Moisture content (%db) at varied sugar concentration					
	40°B Drying rate	40°Brix MC%(db)	50°B Drying rate	50°Brix MC%(db)	60°B Drying rate	60°Brix MC%(db)
30°C	0.172-0	399.83%	0.287-0	257.01%	0.345-0	226.01%
45°C	0.287-0	316.55%	0.345-0	225.94%	0.514-0	163.11%
60°C	0.402-0	316.55%	0.345-0	158.57%	0.632-0	120.55%





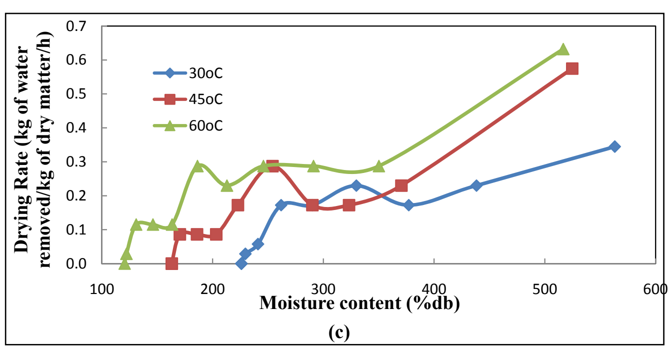


Fig. 5: Drying Rate (kg of water removed/kg of dry matter/h) versus moisture content (%db) at soaking temperature of pineapple cubes at 30, 45, 60°C in Sugar concentration **(a)** 40°B; **(b)** 50°B; and **(c)** 60°B

of pineapple cubes dried osmotically at soaking temperature 30, 45 and 60°C and at 40°B, 50°B and 60°B sugar concentration. At 50°B sugar concentration the drying rate was 0.344 to 0, 0.344 to 0 and 0.287 to 0 at soaking temperature 60, 45 and 30°C respectively. Similarly at 60°B sugar concentration the drying rate was 0.632 to 0, 0.514 to 0 and 0.344 to 0 at soaking temperature 60, 45 and 30°C respectively.

Microwave vacuum drying of osmotically dried pineapple cubes

In this part results of osmotically dehydrated pineapple cubes under microwave drying have been presented. The osmotically dehydrated pineapple cubes samples were taken out of the sugar solution and the surface moisture was removed by tissue paper. These osmotically dehydrated pineapple cubes were then dried in microwave-vacuum dryer at ON/OFF Magnetron time of in sec 15s/30s, 20s/30s, 25s/30s timeings.

The osmotically dried pineapple cubes at sugar concentration as 40, 50 and 60°B and soaking temperature 30, 45 and 60°C were exposed at ON/OFF time of magnetron 15 sec ON and 30 sec OFF, 20 sec ON and 30 OFF and 25 sec ON and 30 sec OFF in the microwave vacuum dryer. Figure 6(a) shows the moisture content (%db) w.r.t. time (minutes) of osmotically dried cubes dried at 30°C soaking temperature and at 40°B sugar concentration and exposed to 15 sec ON and 30 sec OFF, 20 sec ON and 30 OFF and 25 sec ON and 30 sec OFF time of magnetron. It took around 210, 195 and 165 minutes to dry the product from an initial moisture content 399.75 (%db) to 5.03 (%db). Fig. 6(b) shows the moisture content (%db) w.r.t. time (minutes) of osmotically dried pineapple cubes dried at 45°C soaking temperature at 40°B sugar concentration and ON/OFF time of magnetron of in sec 15s/30s, 20s/30s and 25s/30s. It took around 195, 165 and 150 minutes to dry the product from an initial moisture

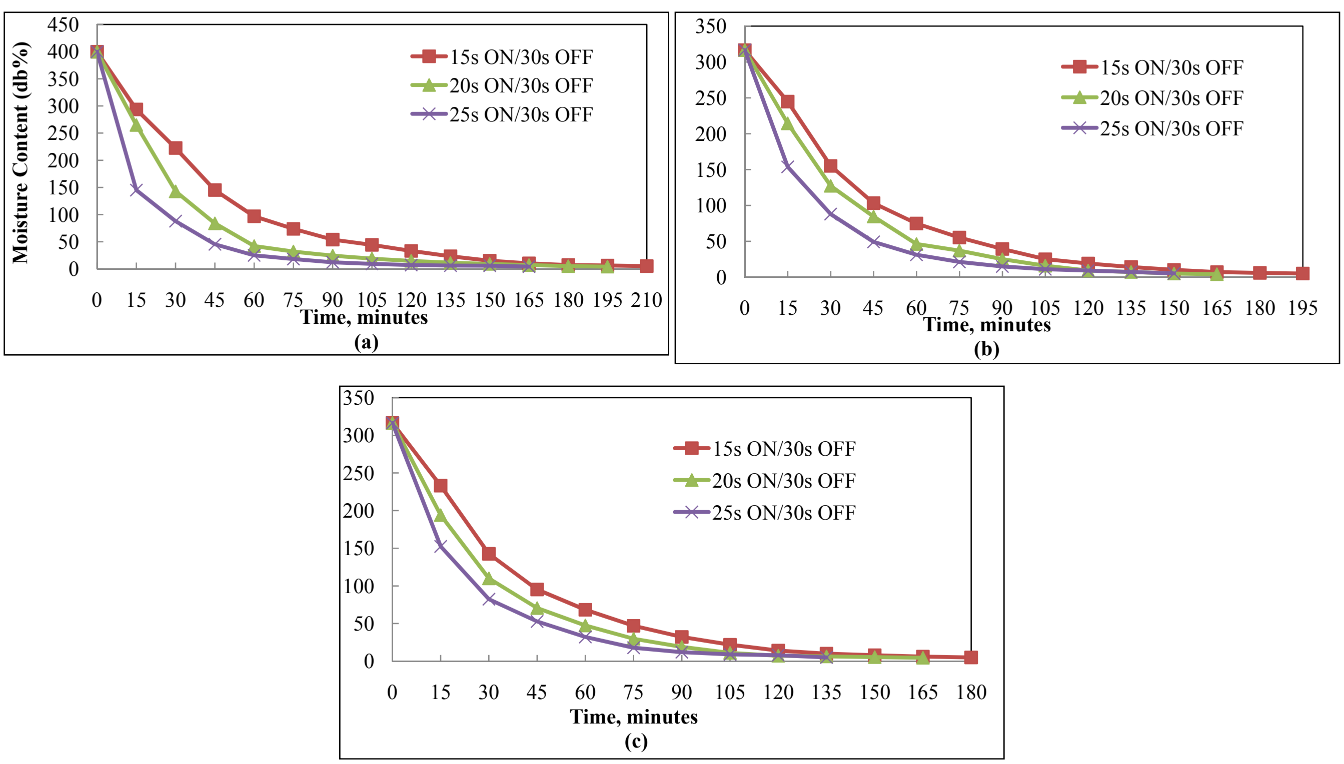


Fig. 6: Moisture content (%db) versus time (min) at soaking temperature of pineapple cubes at **(a)** 30°C; **(b)** 45°C; and **(c)** 60°C in sugar concentration (40°B) at Magnetron ON/OFF time (15/30, 20/30 and 25/30)

content 316.49 (%db) to 4.15 (%db). Figure 6(c) shows the moisture content (%db) w.r.t. time (minutes) of osmotically dried pineapple cubes dried at 60^{0}C soaking temperature at 40^{0}B sugar concentration and exposed to ON/OFF time of magnetron of in sec 15s/30s, 20s/30s and 25s/30s. It took around 180, 165 and 135 minutes to dry the product from an initial moisture content 316.49 (%db) to 4.15 (%db).

Similar trends (trends not shown) were observed in moisture content (%db) versus (time) of osmotically dried pineapple cubes dried at soaking temperature at 30, 45 and 60^{o}C in sugar concentration 50^{0}B and 60^{0}B dried by microwave-vacuum drying at ON/OFF time of magnetron of in sec 15s/30s, 20s/30s and 25s/30s respectively. The drying took place in a falling rate period Table 6 shows the intial and final moisture content (%db) of osmotically dried pineapple cubes dried by microwave vacuum drying at 40^{o}B, 50^{o}B and 60^{0}B sugar concentration soaked at 30, 45 and 60^{o}C and dried at ON/OFF time of Magnetron in sec 15s/30s, 20s/30s and 25s/30s.

Fig. 7 shows the drying rate (kg of water removed/kg of dry matter/h) w.r.t. moisture content (% db) of osmo-microwave vacuum dried pineapple cubes, at sugar concentration (40^{o}B) and at soaking temperature (a) 30^{o}C; (b) 45^{o}C; and (c) 60^{o}C and at ON/OFF time of magnetron in 15s/30s, 20s/30s and 25s/30s respectively. The drying took place in the falling rate period. The drying rate decreases with the decreases in the moisture content and it reaches to zero at the final moisture content of the osmo-microwave vacuum dried of pineapple cubes. The drying rate increases 3.06, 4.25 and 11.95 kg of water removed/kg of dry matter/h as the ON/OFF time of magnetron in increase from the microwave vacuum from 15s/30s to 25s/30s at 400B sugar concentration and soaked at 30^{0}C. The drying rate increases 2.87-8.85 kg of water removed/kg of dry matter/h as the

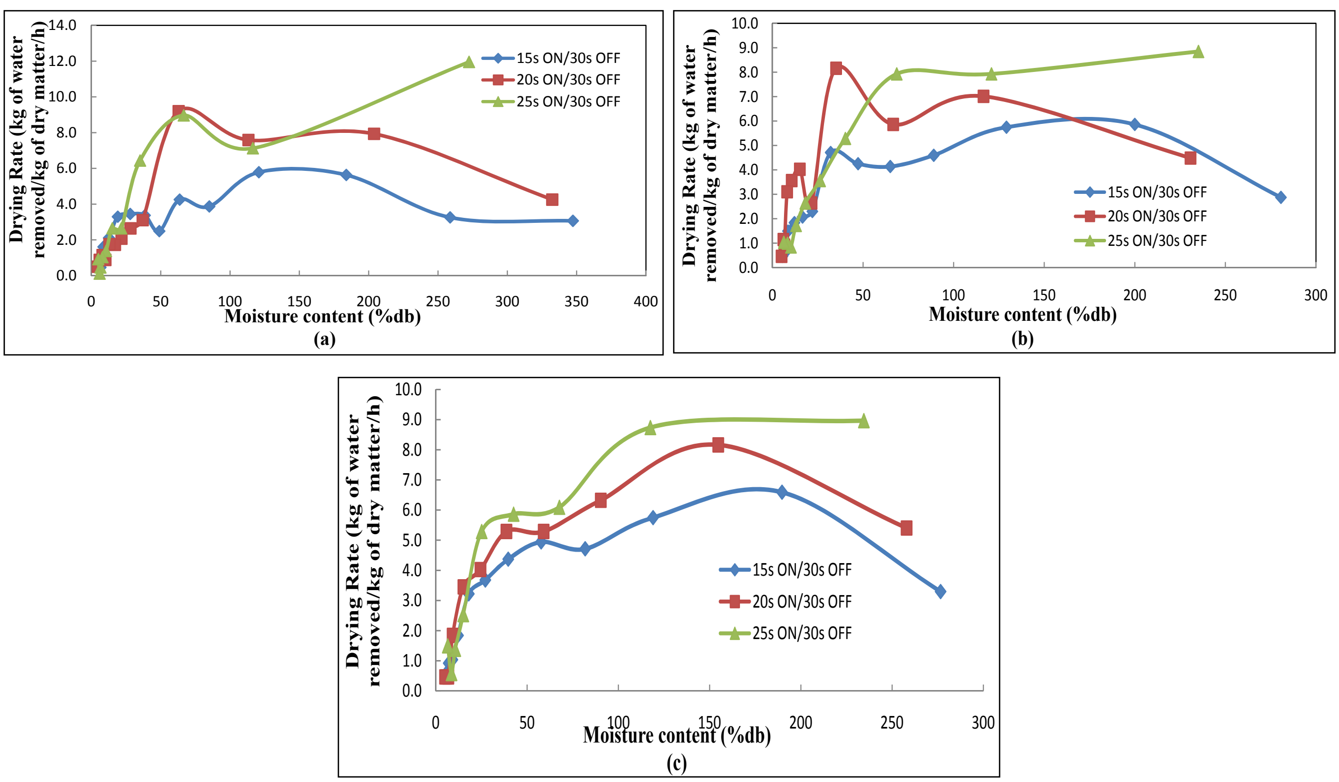


Fig. 7: Drying Rate (kg of water removed/kg of dry matter/h) versus Moisture content (%db) at soaking temperature of pineapple cubes at **(a)** 30^{o}C; **(b)** 45^{o}C; and **(c)** 60^{o}C in Sugar concentration (40^{o}B) at Magnetron ON/OFF time (15/30, 20/30 and 25/30)

ON/OFF time of magnetron increases from 15s/30s to 20s/30s at 40°B sugar concentration and soaking temperature at 45°C, Similarly, the drying rate increases from 3.29-8.96 kg of water removed/kg of dry matter/h as the ON/OFF time of magnetron increases from microwave vacuum from 15s/30s to 25s/30s at 40°B sugar concentration and soaked at 60°C. Table 6 shows the effect of sugar concentration (40°B, 50°B and 60°B), soaking temperature (30, 45 and 60°C) and ON/OFF time of Magnetron in sec (15s/30s, 20s/30s and 25s/30s) of microwave vacuum drying system on the drying rate of pineapple cubes dried by osmo-microwave vacuum drying.

It is revealed from Table 6 that at 50°B sugar concentration and soaking temperature 30°C, as the ON time of Magnetron increases from 15s/30s to 25s/30s, the drying rate increases from 2.98-8.96 kg of water removed/kg of dry matter/h, similarly at 45°C and 60°C soaking temperature as the magnetron ON time increases from 15s/30s to 25s/30s, the drying rate increases from 4.25-8.85 and 4.13-10.91 kg of water removed/kg of dry matter/h respectively. At sugar concentration 60°B and soaking temperature 30°C, 45°C and 60°C at microwave vacuum drying of pineapple cubes, the drying rate was in the range

Table 6: Initial and final moisture content (%db), drying rate data for osmotically dried pineapple cubes dried at microwave vacuum drying methods

Sl. No.	Sugar Concentration (°B)	Soaking temperature (°C)	Magnetron ON/ OFF time in sec	Initial MC (%db)	Final MC (%db)	Drying rate minutes	Drying Rate kg of water removed/kg of dry matter/h
1	40	30	15/30	399.75	5.03	210	3.06-0.0
			20/30	399.75	4.15	195	4.25-0.0
			25/30	399.75	4.15	165	11.95-0.0
		45	15/30	316.49	5.03	195	2.87-0.0
			20/30	316.49	4.15	165	4.48-0.0
			25/30	316.49	5.25	150	8.85-0.0
		60	15/30	316.49	5.03	180	3.29-0.0
			20/30	316.49	4.59	165	5.40-0.0
			25/30	316.49	5.03	135	8.96-0.0
2	50	30	15/30	254.23	5.25	195	2.98-0.0
			20/30	254.23	5.03	180	5.86-0.0
			25/30	254.23	5.03	150	8.96-0.0
		45	15/30	225.94	5.17	180	4.25-0.0
			20/30	225.94	5.17	165	3.65-0.0
			25/30	225.94	4.95	135	8.85-0.0
		60	15/30	158.53	5.17	165	4.13-0.0
			20/30	158.53	4.29	135	7.01-0.0
			25/30	158.53	5.17	120	10.91-0.0
3	60	30	15/30	225.94	5.17	165	5.40-0.0
			20/30	225.94	4.29	150	8.39-0.0
			25/30	225.94	5.17	135	11.37-0.0
		45	15/30	163.08	5.17	150	4.94-0.0
			20/30	163.08	4.29	135	9.08-0.0
			25/30	163.08	5.17	120	11.26-0.0
		60	15/30	120.55	5.32	135	5.51-0.0
			20/30	120.55	5.10	120	7.93-0.0
			25/30	120.55	4.44	105	11.72-0.0

Significant at p≤0.01.

of 5.40-11.37, 4.94-11.26 and 5.51-11.72 kg of water removed/kg of dry matter/h respectively.

Table 7 shows the effect of sugar concentration (^{0}B), soaking temperature (^{0}C) and ON/OFF time of Magnetron on constants of Hendersons and Pabis Model. 'a' represents the coefficient of thin layer model and 'k' represents the drying constant (min/h). It was observed from Table 7 that the Hendersons and Pabis Model was well fitted to the experimental data $r^2 \geq 0.946$. The coefficient of thin layer model 'a' was in the range of 0.8052 to 1.76423 and drying constant was 0.0267386-0.039398 (min/h) for sugar concentration 40^{o}B. The trend shows that the drying constant increases from 0.026773 to 0.03595; from 0.03069 to 0.03583; and from 0.03266 to 0.03939 (min/h) with increases in ON/OFF time of magnetron in sec 15s/30s to 25s/30s for 30^{o}C, 45^{o}C and 60^{o}C soaking temperature. As the soaking temperature increases from 30^{o}C to 60^{o}C the drying constant also increases. At 50^{0}B sugar concentration, as the ON/OFF time of Magnetron in sec increases from 15s/30s to 25s/30s the drying constant were from 0.02248 to 0.03388; from 0.02394 to 0.04462; and from 0.02633 to 0.04175 (min/h). The drying constant increases with increases in magnetron ON/OFF time also it increases with increases in soaking temperature of

Table 7: Effect of sugar concentration (^{0}B), soaking temperature (^{0}C) and Convective hot air drying temperature on drying of component of Hendersons and Pabis Model

Sl. No.	Sugar Concentration (^{0}B)	Soaking temperature (^{o}C)	Magnetron ON/OFF time in sec	a	k (min/h)	r^2
1	40	30	15/30	1.51032	0.02673	0.9754
			20/30	1.08679	0.03033	0.9830
			25/30	0.80526	0.03595	0.9798
		45	15/30	1.69349	0.03069	0.9764
			20/30	1.66960	0.03653	0.9774
			25/30	1.06203	0.03583	0.9951
		60	15/30	1.65521	0.03266	0.9850
			20/30	1.62199	0.03927	0.9921
			25/30	1.86093	0.03939	0.9956
2	50	30	15/30	1.47518	0.02248	0.9897
			20/30	1.54652	0.03273	0.9464
			25/30	1.12708	0.03388	0.9954
		45	15/30	1.23774	0.02394	0.9870
			20/30	1.46166	0.03434	0.9759
			25/30	1.34281	0.04462	0.9844
		60	15/30	1.41406	0.02633	0.9645
			20/30	1.34842	0.03175	0.9881
			25/30	1.33904	0.04175	0.9940
3	60	30	15/30	1.45317	0.03037	0.9834
			20/30	1.17994	0.03080	0.9937
			25/30	1.14044	0.03764	0.9964
		45	15/30	1.76423	0.03764	0.9534
			20/30	1.38002	0.03495	0.9614
			25/30	1.14140	0.03507	0.9957
		60	15/30	1.66694	0.03854	0.9854
			20/30	1.51554	0.04249	0.9922
			25/30	0.87923	0.06230	0.9528

Significant at $p \leq 0.01$.

pineapple cubes. At 60°B sugar concentration, as the ON/OFF time of magnetron in increases from 15s/30s to 25s/30s the drying constant were 0.03037 - 0.03764, 0.03764 - 0.03507 and 0.03854 - 0.0623000 (min/h) respectively. The drying constant found to be increased with increases in magnetron ON/OFF time; also it increased with increases in soaking temperature of pineapple cubes.

1. Effective diffusivity and activation energy of osmotically dried pineapple cubes dried by microwave vacuum drying

Fig. 8 and 9 shows graph of Ln (MR) versus time, min for osmotically dried pineapple cubes at varied sugar concentration 40, 50 and 60°B, soaking temperature 30, 45 and 60°C and at microwave vacuum drying ON/OFF time of magnetron in sec 15s/30s to 25s/30s respectively.

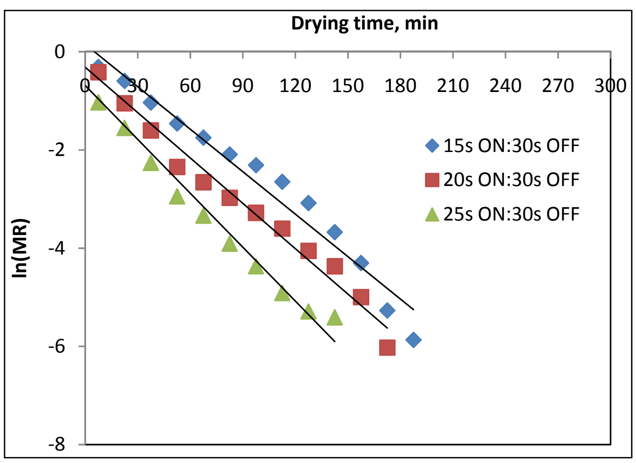


Fig. 8: Ln (MR) versus time, min for effective diffusivity of dried pineapple cubes at sugar concentration 40°B, soaking temperature 30°C and magnetron ON/OFF time 15s/30s, 20s/30s and 25s/30s of magneron

Linear equations obtained from the graph were compared with the standard equation i.e. $y = mx + c$. "m" value indicates the slope of line. Effective diffusivity (D_{eff}) at time (t) for osmotically dried pineapple cubes at sugar concentration 40°B, soaking temperature 30°C and ON/OFF time of magnetron 15s/30s to 25s/30s respectively the values of diffusivity were 3.45×10^{-7}, 3.69×10^{-7} and 4.38×10^{-7} m^2/s, As the sugar concentration 40°B, soaking temperature 45°C and ON/OFF magnetron time of magnetron increases from 15s/30s to 25s/30s respectively the values of diffusivity were 3.74×10^{-7}, 4.45×10^{-7} and 4.36×10^{-7} m^2/s and for sugar concentration 40°B, soaking temperature 60°C and ON/OFF time of magnetron in sec 15s/30s to 25s/30s respectively the values of diffusivity were 3.98×10^{-7}, 4.78×10^{-7} and 4.83×10^{-7} m^2/s. Similar type of trends were observed at 50°B, and 60°B sugar concentration (trends no shown) Table 8 shows the diffusivity values of the sugar concentration 40, 50 and 60°B, soaking temperature 30, 45 and 60°C and 15s, 20s and 25s ON and 30s OFF time of magnetron respectively calculated from equation (10). Nantawan, (2009) reported that effective moisture diffusivities for mint leaves were determined to be 4.6999×10^{-11} m^2/s. Manish and Pareek (2014) reported that the effective moisture diffusivity varied from 5.18×10^{-11} to 6.58×10^{-10} m^2/s for pomegranate. Effective moisture diffusivity (D_{eff}) values were found to increase as microwave power increases or sample mass decreases for constant values of remaining variables while vacuum pressure had negligible effect. Jiang et al. 2016 studied that diffusivity (D_{eff}) values were found to be in the range of 3.68×10^{-8} and 1.52×10^{-7} m^2/s for the microwave vacuum dried Agaricus bisporus. The values of effective diffusivity (D_{eff}) were in the range of 2.91×10^{-7} to $7.58 \times 10^{-7} m^2/s$ for sugar concentration 40, 50 and 60°B at soaking temperature 30, 45 and 60°C and at 15s, 20s and 25s ON and 30s OFF time of magnetron.

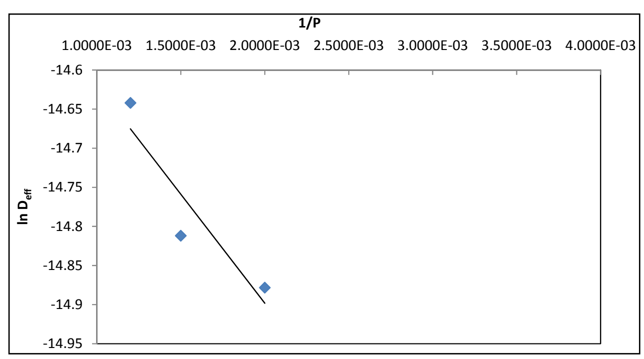


Fig. 9: Arrhenius- type relationship between effective diffusivity and power for osmotically dried pineapple cubes at sugar concentration 40°B, soaking temperature 30°C and ON/OFF Magnetron time of in sec 15/30, 20s/30s and 25/30

Fig. 9 shows results indicated a linear relationship between (ln D_{eff}) and (1/P) as plotted in Fig. 9 for pineapple cubes. The diffusivity constant or pre-exponential factor of Arrhenius equation (D_0) and activation of energy (E_a) calculated from the linear regression at varied sugar concentration 40, 50 and 60^0B, soaking temperature 30, 45 and 60^0C and 15s, 20s and 25s ON and 30s OFF time of magnetron respectively. For osmotically dried pineapple cubes dried by microwave vacuum drying, were at sugar concentration 40^0B, soaking temperature 30^0C and 15s, 20s and 25s ON and 30s OFF time of magnetron the diffusivity constant 6.06×10^7 m^2/s and activation energy were 35.36 kJ/mol, At sugar concentration 40^0B, soaking temperature 45^0C and 15s, 20s and 25s ON and 30s OFF time of magnetron the diffusivity constant 5.71×10^7 m^2/s and activation energy were 24.04 kJ/mol. At the sugar concentration 40^0B, soaking temperature 60^0C and ON/OFF magnetron time of in sec 15/30 to 25/30 respectively, the diffusivity constant 6.54×10^7 m^2/s and activation energy were 28.63 kJ/mol respectively. At 50^0B sugar concentration at 30, 45 and 60^0C soaking temperature the diffusivity coefficients were 6.71×10^7, 13.88×10^7 and 10.11×10^7 m^2/s and the activation energy were 46.06, 94.77 and 70.58 kJ/mole respectively. Similarly at 60^0B sugar concentration at 30, 45 and 60^0C soaking temperature the diffusivity coefficients were 6.04×10^7, 5.27×10^7 and 16.09×10^7 m^2/s and the activation energy were 31.77, 13.79 and 80.43 kJ/mole respectively for sugar concentration 50

Table 8: Osmo-Microwave vacuum drying of pineapple cubes activation energy

Sugar Conc. (°B)	Soaking Temp. (°C)	Microwave ON/ OFF time in sec	Diffusivity (m^2/s)	D_0 (m^2/s)	Activation energy (E_a. (watts))
40	30	15s/30s	3.45×10^{-7}	6.06×10^7	35.36
		20s/30s	3.69×10^{-7}		
		25s/30s	4.38×10^{-7}		
	45	15s/30s	3.74×10^{-7}	5.71×10^7	24.04
		20s/30s	4.45×10^{-7}		
		25s/30s	4.36×10^{-7}		
	60	15s/30s	3.98×10^{-7}	6.54×10^7	28.63
		20s/30s	4.78×10^{-7}		
		25s/30s	4.84×10^{-7}		
50	30	15s/30s	3.03×10^{-7}	6.71×10^7	46.06
		20s/30s	3.98×10^{-7}		
		25s/30s	4.12×10^{-7}		
	45	15s/30s	2.91×10^{-7}	13.88×10^7	94.77
		20s/30s	4.18×10^{-7}		
		25s/30s	5.43×10^{-7}		
	60	15s/30s	3.25×10^{-7}	10.11×10^7	70.58
		20s/30s	4.04×10^{-7}		
		25s/30s	5.08×10^{-7}		
60	30	15s/30s	3.73×10^{-7}	6.04×10^7	31.77
		20s/30s	3.75×10^{-7}		
		25s/30s	4.58×10^{-7}		
	45	15s/30s	4.25×10^{-7}	5.27×10^7	13.79
		20s/30s	4.27×10^{-7}		
		25s/30s	4.69×10^{-7}		
	60	15s/30s	4.66×10^{-7}	16.09×10^7	80.43
		20s/30s	5.17×10^{-7}		
		25s/30s	7.58×10^{-7}		

Significant at p≤0.01.

and 60^0B, soaking temperature 30, 45 and 60^0C and 15s, 20s and 25s ON and 30s OFF time of magnetron respectively. Jiang *et al.* 2016 reported that activation energy values ranges between 41.87 and 49.52 kJ/mol for the microwave vacuum dried Agaricus bisporus.

Osmo-microwave-vacuum drying quality characteristics of pineapple cube

Quality characteristics of pineapple cubes include TSS, pH, acidity, reducing sugar, non-reducing sugar, total sugar. Pineapple cubes dried at varied magnetron ON/OFF time in sec 15s/30s, 20s/30s and 25s/30s respectively.

1. TSS

Table 9 shows the effect of magnetron ON/OFF time, sugar concentration and soaking temperature on the TSS (%) of the osmotically dried pineapple cubes. The TSS for pineapple cubes were in the range of 27.92-32.37% for all the magnetron ON/OFF time (15s/30s, 20s/30s and 25s/30s), at varied sugar concentration (40 to 60°Brix) and soaking temperature (30 to 60^0C). TSS for magnetron ON/OFF time 15/s30s ranges from 27.92-29.75%, for magnetron ON/OFF time 20/30 from 28.44-31.84% and for magnetron ON/OFF time 25/30 from 28.72-32.37% respectively for all the magnetron ON/OFF time (15s/30s, 20s/30s and 25s/30s), sugar concentration (40 to 60°Brix) and soaking temperature (30 to 60^0C). Table 9 shows it was minimum 27.92% at 40^0Brix sugar concentration, 30^0C soaking temperature and 15/30 magnetron ON/OFF time and was maximum 32.37% at 60^0Brix sugar concentration, 60^0C soaking temperature and 25s/30s magnetron ON/OFF time. TSS in pineapple cubes increases as sugar concentration and soaking temperature, and magnetron ON/OFF time increases.

As the sugar concentration increases from 40°B to 60°Brix, the TSS of the dried pineapple cubes increases for all magnetron ON/OFF times. During drying of pineapple cubes magnetron ON/OFF time play important role in TSS of the dried pineapple cubes.

Table 9 shows the ANOVA for the effect of magnetron ON/OFF time, sugar concentration, soaking temperature on the TSS of the pineapple cubes. It is revealed from the table that TSS is significantly affected ($p \leq 0.05$) by the magnetron ON/OFF time, sugar concentration, soaking temperature. The interaction between the magnetron ON/OFF time, sugar concentration, soaking temperature has a significant difference in the TSS. The interactions among independent variables significantly affected the TSS values of pineapple cubes ($p \leq 0.05$). Increase in sugar concentration resulted in increase in TSS.

Similar observations were reported by Rai *et al.* (2007) that there was increase in total soluble solids of osmotic dehydrated pineapple slices when slices were treated with maximum sugar solution concentration having final TSS increased. Expedito *et al.* 1996, reported TSS content osmotically dried pineapple cubes at 50^0B sugar concentration were 28.32%.

2. p^H

Table 10 shows the effect of magnetron ON/OFF time, sugar concentration and soaking temperature on the pH (%) of the dried pineapple cubes. The pH for pineapple cubes were in the range of 4.21-4.52% for all the ON/OFF time of magnetron (15s/30s, 20s/30s and 25s/30s), at varied sugar concentration (40 to 60°Brix) and soaking temperature (30 to 60^0C). pH for magnetron ON/OFF time 15s/30s ranges from 4.21-4.34%, for magnetron ON/OFF time 20/30 from 4.30-4.44% and for magnetron ON/OFF time 25s/30s from 4.38-4.52% respectively for all the magnetron ON/OFF time (15s/30s, 20s/30s and 25s/30s), sugar concentration (40 to 60°Brix) and soaking temperature (30 to 60^0C). Table 10 shows it was minimum 4.21% at 40^0Brix sugar concentration, 30^0C soaking temperature and 15/30 magnetron ON/OFF time and was maximum 4.52% at 60^0Brix sugar concentration, 60^0C soaking temperature and 25s/30s magnetron ON/OFF time. pH in pineapple cubes increased as sugar concentration and soaking temperature, and magnetron ON/OFF time increases. Also acidity of pineapple cubes decreases then p^H of pineapple cubes increases *vice versa.*

Table 9: Effect of magnetron ON/OFF time, sugar concentration and soaking temperature osmo-microwave vacuum on TSS of dried pineapple cubes

Magnetron ON/OFF Time (s)	Sugar concentration 40°Brix			Sugar concentration 50°Brix			Sugar concentration 60°Brix		
	Soaking Temp 30°C	Soaking Temp 45°C	Soaking Temp 60°C	Soaking Temp 30°C	Soaking Temp 45°C	Soaking Temp 60°C	Soaking Temp 30°C	Soaking Temp 45°C	Soaking Temp 60°C
15s/30s	27.92[q]	27.92[q]	28.94[m]	27.74[r]	28.92[m]	29.24[l]	28.25[p]	29.75[ih]	29.57[kj]
20s/30s	28.44[o]	28.44[n]	30.45[f]	28.54[o]	29.45[k]	30.45[f]	29.84[h]	30.74[e]	31.84[b]
25s/30s	28.72[n]	28.72[l]	31.34[c]	29.49[k]	29.64[ij]	31.15[d]	30.18[g]	31.23[dl]	32.37[a]

ANOVA

		Source of Variation	*Df*	*SS*	*MS*	*F*	*P-value*	*F critical*
SE_1	0.015403	Sugar Concentration	2	25.989	12.995	2028.42	<.0001	2.007
CD_1 at 0.05%	0.0434	Soaking Temperature	2	44.356	22.178	3461.93	<.0001	2.007
SE_2	0.026679	Magnetron ON/OFF Time	2	38.936	19.468	3038.92	<.0001	2.007
CD_2 at 0.05%	0.075711	Sugar Concentration and Soaking Temperature	4	2.345	0.586	91.51	<.0001	2.007
SE_3	0.04621	Sugar Concentration and Magnetron ON/OFF Time	4	1.908	0.477	74.47	<.0001	2.007
CD_3 at 0.05	0.131135	Soaking Temperature and Magnetron ON/OFF Time	4	3.973	0.993	155.06	<.0001	2.007
		Sugar concentration, Soaking Temperature and Magnetron ON/OFF Time	8	1.284	0.160	25.04	<.0001	2.007
	Replication		2	0.002	0.001	0.12	0.8869	
	Error		52	0.333	0.006			
	Corrected Total		80	119.127				

Same letter are not significantly different, SE_1= Effect of individual Sugar concentration or soaking temperature or ON/OFF time of magnetron on TSS, SE_2= Effect of sugar concentration and soaking temperature, effect of sugar concentration and ON/OFF time of magnetron, effect of soaking temperature and ON/OFF time of magnetron on TSS, SE_3= Combine effect sugar concentration, soaking temperature and ON/OFF time of magnetron on TSS.

Table 10: Effect of magnetron ON/OFF time, sugar concentration and soaking temperature on pH of osmo-microwave dried pineapple cubes

Magnetron ON/ OFF Time (s)	**Sugar concentration 40°Brix**				**Sugar concentration 50°Brix**				**Sugar concentration 60°Brix**	
	Soaking Temp 30°C	**Soaking Temp 45°C**	**Soaking Temp 60°C**	**Soaking Temp 30°C**	**Soaking Temp 45°C**		**Soaking Temp 60°C**	**Soaking Temp 30°C**	**Soaking Temp 45°C**	**Soaking Temp 60°C**
15s/30s	4.21[on]		4.24[mn]	4.37[fed]	4.15[p]	4.20[on]	4.33[fhig]	4.18[op]	4.26[ml]	4.35[feg]
20s/30s	4.30[kjhil]		4.31[kjhig]	4.45[b]	4.20[on]	4.28[kjmil]	4.34[fheg]	4.26[kml]	4.32[hig]	4.44[c]
25s/30s	4.38[ed]		4.43[cb]	4.54[a]	4.27[kjml]	4.41[cbd]	4.43[cb]	4.31[jhig]	4.39[ced]	4.52[a]

ANOVA

		Source of Variation	*Df*	*SS*	*MS*	*F*	*P-value*	*F critical*
SE_1	0.005703	Sugar Concentration	2	0.0640	0.032	36.47	<.0001	2.007
CD_1 at 0.05%	0.0162	Soaking Temperature	2	0.3827	0.191	218	<.0001	2.007
SE_2	0.009877	Magnetron ON/OFF Time	2	0.3281	0.164	186.89	<.0001	2.007
CD_2 at 0.05%	0.028029	Sugar Concentration and Soaking Temperature	4	0.0116	0.003	3.3	0.0175	2.007
SE_3	0.017108	Sugar Concentration and Magnetron ON/OFF Time	4	0.0051	0.001	1.47	0.2258	2.007
CD_3 at 0.05	0.048548	Soaking Temperature and Magnetron ON/OFF Time	4	0.0047	0.001	1.33	0.2723	2.007
		Sugar concentration, Soaking Temperature and Magnetron ON/OFF Time	8	0.0088	0.001	1.25	0.2887	2.007
	Replication		2	0.0038	0.002	2.14	0.128	
	Error		52	0.0456	0.001			
	Corrected Total		80	0.8544				

Same letter are not significantly different, SE_1= Effect of individual Sugar concentration or soaking temperature or ON/OFF time of magnetron on pH, SE_2= Effect of sugar concentration and soaking temperature, effect of sugar concentration and ON/OFF time of magnetron, effect of soaking temperature and ON/OFF time of magnetron on pH, SE_3= Combine effect sugar concentration, soaking temperature and ON/OFF time of magnetron on pH.

As the sugar concentration increases from 40°B to 60°Brix, the pH of the dried pineapple cubes increases for all magnetron ON/OFF time. However in 15s/30s magnetron ON/OFF time the pH increases gradually form sugar concentration 40°B to 60°Brix.

Table 10 shows the ANOVA for the effect of magnetron ON/OFF time, sugar concentration, soaking temperature on the pH of the cubes. It is clear from the table that pH is significantly affected ($p \leq 0.05$) by the magnetron ON/OFF time, sugar concentration, soaking temperature. The interaction between the magnetron ON/OFF time, sugar concentration, soaking temperature has also a significant difference in the pH. The interactions among independent variables significantly affected the pH values of pineapple cubes ($p \leq 0.05$).

Increase in sugar concentration resulted in increase in pH. similar observations were reported by Exepedito *et al*. (1996) reported that there was increase in pH of osmotic dehydrated pineapple slices when slices were treated with 70^0B sugar solution having final pH 3.40 in osmo-vacuum dried pineapple samples.

3. Acidity

Table 11 shows the effect of magnetron ON/OFF time, sugar concentration and soaking temperature on the acidity (%) of the dried pineapple cubes. The acidity for pineapple cubes were in the range of 0.573-0.800% for all the magnetron ON/OFF time (15s/30s, 20s/30s and 25s/30s), at varied sugar concentration (40 to 60°Brix) and soaking temperature (30 to 60^0C). Acidity for magnetron ON/OFF time 15/30 ranges from 0.663-0.800%, for magnetron ON/OFF time 20/30 from 0.605-0.676% and for magnetron ON/OFF time 25/30 from 0.573-0.674% respectively for all the magnetron ON/OFF time (15/30, 20/30 and 25/30), sugar concentration (40 to 60°Brix) and soaking temperature (30 to 60^0C). Table 11 shows it was maximum 0.800% at 40^0Brix sugar concentration, 30^0C soaking temperature and 15/30 magnetron ON/OFF time and was minimum 0.573% at 60^0Brix sugar concentration, 60^0C soaking temperature and 25/30 magnetron ON/OFF time. The acidity of pineapple cubes is decreased as increases sugar concentration and soaking temperature, and magnetron ON/OFF time increases. Also acidity of pineapple cubes decreases then p^H of pineapple cubes increases.

As the sugar concentration increases from 40°B to 60°Brix, the acidity of the dried pineapple cubes decreases for all magnetron ON/OFF time. Similarly as the soaking temperature of the pineapple cubes increases from 30 to 60^0C acidity decreases for all magnetron ON/OFF time. Magnetron ON/OFF time during drying of pineapple cubes play important role in acidity of the dried pineapple cubes.

Table 11 shows the ANOVA for the effect of magnetron ON/OFF time, sugar concentration, soaking temperature on the acidity of the pineapple cubes. It is clear from the Table that acidity is significantly affected ($p \leq 0.05$) by the magnetron ON/OFF time, sugar concentration, soaking temperature. The interaction between the magnetron ON/OFF time, sugar concentration, soaking temperature has a significant difference the acidity. The interactions among independent variables significantly affected the acidity values of pineapple cubes ($p \leq 0.05$).

Increase in sugar concentration, soaking temperature and magnetron ON/OFF time resulted in decreases in acidity. Similar observations were reported by Exepedito *et al*. (1996) for osmotic dehydrated pineapple slices when slices were treated with 70^0B sugar solution having final acidity 0.300 in osmo-vacuum dried pineapple samples.

4. Reducing sugar

Table 12 shows the effect of magnetron ON/OFF time, sugar concentration and soaking temperature on the reducing sugar (%) of the dried pineapple cubes. The reducing sugar for pineapple cubes were in the range of 14.12-24.13% for all the magnetron ON/OFF time (15/30, 20/30 and 25/30), at varied sugar concentration (40 to 60°Brix) and soaking temperature (30 to 60^0C). Reducing sugar of dehydrated pineapple cubes at magnetron ON/OFF time 15/30 ranges from 14.12-19.90%, for magnetron ON/OFF time 20/30 from 15.73-21.87% and for magnetron ON/OFF time 25/30 from 15.81-24.13% respectively for all the

Table 11: Effect of magnetron ON/OFF time, sugar concentration and soaking temperature on acidity of osmo-microwave dried pineapple cubes

Magnetron ON/OFF Time (s)	**Sugar concentration 40°Brix**			**Sugar concentration 50°Brix**				**Sugar concentration 60°Brix**		
	Soaking Temp 30°C	**Soaking Temp 45°C**	**Soaking Temp 60°C**	**Soaking Temp 30°C**	**Soaking Temp 45°C**		**Soaking Temp 60°C**	**Soaking Temp 30°C**	**Soaking Temp 45°C**	**Soaking Temp 60°C**
15s/30s	0.800^{a}		0.676^{dc}	0.652^{dfe}	0.800^{a}	0.667^{dce}	0.661^{dfce}	0.746^{b}	0.736^{b}	0.663^{dfce}
20s/30s	0.676^{dc}		0.646^{fe}	0.620^{hg}	0.727^{b}	0.608^{hij}	0.642^{fg}	0.618^{hg}	0.682^{c}	0.605^{hij}
25s/30s	0.614^{hi}		0.618^{hg}	0.608^{hij}	0.610^{hi}	0.592^{kij}	0.608^{hij}	0.584^{kj}	0.674^{dc}	0.573^{k}

ANOVA

		Source of Variation	*Df*	*SS*	*MS*	*F*	*P-value*	*F critical*
SE_1	0.00288	Sugar Concentration	2	0.0002	0.000	0.47	0.6289	2.007
CD_1 at 0.05%	0.0082	Soaking Temperature	2	0.0490	0.024	109.18	<.0001	2.007
SE_2	0.004989	Magnetron ON/OFF Time	2	0.1438	0.072	320.59	<.0001	2.007
CD_2 at 0.05%	0.014158	Sugar Concentration and Soaking Temperature	4	0.0477	0.012	53.22	<.0001	2.007
SE_3	0.008641	Sugar Concentration and Magnetron ON/OFF Time	4	0.0030	0.001	3.29	0.0176	2.007
CD_3 at 0.05	0.024522	Soaking Temperature and Magnetron ON/OFF Time	4	0.0406	0.010	45.29	<.0001	2.007
		Sugar concentration, Soaking Temperature and Magnetron ON/OFF Time	8	0.0060	0.001	3.34	0.0037	2.007
	Replication	2	0.0024	0.001	5.35	0.0077		
	Error	52	0.0117	0.000				
	Corrected Total	80	0.3043					

Same letter are not significantly different, SE_1= Effect of individual Sugar concentration or soaking temperature or ON/OFF time of magnetron on acidity, SE_2= Effect of sugar concentration and soaking temperature, effect of sugar concentration and ON/OFF time of magnetron, effect of soaking temperature and ON/OFF time of magnetron on acidity, SE_3= Combine effect sugar concentration, soaking temperature and ON/OFF time of magnetron on acidity.

magnetron ON/OFF time (15/30, 20/30 and 25/30), sugar concentration (40 to 60°Brix) and soaking temperature (30 to 60^{0}C). Table 12 also indicated that it was minimum 14.12% at 40^{0}Brix sugar concentration, 30^{0}C soaking temperature and 15/30 magnetron ON/OFF time and was maximum 24.13% at 60^{0}Brix sugar concentration, 60^{0}C soaking temperature and 25/30 magnetron ON/OFF time. Reducing sugar content in pineapple cubes is increases as sugar concentration and soaking temperature, and magnetron ON/OFF time.

As the sugar concentration increases from 40°B to 60°Brix, the Reducing sugar of the dried pineapple cubes increases for all magnetron ON/OFF time. However in 15/30 magnetron ON/OFF time the Reducing sugar increases gradually from sugar concentration 40°B to 60°Brix. Similarly in 25/30 magnetron ON/OFF time reducing sugar increases rapidly from sugar concentration 40 to 60°Brix. Similarly as the soaking temperature of the pineapple cubes increases from 30 to 60^{0}C reducing sugar increases for all magnetron ON/OFF time. During drying of pineapple cubes magnetron ON/OFF time play a important role in reducing sugar of the dried pineapple cubes.

Table 12 shows the ANOVA for the effect of magnetron ON/OFF time, sugar concentration, soaking temperature on the reducing sugar of the pineapple cubes. It is clear from the table that reducing sugar is significantly affected ($p \leq 0.05$) by the magnetron ON/OFF time, sugar concentration, soaking temperature. The interaction between the magnetron ON/OFF time, sugar concentration, soaking temperature has also significant ($p \leq 0.05$) on the reducing sugar. The interactions among independent variables significantly affected the reducing sugar values of pineapple cubes ($p \leq 0.05$).

Increase in sugar concentration, soaking temperature and magnetron ON/OFF time resulted in increase in reducing sugar. Similar observations were reported by Exepedito *et al*. (1996) that there was increase in reducing sugar of osmotic dehydrated pineapple slices when slices were treated with 70^{0}B sugar solution having final reducing sugar 31.98 in osmo-vacuum dried pineapple samples.

5. Non-Reducing sugar

Table 13 shows the effect of magnetron ON/OFF time, sugar concentration and soaking temperature on the non-reducing sugar (%) of the dried pineapple cubes. The Non-Reducing sugar for pineapple cubes were in the range of 34.97-51.49% for all the magnetron ON/OFF time (15s/30s, 20s/30s and 25s/30s), at varied sugar concentration (40 to 60°Brix) and soaking temperature (30 to 60^{0}C). Non-Reducing sugar for magnetron ON/OFF time 15s/30s ranges from 34.97-45.09%, for magnetron ON/OFF time 20s/30s from 35.29-46.08% and for magnetron ON/OFF time 25/30 from 36.05-51.49% respectively for all the magnetron ON/OFF time (15/30, 20/30 and 25/30), sugar concentration (40 to 60°Brix) and soaking temperature (30 to 60^{0}C). It is also revealed from the table that it was minimum 34.97% at 40^{0}Brix sugar concentration, 30^{0}C soaking temperature and 15/30 magnetron ON/OFF time and was maximum 51.49% at 60^{0}Brix sugar concentration, 60^{0}C soaking temperature and 25/30magnetron ON/OFF time. Non-Reducing sugar content in pineapple cubes increased as sugar concentration and soaking temperature, and magnetron ON/OFF time increases.

As the sugar concentration increases from 40°B to 60°Brix, the Non-Reducing sugar of the dried pineapple cubes increases for all magnetron ON/OFF times. However in 15/30 magnetron ON/OFF time the Non-Reducing sugar increases gradually form sugar concentration 40°B to 60°Brix. Similarly in 25/30 magnetron ON/OFF time Non-Reducing sugar increases from sugar concentration 40 to 60°Brix. Similarly as the soaking temperature of the pineapple cubes increases from 30 to 60^{0}C Non-Reducing sugar increases for all magnetron ON/OFF time. During drying of pineapple cubes magnetron ON/OFF time play important role in Non-Reducing sugar of the dried pineapple cubes.

Table 13 shows the ANOVA for the effect of magnetron ON/OFF time, sugar concentration, soaking temperature on the Non-Reducing sugar of the pineapple cubes. It is clear from the table that

Table 12: Effect of magnetron ON/OFF time, sugar concentration and soaking temperature on reducing sugar of osmo-microwave dried pineapple cubes

Magnetron ON/OFF Time (s)	Sugar concentration 40°Brix			Sugar concentration 50°Brix			Sugar concentration 60°Brix		
	Soaking Temp 30°C	Soaking Temp 45°C	Soaking Temp 60°C	Soaking Temp 30°C	Soaking Temp 45°C	Soaking Temp 60°C	Soaking Temp 30°C	Soaking Temp 45°C	Soaking Temp 60°C
15s/30s	14.12^{l}	15.28^{k}	16.20^{ij}	16.20^{ij}	17.24^{h}	18.80^{fg}	18.20^{g}	18.38^{fg}	19.90^{dc}
20s/30s	15.73^{kj}	16.17^{ij}	17.16^{h}	16.55^{ih}	18.16^{g}	19.68^{de}	19.08^{fe}	19.63^{de}	21.87^{b}
25s/30s	15.81^{kj}	17.20^{h}	20.06^{dc}	17.20^{h}	19.79^{de}	22.01^{b}	19.90^{dc}	20.60^{c}	24.13^{a}

ANOVA

		Source of Variation	*Df*	*SS*	*MS*	*F*	*P-value*	*F critical*
SE_1	0.086012	Sugar Concentration	2	192.367	96.184	481.53	<.0001	2.007
CD_1 at 0.05%	0.2441	Soaking Temperature	2	125.007	62.503	312.91	<.0001	2.007
SE_2	0.148977	Magnetron ON/OFF Time	2	84.183	42.091	210.72	<.0001	2.007
CD_2 at 0.05%	0.42277	Sugar Concentration and Soaking Temperature	4	4.936	1.234	6.18	0.0004	2.007
SE_3	0.258035	Sugar Concentration and Magnetron ON/OFF Time	4	1.049	0.262	1.31	0.2773	2.007
CD_3 at 0.05	0.73226	Soaking Temperature and Magnetron ON/OFF Time	4	14.506	3.626	18.16	<.0001	2.007
		Sugar concentration, Soaking Temperature and Magnetron ON/OFF Time	8	2.416	0.302	1.51	0.1758	2.007
	Replication	2	0.059	0.030	0.15	0.8621		
	Error	52	10.387	0.200				
	Corrected Total	80	434.911					

Same letter are not significantly different, SE_1= Effect of individual Sugar concentration or soaking temperature or ON/OFF time of magnetron on reducing sugar, SE_2= Effect of sugar concentration and soaking temperature, effect of sugar concentration and ON/OFF time of magnetron, effect of soaking temperature and ON/OFF time of magnetron on reducing sugar, SE_3= Combine effect sugar concentration, soaking temperature and ON/OFF time of magnetron on reducing sugar.

Table 13: Effect of magnetron ON/OFF time, sugar concentration and soaking temperature on non-reducing sugar of osmo-microwave dried pineapple cubes

Magnetron ON/OFF Time (s)	Sugar concentration 40°Brix			Sugar concentration 50°Brix			Sugar concentration 60°Brix		
	Soaking Temp 30°C	Soaking Temp 45°C	Soaking Temp 60°C	Soaking Temp 30°C	Soaking Temp 45°C		Soaking Temp 30°C	Soaking Temp 45°C	Soaking Temp 60°C
15s/30s	34.97^{no}	35.26^{no}	37.00^{lmh}	34.61^{o}	36.18^{nmo}	36.35^{nm}	39.31^{gih}	43.00^{ed}	45.09^{c}
20s/30s	35.29^{no}	37.40^{jlmn}	38.14^{jlik}	36.49^{nlm}	37.57^{jlmk}	38.29^{jik}	40.16^{gfh}	44.48^{cd}	46.08^{cb}
25s/30s	36.05^{nmo}	38.77^{jih}	40.72^{gf}	38.76^{jih}	38.36^{jik}	41.65^{ef}	41.08^{f}	46.96^{b}	51.49^{a}

ANOVA

		Source of Variation	*Df*	*SS*	*MS*	*F*	*P-value*	*F critical*
SE_1	0.199314	Sugar Concentration	2	850.316	425.158	396.38	<.0001	2.007
CD_1 at 0.05%	0.5656	Soaking Temperature	2	243.149	121.575	113.35	<.0001	2.007
SE_2	0.345221	Magnetron ON/OFF Time	2	174.907	87.453	81.53	<.0001	2.007
CD_2 at 0.05%	0.97968	Sugar Concentration and Soaking Temperature	4	73.966	18.492	17.24	<.0001	2.007
SE_3	0.597941	Sugar Concentration and Magnetron ON/OFF Time	4	6.372	1.593	1.49	0.2202	2.007
CD_3 at 0.05	1.696856	Soaking Temperature and Magnetron ON/OFF Time	4	24.193	6.048	5.64	0.0008	2.007
		Sugar concentration, Soaking Temperature and Magnetron ON/OFF Time	8	13.409	1.676	1.56	0.159	2.007
	Replication		2	1.522	0.761	0.71	0.4966	
	Error		52	55.775	1.073			
	Corrected Total		80	1443.609				

Same letter are not significantly different, SE_1= Effect of individual Sugar concentration or soaking temperature or ON/OFF time of magnetron on non-reducing sugar, SE_2= Effect of sugar concentration and soaking temperature, effect of sugar concentration and ON/OFF time of magnetron, effect of soaking temperature and ON/OFF time of magnetron on non-reducing sugar, SE_3= Combine effect sugar concentration, soaking temperature and ON/OFF time of magnetron on non-reducing sugar.

Table 14: Effect of magnetron ON/OFF time, sugar concentration and soaking temperature on total sugar of osmo-microwave dried pineapple cubes

Magnetron ON/OFF Time (s)	**Sugar concentration 40°Brix**			**Sugar concentration 50°Brix**			**Sugar concentration 60°Brix**		
	Soaking Temp 30°C	**Soaking Temp 45°C**	**Soaking Temp 60°C**	**Soaking Temp 30°C**	**Soaking Temp 45°C**	**Soaking Temp 60°C**	**Soaking Temp 30°C**	**Soaking Temp 45°C**	**Soaking Temp 60°C**
15s/30s	49.09^{k}	50.53^{j}	53.20^{ih}	50.81^{j}	53.42^{h}	55.15^{g}	57.51^{f}	61.38^{d}	64.99^{c}
20s/30s	51.02^{j}	53.57^{h}	55.31^{g}	53.04^{ih}	55.73^{g}	57.97^{fe}	59.24^{e}	64.11^{c}	67.96^{b}
25s/30s	51.86^{ij}	55.97^{g}	60.79^{d}	55.96^{g}	58.15^{fe}	63.67^{c}	60.97^{d}	67.57^{b}	75.62^{a}

ANOVA

		Source of Variation	*Df*	*SS*	*MS*	*F*	*P-value*	*F critical*
SE_1	0.160755	Sugar Concentration	2	1756.402	878.201	1258.63	<.0001	2.007
CD_1 at 0.05%	0.4562	Soaking Temperature	2	707.656	353.828	507.11	<.0001	2.007
SE_2	0.278436	Magnetron ON/OFF Time	2	501.280	250.640	359.22	<.0001	2.007
CD_2 at 0.05%	0.790155	Sugar Concentration and Soaking Temperature	4	62.897	15.724	22.54	<.0001	2.007
SE_3	0.482266	Sugar Concentration and Magnetron ON/OFF Time	4	6.254	1.563	2.24	0.0772	2.007
CD_3 at 0.05	1.368589	Soaking Temperature and Magnetron ON/OFF Time	4	74.950	18.738	26.85	<.0001	2.007
		Sugar concentration, Soaking Temperature and Magnetron ON/OFF Time	8	9.302	1.163	1.67	0.1291	2.007
		Replication	2	2.121	1.060	1.52	0.2283	
		Error	52	36.283	0.698			
		Corrected Total	80	3157.145				

Same letter are not significantly different, SE_1= Effect of individual Sugar concentration or soaking temperature or ON/OFF time of magnetron on total sugar, SE_2= Effect of sugar concentration and soaking temperature, effect of sugar concentration and ON/OFF time of magnetron, effect of soaking temperature and ON/OFF time of magnetron on total sugar, SE_3= Combine effect sugar concentration, soaking temperature and ON/OFF time of magnetron on total sugar.

Non-Reducing sugar is significantly affected ($p \leq 0.05$) by the magnetron ON/OFF time, sugar concentration, soaking temperature. The interaction between the magnetron ON/OFF time, sugar concentration, soaking temperature has also significant difference in the Non-Reducing sugar. The interactions among independent variables significantly affected the Non-Reducing sugar values of pineapple cubes ($p \leq 0.05$).

6. Total sugar

Table 14 shows the effect of magnetron ON/OFF time, sugar concentration and soaking temperature on the total sugar (%) of the dried pineapple cubes. The total sugar for pineapple cubes were in the range of 49.09-75.62% for all the magnetron ON/OFF time (15/30, 20/30 and 25/30), at varied sugar concentration (40 to 60°Brix) and soaking temperature (30 to 60^{0}C). Total sugar for magnetron ON/OFF time 15/30 ranges from 49.09-64.99%, for magnetron ON/OFF time 20/30 it ranges from 51.02-67.95% and for magnetron ON/OFF time 25/30 it ranges from 51.86-75.62% respectively for all the magnetron ON/OFF time (15/30, 20/30 and 25/30), sugar concentration (40 to 60°Brix) and soaking temperature (30 to 60^{0}C). It is revealed from the table that the total sugar was minimum 49.09% at 40^{0}Brix sugar concentration, 30^{0}C soaking temperature and 15/30 magnetron ON/OFF time and was maximum 75.62% at 60^{0}Brix sugar concentration, 60^{0}C soaking temperature and 25/30 magnetron ON/OFF time. Total sugar content in pineapple cubes is increases as sugar concentration and soaking temperature, and magnetron ON/OFF time increases.

As the sugar concentration increases from 40°B to 60°Brix, the total sugar of the dried pineapple cubes increased for all magnetron ON/OFF time. However in 15/30 magnetron ON/OFF time the total sugar increases gradually form sugar concentration 40°B to 60°Brix. Similarly in 25/30 magnetron ON/OFF time total sugar increases rapidly from sugar concentration 40 to 60°Brix. Similarly as the soaking temperature of the pineapple cubes increases from 30 to 60^{0}C total sugar increases for all magnetron ON/OFF times. During drying of pineapple cubes magnetron ON/OFF time play a important role on total sugar of the dried pineapple cubes.

Table 14 shows the ANOVA for the effect of magnetron ON/OFF time, sugar concentration, soaking temperature on the total sugar of the pineapple cubes. It is clear from the table that total sugar is significantly affected ($p \leq 0.05$) by the magnetron ON/OFF time, sugar concentration, soaking temperature. The interaction between the magnetron ON/OFF time, sugar concentration, soaking temperature has a significant difference in the total sugar.

The interactions among independent variables also significantly affected the total sugar values of pineapple cubes ($p \leq 0.05$).

Increase in sugar concentration, soaking temperature and magnetron ON/OFF time resulted in increases in reducing sugar. Similar observations were reported by Exepedito *et al*. (1996) that there was increase in total sugar of osmotic dehydrated pineapple slices when slices were treated with 70^{0}B sugar solution having final total sugar 49.43% in osmo-vacuum dried pineapple samples. Rashmi *et al.* (2005) reported the total sugar content in pineapple slices which was 61.54, 65.64and 67.17 per cent when treated in different sugar concentration i.e. 50^0, 60^0 and 70^{0}Brix, respectively. Sagar *et al.* (1999) reported the total sugar percentage in dehydrated mango slices which ranged from 56.21 to 67.30 per cent at 60^{0}B sugar concentartion.

Sensory evaluation of developed product

The sensory evaluation was carried out by the trained taste panel consisting of students and staff from the College of Agricultural Engg. and Tech., Dapoli. The number of panelists who evaluated osmo microwave vacuum dried pineapple cubes were 41 (22 female and 19 male).

Sensory evaluation of the Osmo-microwave vacuum dried pineapple cubes shown in Table 15. Overall score of sensory characteristics ranged from 6.3 to 8.7 for all magnetron ON/OFF time (15/30, 20/30 and 25/30), at varied sugar concentration (40 to 60°B) and

Table 15: Sensory evaluation of microwave-vacuum dried pineapple cubes of various treatments

Sample Code	Sugar concentration (^{0}B)	Soaking Temp. (^{0}C)	Magnetron ON/ OFF time	Sensory Parameters				
				Colour	Texture	Taste	Flavour	Overall Acceptabbility
A	40	30	15/30	6.0	6.1	6.5	6.3	6.5
B	40	30	20/30	6.4	6.3	6.5	6.5	6.4
C	40	30	25/30	6.4	6.4	6.4	6.6	6.6
D	40	45	15/30	6.2	6.5	6.6	6.2	6.5
E	40	45	20/30	6.5	6.6	6.6	6.4	6.6
F	40	45	25/30	6.4	6.4	6.4	6.5	6.5
G	40	60	15/30	6.6	6.2	6.5	6.4	6.4
H	40	60	20/30	6.0	6.3	6.5	6.2	6.7
I	40	60	25/30	6.8	6.6	6.8	6.4	6.7
J	50	30	15/30	6.6	6.3	6.5	6.6	6.7
K	50	30	20/30	6.6	6.7	6.3	6.5	6.7
L	50	30	25/30	6.8	6.5	6.5	6.5	6.6
M	50	45	15/30	6.6	6.3	6.3	6.5	6.7
N	50	45	20/30	6.6	6.7	6.7	6.9	6.9
O	50	45	25/30	6.7	6.8	6.7	6.8	6.7
P	50	60	15/30	6.5	6.6	6.7	6.9	6.8
Q	50	60	20/30	6.8	6.7	6.8	6.4	6.8
R	50	60	25/30	6.6	6.8	6.8	6.6	6.7
S	60	30	15/30	6.6	6.6	6.7	6.8	6.9
T	60	30	20/30	6.4	6.5	6.7	6.8	6.8
U	60	30	25/30	6.6	6.2	6.6	6.6	6.6
V	60	45	15/30	6.6	6.4	6.6	6.5	6.6
W	60	45	20/30	6.9	6.7	7.0	6.8	6.9
X	60	45	25/30	6.6	6.9	6.8	6.8	6.9
Y	60	60	15/30	6.8	6.9	7.0	6.9	7.0
Z	**60**	**60**	**20/30**	**7.5**	**7.9**	**8.0**	**7.8**	**8.1**
AA	60	60	25/30	7.8	7.8	7.7	7.8	7.9

Table 16: Sensory analysis of microwave vacuum dried pineapple cubes

Source of Variation	SS	df	MS	F	P-value	F crit
(A) Colour						
Rows	419.149	40	10.478	10.382	3.12E-52	1.405
Columns	149.579	26	5.7530	5.6999	1.31E-17	1.506
Error	1049.68	1040	1.0093			
Total	1618.40	1106				
(B) Flavour						
Rows	272.6016	40	6.8150	6.6742	1.08E-30	1.405
Columns	157.7687	26	6.0680	5.9426	1.28E-18	1.506

Error	1061.935	1040	1.0210			
Total	1492.305	1106				
(C) Overall Acceptabbility						
Rows	318.206	40	7.9551	10.151	6.26E-51	1.405
Columns	150.146	26	5.7748	7.3694	1.41E-24	1.506
Error	814.964	1040	0.7836			
Total	1283.31	1106				
(D) Taste						
Rows	345.304	40	8.63261	10.002	4.41E-50	1.405
Columns	146.056	26	5.61753	6.5089	5.57E-21	1.506
Error	897.573	1040	0.86305			
Total	1388.93	1106				
(E) Texture						
Rows	249.4399	40	6.23599	5.889	5.06E-26	1.405
Columns	180.6829	26	6.94934	6.562	3.31E-21	1.506
Error	1101.243	1040	1.05888			
Total	1531.366	1106				

soaking temperature (30 to 45°C). Increase in sugar concentration increased the sensory score. Maximum acceptability was observed at the maximum level of sugar concentration. The sensory analysis of Osmo-microwave vacuum dried pineapple cubes indicated that the overall acceptability of the dried pineapple cubes were highest at (sample code 'Z') at which the colour, texture, taste, flavour and overall acceptability was 7.5, 7.9, 8.0, 7.8 and 8.1 respectively. The treatment at which the sugar concentration 60^0Brix, soaking temperature 60^0C and magnetron ON/OFF time 20/30. Table 16 shows the ANOVA for the sensory analysis of the scores obtained for osmo-microwave vacuum dried pineapple cubes at each treatment combinations. All the sensory scores was significantly different at $p \leq 0.05$.

Nutritional quality of best product

Best product sample based on the sensory score the sugar concentration 60^0Brix, Soaking temperature 60^0C and magnetron ON/OFF time 20/30 which contain best sensory scores i.e. Colour 7.5, Texture 7.9, Taste 8.0, Flavour 7.8 and Overall Acceptability 8.1 respectively. TSS 32.37%, pH 4.44%, acidity 0.605%, reducing sugar 21.87%, non-reducing sugar 46.08% and total sugar 67.96%. The time of drying of this treatment was osmosis time 120 min, 120 min microwave-vacuum drying time and total time for this treatment 240 min.

CONCLUSION

Osmo-microwave vacuum drying of pineapple cubes indicated that the drying was carried in the falling rate period. Osmotically dried cubes dried at 60^0C soaking temperature at 60^0B sugar concentration and exposed to magnetron ON/OFF time 15/30, 20/30 and 25/30 in sec. It took around 135, 120 and 105 mintues to dry the product from an initial moisture content 120.55 (%db) to 4.44 (%db).The drying rate increases 5.51 to 11.72 kg of water removed/kg of dry matter/h as the microwave vacuum magnetron ON/OFF time in sec increases from ON/OFF time 15s/30s to 25s/30s of magnetron at 60^0B sugar concentration and soaked at 60^0C.

The drying constant increases with increases in ON time of magnetron; also it increases with increases in soaking temperature of pineapple cubes. At 60^0B sugar concentration, soaking temperature increases from 30^0C to 60^0C the drying constant were 0.03037-0.03764, 0.03764-0.03507 and 0.038542-0.06230 (min/h) for 15s, 20s and 25s ON time of magnetron respectively.

Effective diffusivity (D_{eff}) at time (t) for osmotically dried pineapple cubes at sugar concentration 60^0B, soaking temperature 60^0C and magnetron ON/OFF time 15s/30s, 20s/30s and 25s/30s respectively was 4.64×10^{-7}, 5.17×10^{-7} and $7.58\ \times10^{-7}$ m^2/s, the diffusion coefficient was 16.09×10^{-7} m^2/s and the activation energy for pineapple cubes, was in the range of (using Arrehenius equation) 31.77 to 80.43 kJ/mole for all the treatment.

Osmo-microwave vacuum dried pineapple cubes indicated that the best sample could be prepared at cubes soaked in at 60^0B sugar concentration at 60^0C soaking temperature and dried at 20 sec on time of magnetron and 30 sec off time of the magnetron resulted best sensory scores i.e. Colour 7.5, Texture 7.9, Taste 8.0, Flavour 7.8 and Overall Acceptability 8.1 respectively. The nutritional analysis indicated that the pineapple cubes dried at these condition had TSS 32.37%, p^H 4.44%, acidity 0.605%, reducing sugar 21.87%, non-reducing sugar 46.08% and total sugar 67.96% etc.

REFERENCES

Azuara, E., Beristain, C.I. and Garcia, H.S. 1996. Development of a mathematical model to predict kinetics of osmotic dehydration. *Journal of Food Science and Technology*, **29**(4): 239-242

Azuara, Hugo S. Garciab and Cesar I. Beristain, 1996. Effect of the centrifugal force on osmotic dehydration of potatoes and apples *Food Research International*, **29**(2): 195-199.

Brooker, D.B., Bakker, F.W. and Hall, C.W. 1974. Drying and Storage of Grains and Oilseeds. *The AVI Publishing Company, Inc*. Westport, Connecticut. : 56-71.

Corrêa , S.R.S. Dev, Y. Gariepy and Raghavan, G.S.V. 2014. Drying of Pineapple hurdle technology, *Food Science and Technology*, **42**: 1681–1687.

Crank, J. 1975. The Mathematics of Diffusion (2nd ed.) UK, Clearendon Press, Oxford.

Decareau, R.A. 1986. Peterson."Microwave processing and engineering". Chichester : Ellis Horwood, pp. 224 .

Devi, M. and Genitha Er T.R. 2012. Optimization of osmotic dehydration process of pineapple br response surface methodology, *Food Processing Technology*, **3**: 8.

Drouzas, A.E. and Schubert, H. 1996. Microwave application in vacuum drying of fruits, *Journal of Food Engineering*, **28**: 203-209.

Ertekin, F.K. and Cakaloz, T. 1996. Osmotic dehydration of peas: I. Influence of process variables on mass transfer. *Journal of Food Processing and Preservation*, **20**: 87–95.

Expedito, T.F. Silveira, M. Shafiur Rahman & Ken A. Buckle, 1996. Osmotic dehydration of pineapple: kinetics and product quality, *Food Research International*, **29**(34): 227233.

Filho Ronaldo dos santos, Rennam Pereira de Gusmao, 2015. Osmotic dehydration of pineapple stems in hypertonic solutions, Agricultural Sciences, *Journal of Food Engineering*, **6**: 916-924.

Gardener, D.R. and Butler, J.L. 1982 preparing crops for storage with a microwave vacuum (MIVAC) system. Drying 82; Mujumdar, A.S., Ed.: *Elsevier Science Publishers*; Amsterdam; pp. 248-257.

Gökçe , Apar, Dilek Kılıç and Özbek, Belma. 2007. 'Microwave Drying Kinetics of Okra', DryingTechnology, **25**(5): 917-924.

Hawkes and Flink, J.M. 1970. Osmotic concentration of fruit slices prior to freeze dehydration. *Journal of Food Processing and Preservation*, **2**: 265-84.

Henderson, S.M. and Pabis, S. 1961. Grain drying theory I: Temperature effect on drying coefficient. *Journal of Agricultural Research Engineering*, **7**: 85–89.

Jiang, N., Liu, C., Li, D., Zhang, Z., YU, Z. and Zhou, Y. 2016. Effect of thermosonic pretreatment on drying kinetics and energy consumption of microwave vacuum dried *Agaricus bisporus* slices, *Journal of Food Engineering*, pp. 344-352.

Kaleemullah, S., Kallippan, R. and Varadhraju, N. 2002. Studies an osmotic air drying characteristics of papaya cubes. *Journal of Food Science and Technology*, **39**(1): 82-84.

Karthanos, V.T., Kastaropoulus, A.E. and Saravacos, G.D. 1995. Airdrying behaviour of osmotically dehydrated fruits. *Drying Technology*, **13**(5–7): 1503–1506.

Lazarides, H.N. and Mavroudis, N. 1995. Freeze/thaw effect on mass transfer rates during osmotic dehydration. *Journal of Food Science*, **60**(4): 826–829.

Lenart, A. and Flink, J.M. 1984. Osmotic concentration of potato. I. Criteria for the end-point of the osmosis process *Journal of Food Technology*, **19**(1): 45.

Lenart, A. and Flink, J.M. 1984. Osmotic concentration of potato. I. Criteria for the end-point of the osmosis process *Journal of Food Technology*, **19**(1): 45.

Manish Dak and Pareek, N.K. 2014. Effective moisture diffusivity of pomegranate arils under going microwave-vacuum drying, *Journal of Food Engineering*, **122**: 117–121.

Musa, N. and Farid, M. 2002. Microwave drying of Banana Slices. *Drying Technology*, **20**(10): 2055-2066.

Nantawan Therdthai and Weibiao Zhou. 2009. Characterization of microwave vacuum drying and hot air drying of mint leaves (*Mentha cordifolia Opiz ex Fresen*) *Journal of Food Engineering*, **91**: 482–489.

Nieuwenhuijzen, N.H., Zareifard, M.R. and Ramaswamy, H.S. 2001. Osmotic drying kinetics of cylindrical apple slices of different sizes. *Drying Technology*, **19**(3 and 4): 525–545.

Nsonzi, F. and Ramaswamy, H.S. 1998. Quality evaluation of osmo-convective dried blueberries. *Drying Technology,* **16**(3-5): 705-723.

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

Pala, M., Mahmutoglu, T. and Saygi, B. 1996. Effects of pretreatments on the quality of open-air and solar dried apricots. Nahrung, *Journal of Food Engineering,* **40**(3): 137–141.

Pokharkar, S.M. and Prasad, S. 1998. Mass transfer during osmotic dehydration of banana slices. *Journal of Food Science and Technology,* **35**(4): 336-38

Pokharkar, S.M. and Prasad, S. 1998b. Air drying behavior of osmotically dehydrated pineapple. *Journal of Food Science and Technology*, **39**: 384-387

Pokharkar, S.M., Prasad, S. and Das, H.A. 1998a. Model for osmotic concentration of banana slices. *Journal of Food Science and Technology*, **34**: 230-235.

Ranganna, S. 1986. Handbook of Analysis and Quality Control for Fruits and Vegetables products, Tata McGraw- Hill Publishing Company Limited, New Delhi.

Rashmi, H.B., Doreyappa Gowda, I.N. and Mukanda, G.K. 2005. Studies on osmo-air dehydration of pineapple fruits. *Journal Food Science Technology,* **42**: 64–67.

Rastogi, N.K. and Raghavarao, K.S.M.S. 1997. Water and solute diffusion coefficients of carrot as a function of temperature and concentration. *Journal of Food Engineering*, **34**: 429–440.

Sagar, V.R. 1999. Preparation of onion powder by means of osmotic dehydration and its packaging and storage. *Journal of Food Science and Technology,* **38**(5): 525-528.

Sanga, E., Mujumdar, A.S. and Raghavan, G.S.V. 2000. Principal and application of microwave drying. In drying technology In Agriculture and Food Sciences; Mujumdaer, A.S. Ed., Science publishers, Inc: Enfield, N.H.; pp. 253-289.

Schiffmann, R.F. 1995. Microwave and Dielectric drying. *In* handbook of industrial Drying; Mujumdar, A.S., Ed.; Marcel Dekker: N.Y Vol. I.

Shi, J., Pan, Z., McHugh, T.H., Wood, D., Hirschberg, E. and Olson, D. 1995. Drying and quality characteristics of fresh and sugar-infused blueberries dried with infrared radiation heating. LWT *Food Science and Technology*, **41**: 1962–1972.

Silveira, E.T.F., Rahman, M.S. and Buckle, K. 1996. Osmotic dehydration of pineapple: kinetics and product quality. *Food Research International,* **29**(3-4): 227-233.

Silveira, E.T.F., Rahman, M.S. and Buckle, K. 1996. Osmotic dehydration of pineapple: kinetics and product quality. *Food Research International*, **29**(3-4): 227-233.

Song, X.J., Zhang, M., Mujumdar, A.S. and Fan L.P. 2009. Drying Characteristics and Kinetics of Vacuum Microwave-dried Potato slices, *Drying Technology*, **27**(9): 960-974.

Sridevi, M. and Genitha, Er T.R. 2012. Optimization of osmotic dehydration process of pineapple br response surface methodology, *Food Processing Technology,* **3**: 8.

Suresh Kumar, P. and Genitha. 2011. Optimization of some process variables in mass transfer kinetics of osmotic dehydration of pineapple slices, *International Food Research Journal,* **18**: 221-238.

Yetenayet Bekele and Hosahalli Ramaswamy. 2010. Going beyond conventional osmotic dehydration for quality advantage and energy savings, Department of Food Science and Agricultural Chemistry, McGill University, Macdonald Campus, 21111 Lakeshore Road, Ste Anne de Bellevue, Quebec, H9X 3V9, Canada.

Zang, M., Li, C.L. and Ding, X.L. 2000. Application of various drying methods in selenium – enriched vegetable dehydration. *Drying Technology*, **18**(4-5): 1139-1146.

Zhang, J., Zhan, M. Shan, L. and Fang, Z.X. 2007. Microwave –vacuum heating parameters for processing savory crisp bighead carp (*Hypophthalmichthys nobilis*) slices. *Journal Food Engineering*, **79**: 885-891.