OSMOTIC DRYING RATE ESTIMATION FOR ALOE VERA SLICES USING ARTIFICIAL NEURAL NETWORK

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ABSTRACT

Osmotic dehydration is one of the suitable methods to increase the shelf life of fruits and vegetables. This process is preferred over others due to its vitamin and minerals, color, flavor and taste retention property. ANN is a parallel adaptive system, which can gather knowledge by detecting the patterns and relationships in data and learn through experience, and can perform well for optimization and approximation in complex non-linear systems. The main objective of the present work is drying of aloe Vera slices using the technique of osmotic dehydration. It also compares the drying characteristics of osmotic dehydration with the conventional methods. The process is carried out using sucrose solution of different concentrations, temperatures and thicknesses of the aloe vera slices. The weight loss and rate is estimated and the effect of process parameters is studied. It is observed a significant amount of water removal without altering the quality of Aloe vera. Development of Artificial Neural Network models based on experimental data using elite-ANN© is the novel feature of present work.

KEYWORDS: *Artificial Neural Network, Osmotic dehydration, Aloe vera slices, Vacuum drying*

I. INTRODUCTION

Dehydration of fruits, food grains and vegetables is probably the oldest method of food preservation practiced by mankind. Osmotic dehydration has evolved as a technique for this purpose due to its low temperature and low cost attributes. The process involves minimized heat damage to color and flavor, with less energy consumption as water is removed without change of phase.

Various studies have been conducted on the osmotic dehydration of vegetables and fruits under different conditions of pressure, temperature and concentration. The effect of osmotic dehydration is usually observed in terms of weight loss and solid gain with respect to time.

Three kinds of fruits-apricots, strawberries and pineapples - have been studied, by X. Q. Shi, P. Fito& A. Chiralt [2], as experimental material to analyze the influence of operating pressure of osmotic dehydration on the mass transfer rate in fruits. Vacuum treatments increased water transfer rate, but had no effect on sugar uptake between vacuum and normal pressure treatments during osmotic dehydration.

Optimization of osmotic dehydration of papaya followed by air drying was studied by Fabiano A.N. Fernandes, Sueli Rodriguez, Odisse´ia C.P. Gaspareto, Edson L. Oliveira [3]. The process of osmotic dehydration followed by air-drying was studied and modeled for papaya preservation. The developed model has been validated with experimental data and simulations have shown how the operating conditions affect the process. An optimization was done using the model in order to search for the best operation condition that would reduce the total processing time.

Artificial neural network is an effective method in correlating processes involving multi variable, non-linear relations. These are also known as black box modeling tools and are similar to the way biological networks function. Amongst various types, 'Multilayer Perceptron (MLP)' is common in development of models related to engineering processes. 'MLP' consists of layers of interconnected neurons also called as nodes to process the incoming information, from input to output, through the hidden layers. Error back propagation algorithm is one amongst training algorithms that decides its efficacy in development of model.

Various applications of ANN are reported in literature that includes estimation, prediction, fault detection and control of complete processes. Some of these are fault diagnosis in complex chemical plants [4], Osmotic drying rate estimation for dehydration of beetroot slices using artificial neural network [5], Modeling of osmotic dehydration kinetics of banana slices using Artificial neural network [6].

II. PRESENT WORK

The main objective of the present work is drying of Aloe Vera slices using the technique of osmotic dehydration. It also compares the drying characteristics using osmotic dehydration with the conventional methods based on experimental observations. The process is carried out using sucrose solution of different concentrations, temperatures and thicknesses of the aloe vera slices. The weight loss and drying rate data is calculated and is analyzed. Developing Artificial neural network models based on experimental data using elite-ANN© [7] are developed.

The material used for osmotic dehydration were locally procured aloe vera leaves. Aloe vera slices samples are also dried using conventional methods such oven drying, convective tray drying and vacuum drying and rates are compared.

2.1. Experimental work [8]

- Aloe vera slices of dimensions 5x1.5cm are cut from the peeled whole leaf. Initial weight of aloe vera slices was measured using an electronic balance and the slices were dipped in the sucrose solution of 30, 40 and 50 ^{0}Brix.
- After every 20 minutes the slices were removed from the solution, wiped off using filter paper and weighed.
- The procedure was repeated for 303, 313 and 323K. The weight of aloe vera slices was measured and the osmotic drying rate was calculated using following formula
  Rate= (W0-Wn)/tn
  W0→initial weight of aloe vera slice at time t=0
  Wn→weight of aloe vera slice after time t=tn

III. RESULTS AND DISCUSSION

3.1. Effect of time on the weight loss

Figures 1,2 and 3 show the graphs plotted between the weight of aloe vera slices against time of osmosis at different concentration of sucrose solution of 30, 40 and 50^{0}Brix and temperature conditions of 303K,313K and 323K. It is observed that weight of the aloe vera slices decreases with time in a nonlinear fashion. Initially the weight loss is the highest, the weight loss gradually decreases at a slower pace. This is due to the moisture migration from the aloe vera slices to the sucrose solution and the solid travel from the solution to the aloe vera slices. In almost all cases the weight loss is more for 323K for various concentrations. It is primarily due to the fact that the driving force increases with respect to temperature and concentration.

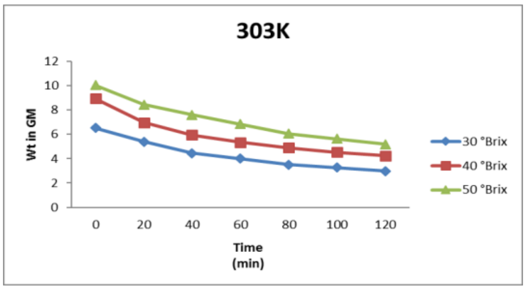

Figure 1.Effect of sucrose solution concentration on weight loss as a function of time, at 303K

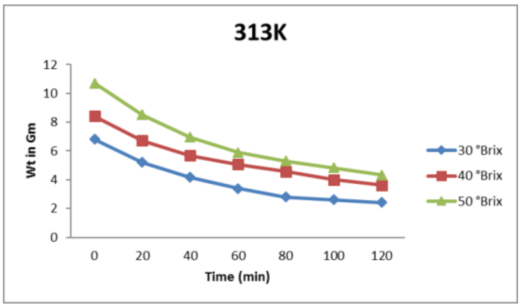

Figure 2. Effect of sucrose solution concentration on weight loss as a function of time, at 313K

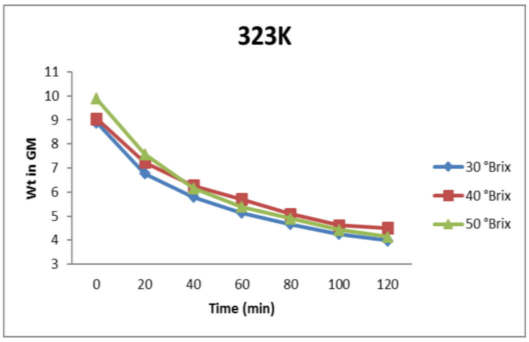

Figure 3. Effect of sucrose solution concentration on weight loss as a function of time, at 323K

3.2. Effect of concentration on the drying rate

Figures 4,5 and 6 show the effect of concentration on drying rate for different time elements when osmotic dehydration is carried out at 303,313 and 323K respectively.

The drying rate in each case increases initially and attains the maximum value. Then the rate drops with time. The initial high drying rate is primarily due to bound moisture and the sufficient surface moisture. However, the bound moisture decreases with time thus making it difficult for removal. Hence the rate decreases thereafter.

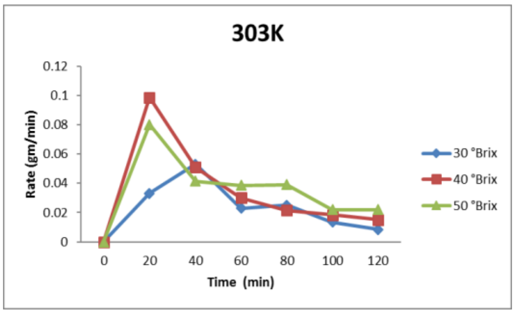

Figure 4.Effect of concentration of sucrose solution, on rate of drying, at 303K

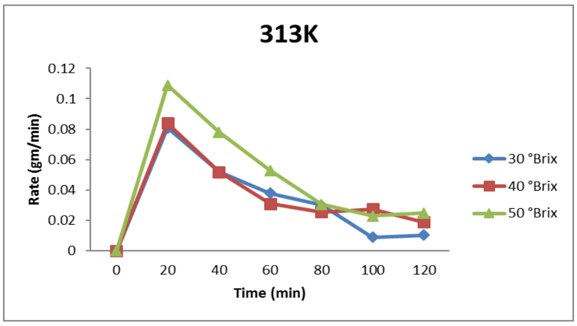

Figure 5.Effect of concentration of sucrose solution, on rate of drying, at 313K

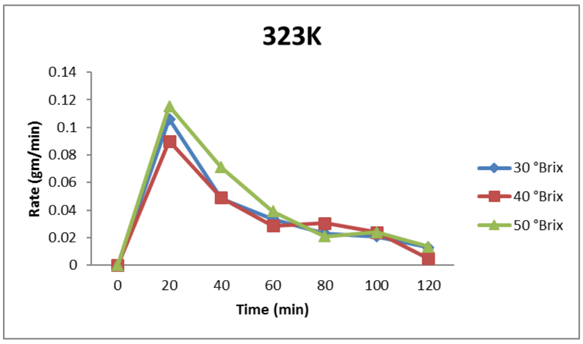

Figure 6.Effect of concentration of sucrose solution, on rate of drying, at 323K

3.3. Effect of thickness of aloe vera slices at constant temperature on weight loss

Figures 7, 8 and 9 show the effect of thickness of aloe vera slices at constant temperature on weight loss for different time elements when osmotic dehydration is carried out at 30, 40 and 50^{0}Brix respectively. The increase in thickness of Aloe Vera slices results in more water loss. This is primarily due to the increase in surface area that results in an increase in more water removal as more area is available for the dehydration process.

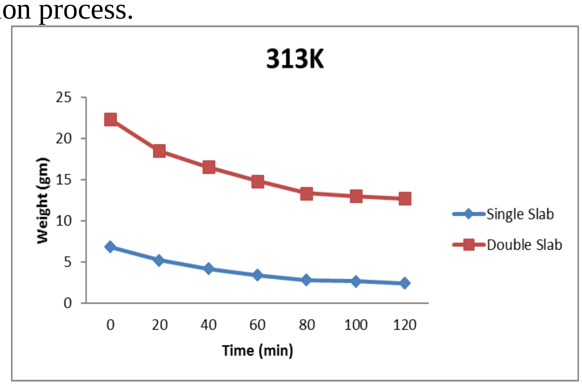

Figure 7.Effect of thickness of aloe Vera slices, on weight loss at 30 ^{0}BRIX and 313K

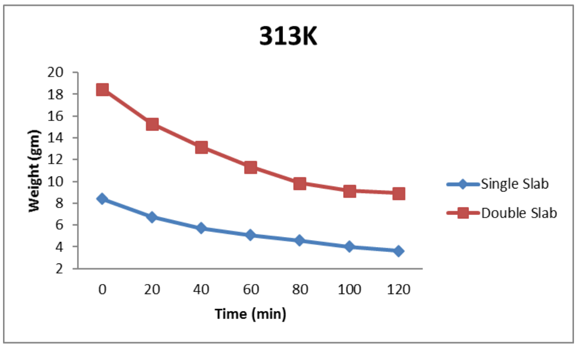

Figure 8. Effect of thickness of aloe Vera slices, on weight loss at 40 ^{0}BRIX and 313K

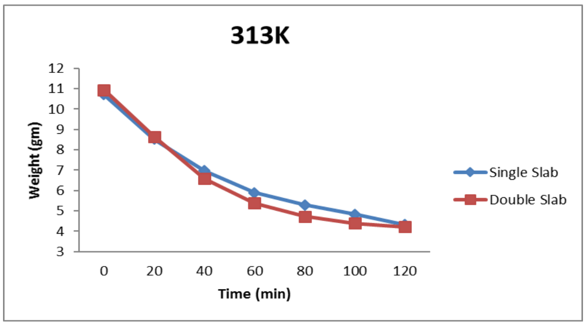

Figure 9. Effect of thickness of aloe Vera slices, on weight loss at 50 ^{0}BRIX and 313K

3.4. Effect of thickness of aloe vera slices at constant temperature on Rate of drying

Figures 10, 11 and 12 show the effect of time on the aloe vera slices of double thickness at constant temperature of 313K. The rate in case of slice having double thickness is more as compared to the one having less thickness. Higher surface area in the double slice results in more water removal and hence the rate is also more. The value of rate varies between 0.1925-0.0095 gm/min.

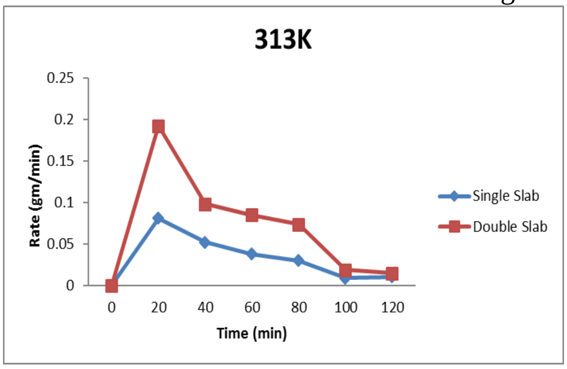

Figure 10.Effect of thickness of aloe Vera slices, on Rate of drying at 30 ^{0}BRIX and 313K

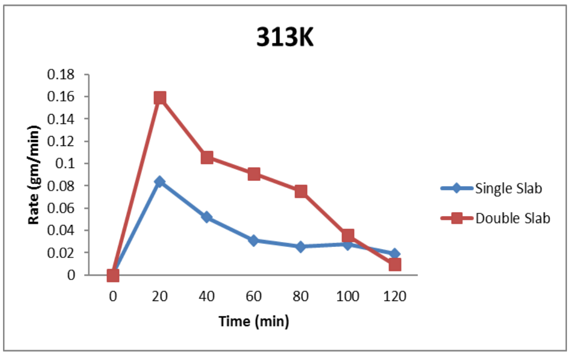

Figure 11.Effect of thickness of aloe Vera slices, on Rate of drying at 40 ^{0}BRIX and 313K

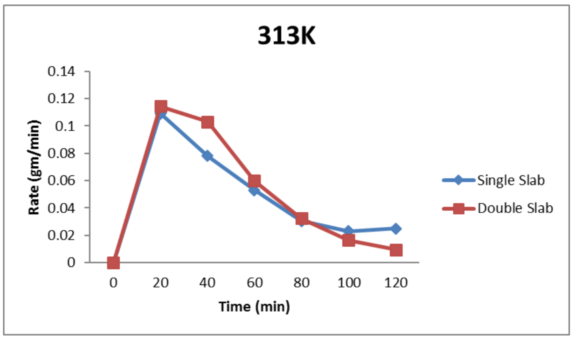

Figure 12.Effect of thickness of aloe Vera slices, on Rate of drying at 50 ^{0}BRIX and 313K

3.5. Effect of hot air (Convective drying) on the Weight loss

Figure 13 shows the effect of time on weight loss for aloe vera slices under convective drying at constant air temperature of 313K and constant air flow rate. It is observed that weight of the aloe vera slice decreases with time. The percent water removal in convective drying is less as compared to the osmotic dehydration. This is primarily due to higher driving force in case of osmotic dehydration than after convective drying. The aloe Vera slices after drying were acceptable however with shrinkages.

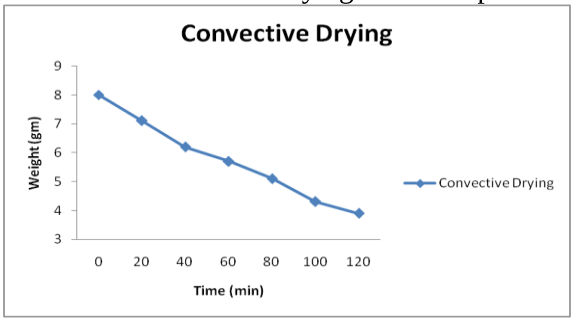

Figure 13.Effect of Convective Drying on aloe Vera slices

3.6 Effect of hot air (Convective drying) on the Rate of drying

Figure 14 shows the effect of convective drying at constant air temperature of 313K and constant air flow rate on the rate of drying. Initially the rate is constant due to the presence of unbound moisture in aloe vera slices. Then the rate decreases due to the bound moisture. The rate in case of convective drying varies from .045 to .02 gm/min.

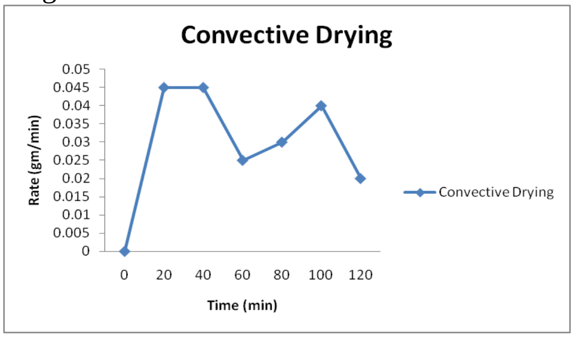

Figure 14.Effect of Convective Drying on the rate of drying

3.7 Effect of oven drying on the weight loss

Figure 15 exhibits the weight vs. time relationship for aloe vera slices under oven drying at constant temperature of 313K. It is observed that weight of the aloe vera slice decreases with time. The weight loss is less as compared to other methods of dehydration. This is mainly due to the less driving force in oven drying technique. Percent water removal is also less in oven drying i.e. 33%. The quality of aloe Vera slices after drying were acceptable however with shrinkages.

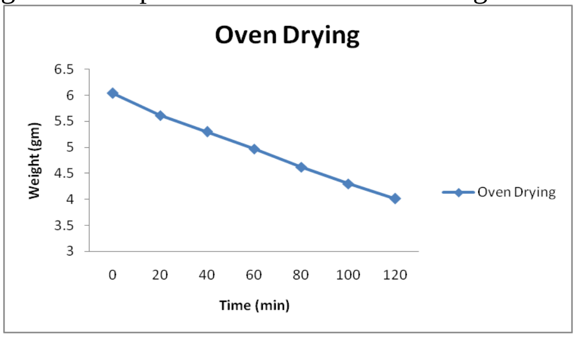

Figure 15.Effect of Oven Drying on weight at constant temperature

3.8. Effect of oven drying on the Rate of drying

Figure 16 exhibits the rate vs. time relationship for aloe vera slices under oven drying at constant temperature of 313K. The rate is maximum initially but as time passes the rate remains nearly constant. Rate varies between 0.0215 & 0.0145 gm/min. The rate of drying decreases gradually owing to the fact that the absolute humidity of the air surrounding the aloe vera slice goes on increasing as time passes.

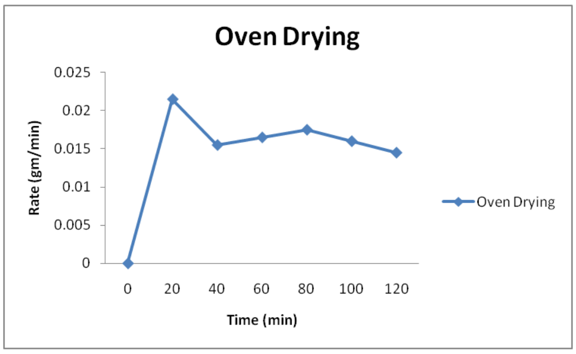

Figure 16.Effect of Oven Drying on the rate of drying at constant temperature of 313K

3.9 Comparison between vacuum osmotic drying and vacuum dehydration

Figure 17 exhibits the weight vs. time relationship for aloe vera slices under vacuum drying at constant temperature of 313K. Figure 18 exhibits the weight vs. time relation for osmotic dehydration under vacuum and a constant temperature of 313K.

As seen from the graphs the weight loss in case of the vacuum osmotic dehydration is more as compared to the vacuum drying. In both cases it is observed that the weight of Aloe Vera slice decreases with time. The percent water removal in vacuum drying, 38.9%, is less as compared to the vacuum osmotic dehydration, 50.8%. This is primarily due to low driving force in case of vacuum drying as compared to vacuum osmotic dehydration.

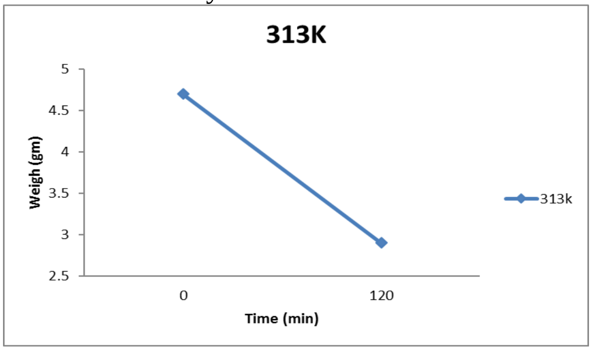

Figure 17.Effect of Vacuum Drying on the weight at constant temperature of 313K

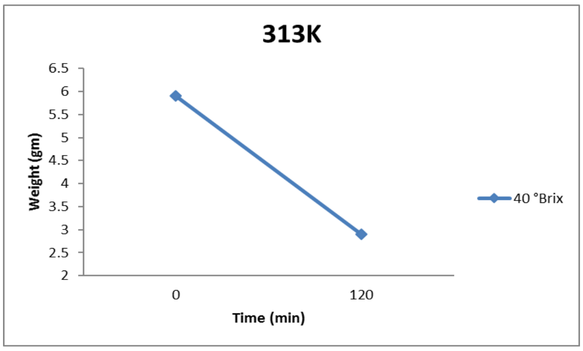

Figure 18.Effect of Vacuum Osmotic dehydration on the weight at constant temperature of 313K and 40 ^{0}Brix concentration

Table no. 1 Details of various techniques of drying and percentage weight reduction obtained

Sr.no	**Technique of drying**	**Temperature (K)**	**Sucrose solution concentration(^{0}BRIX)**	**Percentage weight reduction**
1	Osmotic dehydration	313	30	64.66
2	Convective drying	313	-	51.25
3	Vacuum osmotic dehydration	313	40	50.8
4	Vacuum drying	313	-	38.29
5	Oven drying	313	-	33.61

As seen from the table 1 the highest moisture removal is obtained in the osmotic dehydration of aloe vera slices at sucrose solution concentration of 30 ^{0}BRIX and temperature of 313K.
Table 1 shows the details of various techniques and percentage weight reduction obtained. It can be seen that osmotic dehydration is more effective as compared to conventional drying and vacuum drying technique.
Best conditions recorded for water removal are 30 ^{0}BRIX and 313K, with maximum weight reduction of 64.66%.

IV. DEVELOPING ARTIFICIAL NEURAL NETWORK (ANN) MODEL USING "ELITE"-ANN©":

The total data set generated in various experimental runs is divided into two parts. One part is called as training data set whereas the other one as test data set. The training of ANN is done by training data set and its effectiveness in estimation is judged by the test data set.
There are five input parameters, temperature, concentration of sugar solution, weights, coding and time and one output parameter, weight loss. The details of topology of ANN models developed using "elite-ANN" are given in table no.2.The typical schematic of the sample of ANN architecture used in this part is as shown in figure 19.
Figure no 20 shows the graph of comparison of actual and predicted values of weight loss for training data set whereas figure no 21 shows the same for test data set. As can be seen from graphs, these values are very close to each other indicating higher accuracy of ANN model developed for correlating these parameters in osmotic dehydration of Aloe Vera slices.

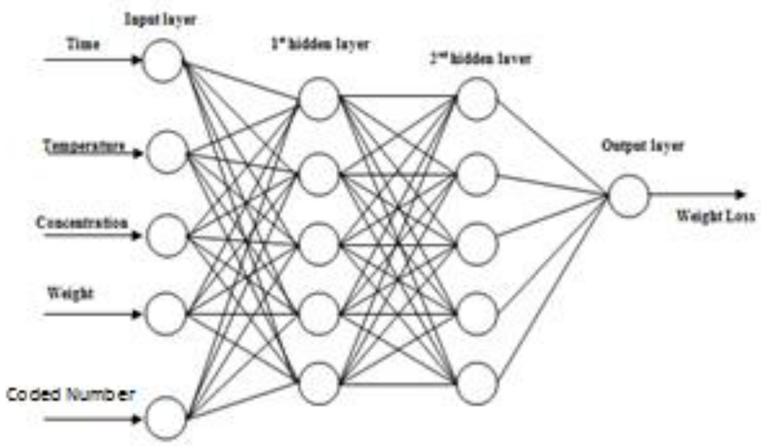

Figure 19.Artificial Neural Network Architecture

Table no. 2 Details of topology of ANN models developed

Model code	Number of Neurons					Date points	
	Input layer	1st hidden layer	2nd hidden layer	3rd hidden layer	Output layer	Training data set	Test data set
B_S	5	0	5	5	1	67	14
B_M	5	0	10	10	1	67	14
B_C	5	10	10	10	1	67	14
B_S: Model for Simple complexity; B_M: Model for Moderate complexity; B_C: Model for complex complexity; Input: Temperature, concentration, weights, coding and time; Output: Weight loss.							

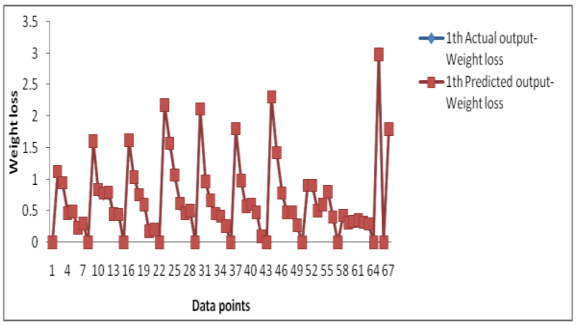

Figure 20.Comparison of actual and predicted values of weight loss for training data set using B_M ANN model

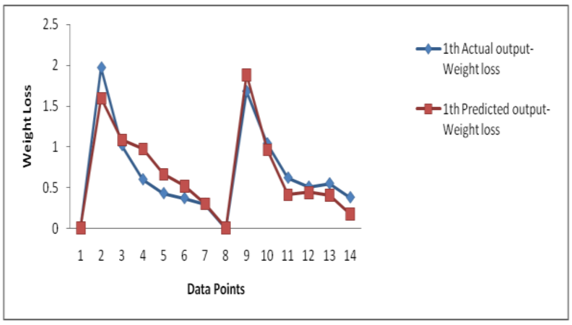

Figure 21. Comparison of actual and predicted values of weight loss for test data set using B_M ANN model

V. CONCLUSION

Osmotic dehydration of Aloe Vera slices in sucrose solution was carried out and based on the observations, results and discussion, it can be said that, aloe Vera can be partially dewatered (dehydrated) by osmotic dehydration in sucrose solution and percent weight loss is from 33 to 65% depending upon the operating parameters like sucrose solution concentration, solution temperature and time for osmosis.

The favored operating parameters were sucrose solution concentration of 30 ^{0}Brix, temperature of 313K and time duration of osmosis around 120 minutes. This resulted in the maximum weight loss of 64.66%.

Inference can be made that the large slices of aloe Vera can be dehydrated by osmotic dehydration as more effectively as the small slices could.

Comparisons between the conventional techniques and osmotic dehydration have been made. The technique of osmotic dehydration was found to be more efficient in water removal than other conventional techniques.

It can be inferred that the ANN model developed for correlating the parameters was showing high accuracy with an average percentage error of 0.711 which is highly acceptable.

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