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Osmotic Dehydration Process Optimization of Papaya

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Abstract: An investigation was carried out to study the effect of processing parameters on osmotic dehydration in sugar solution and liquid jaggery and to evaluate the quality of the osmotically dehydrated product after tray drying. A Box-Behnken design was used to optimize the level of concentration (50^0, 60^0, 70^0), temperature (35^0,40^0,45^0), solution to sample ratio (2, 3.5, 5) and agitation (0,100,200rpm). Optimization was done on the basis of overall acceptability. The samples were analyzed for drying characteristics, proximate analysis (moisture content, titratable acidity) and sensory evaluation. Investigations indicated that the lowest moisture content observed was at high levels of operating conditions (70^0 Brix, 45^0 C, ratio – 5 and agitation – 200 rpm) , while the highest was at low levels of parameters i.e. 50^0 Brix, 25^0 C, ratio – 2 and no agitation. The moisture content after the osmotic treatment was in the range between 51.81 and 70.38 % (w.b.) while the final moisture content after tray drying varied from 15.11 – 19.20 % (w.b.). It was also found that weight of the material was reduced by more than 50% using osmotic dehydration. The water loss was in range 27.43- 58.96%, based on initial solid content. On the basis of studies conducted using RSM, the optimum operating condition observed in case of osmotic dehydration process with sugar solution was 69.5 % concentration, 44.5 ^{0}C temperature, solution to sample ratio was 2 and agitation speed was 185 rpm while in liquid jaggery solution the optimum operating condition observed was 59.5 % concentration, 38 ^{0}C temperature, solution to sample ratio was 5 and agitation speed 185 rpm. The product osmotically dehydrated in sugar solution was found to be better than that when it was osmotically dehydrated in liquid jaggery as overall acceptability value of sugar solution was more than jaggery solution.
Keywords: Dehydration, Titratable Acidity, Sensory Evaluation, Box-Behnken Design

I. INTRODUCTION

Papaya (*Carica papaya*) is a tropical fruit having commercial importance because of its high nutritive and medicinal value. Papaya cultivation had its origin in South Mexico and Costa Rica. Total annual world production is estimated at 6 million tonnes of fruits. India leads the world in papaya production with an annual output of about 3 million tonnes. Other leading producers are Brazil, Mexico, Nigeria, Indonesia, China, Peru, Thailand and Philippines. Papaya is primarily used as a table fruit and to a limited extent for extraction of papain and pectin. The post harvest shelf life of ripe papaya is very short and it exhibits many difficulties in bulk handling and transport. Thus, there is a need to process the papayas and manufacture products using various preservation techniques such as drying, freezing, canning etc. Osmotic dehydration is one of the potential preservation methods for producing high quality product. This is a low temperature water removal process and hence there is a minimal thermal degradation of the nutrients. Other advantages of osmotic dehydration are more flavor retention, enzymatic and oxidative browning prevention, pretreatment for further processing (water removal load decreases), less freezing load, less energy consumption due to no phase change involved, better textural quality, increased shelf life, etc. However, there exists few disadvantages which should be taken care of. They are reduced characteristic taste due to reduction in acidity, surface coating by osmotic agent, etc. (Chaudhary et al. 1993). Osmotic dehydration process depends on no. of factors, namely, type and variety of fruits and vegetables, pretreatments, type and concentration of osmotic agent, process temperature, agitation/circulation of osmotic solution, solution to sample ratio, size and shape of the sample, time of treatment, etc. (Chaudhary et al. 1993). Drying is an energy intensive operation that easily accounts for up to 15% of all industrial energy usage, often resulting in relatively low thermal efficiency in the range of 25–50%. Thus, to reduce energy consumption per unit of product moisture, it is necessary to improve the energy efficiency of the drying equipment, reducing the processing time (Chua *et al*., 2001). Mazza (1983) reported some of major problems associated with air-dried products are high shrinkage, relatively poor rehydration characteristics, and possible unfavorable changes in color, texture, flavor, and nutritional value, which could be improved by adopting osmotic dehydration process.

Since osmotic dehydration generally will not give a product of low moisture content to be considered self stable, it has to be coupled with other methods of drying, viz., hot air drying, tray drying, freeze drying etc (Ponting, 1973). Rastogi and Raghavan, (1997) reported that up to a 50% reduction in the fresh weight of fruits or vegetables may be brought about by osmosis.

Little work has been reported on Papaya (Mehta and Tomar, 1980; Moy and Kuo, 1985; Levi et al., 1985; Chaudhary et al. 1993). Since no work has been reported on Pant-2 papaya, it was decided to study osmotic dehydration characteristics with the specific objectives to study the effect of osmotic agent concentration, temperature, solution to sample ratio and agitation on osmotic drying behavior.

II. MATERIAL AND METHODS

The experiments were conducted to characterize the osmotic dehydration of papaya (Carica, Papaya L.) with respect to drying behavior and the quality of dehydrated product. This was done by taking weight of sample at different time intervals and measuring quality attributes such as moisture content, acidity, and soluble solids of the material subjected to various process conditions. The materials used were papaya, sugar, liquid jaggary and chemicals. Pant Papaya-2 variety was selected for the experiments as it was commonly grown in Tarai region of Uttarakhand and Uttar Pradesh. The raw papayas were procured in sufficient quantity from the Horticultural Research Centre of the University. They were used after ripening at room temperature. The cane sugar was procured from the local market. A number of chemicals were used for proximate analysis.

A. Experimental Setups

A number of experimental setups were required in the study. The equipments used for experimental setups were incubator shaker, constant ovenand refractometer etc. They are listed in Table 3.1.

B. Experimental Design

Based on the literature review, the variables, namely, temperature, concentration of solution, solution to sample ratio and agitation were selected. The levels of the process variables are given in Table 3.2. Coding of the variables was done and is as follows.

$$X_1 = \frac{concentration-60}{10} \quad (3.1)$$

$$X_2 = \frac{Temperature-40}{5} \quad (3.2)$$

$$X_3 = \frac{Ratio-3.5}{1.5} \quad (3.3)$$

$$X_4 = \frac{Agitation-100}{100} \quad (3.4)$$

Box-Behnken was used to determine the number of experiments at three levels. The experiments were also carried out at centre point. Detailed experimental plan is given in Table 3.3. The number of experiments performed is 29. The blocking was done in order to avoid variation in sample lots. Sample and solution preparation

Table 2.1. List of equipment and their specifications

Sr. No.	Equipment	Specification
1	Electronic balance (Melter AE 166)	Capacity : 150 g Least count : 0.0001 g
2	Desiccator	Size : 20cmx20cmx12cm
3	Digital thermometer	Range : 55 - 150^0 C
4	Hand refractometers	Range : 0-32, 28-62 and 58-92 ^{0} Brix
5	Incubator shaker	Volt : 220 Amp : 5.6 Speed : 0 -500 RPM Thermostat : 0 -100^0 C
6	Ovens Hot air oven (Thermo statically Controlled)	Watt : 1200 Volt : 220 Temp. : 20 - 250^0 C Least count : 1^0 C
7	Tray dryer	Range : 50 - 250^0 C

Ripened papayas of uniform size, color and firm texture were sorted out for the experiments. They were washed, peeled with the help of a vegetable peeler and cut into two halves. Seeds along with supporting fibers were scraped off and the layer of the flesh from inside was also removed. The peeled and prepared segments were further cut into 2 x 2 x 0.5 cm pieces. Width and length were taken more than 3 times to that of thickness to ensure one dimensional mass transfer. Sugar syrups and liquid jaggery of various concentrations were prepared by weighing required amount of sugar and jaggery with the help of triple beam balance and dissolving it in to water.

Table 2.2. Process variables and their levels

Process variable	code	Coded level		
		-1	0	+1
Concentration (^{0}brix)	X_1	50	60	70
Temperature (^{0}c)	X_2	35	40	45
Solution to sample ratio	X_3	2	3.5	5
Agitation, (rpm)	X_4	0	100	200

Table 2.3. Detailed experimental plan

Std Run	Concentration,X_1	Temperature, X_2	Solution to sample ratio,X_3	Agitation,X_4
1	-1	-1	0	0
2	1	-1	0	0
3	-1	1	0	0
4	1	1	0	0
5	0	0	-1	-1
6	0	0	1	-1
7	0	0	-1	1
8	0	0	1	1
9	-1	0	0	-1
10	1	0	0	-1
11	-1	0	0	1
12	1	0	0	1
13	0	-1	-1	0
14	0	1	-1	0
15	0	-1	1	0
16	0	1	1	0
17	-1	0	-1	0
18	1	0	-1	0
19	-1	0	1	0
20	1	0	1	0
21	0	-1	0	-1
22	0	1	0	-1
23	0	-1	0	1
24	0	1	0	1
25	0	0	0	0
26	0	0	0	0
27	0	0	0	0
28	0	0	0	0
29	0	0	0	0

C. Pretreatment

The sulphur dioxide treatment was given prior to the osmotic dehydration as it helps to prevent browning and preserve the original color. For this, the sulphur dioxide (SO_2) evolved during a chemical reaction was passed into the sugar solution to make SO_2 concentration to 1000 ppm in solution.

The SO_2 was obtained from the chemical reaction between sodium metabisulphite and concentrated sulphuric acid which is given below:

$Na_2S_2O_5 + H_2SO_4 = H_2O + Na_2SO_4 + 2SO_2$… (3.5)

D. Experimental Procedure

The papaya pieces were first subjected to osmotic dehydration and then to tray drying. The detailed procedure is given below:

E. Osmotic Dehydration

About 15 papaya pieces were weighed on a digital balance and placed in a beaker containing sugar solution with required concentration and solution to sample ratio. The beaker was either kept in constant temperature water bath or incubator shaker depending upon the level of process variable agitation. The initial weight and volume of solution as well as that of pieces were measured. The concentration and temperature of the solution were determined with hand refractometer and digital thermometer, respectively.

The sample was removed from the beaker after every 15 minutes and was washed in running tap water. It was then wiped with blotting paper immediately for surface moisture removal and weighed. The concentration and temperature of the solution were also measured at the same time.

The osmosis was carried out until relatively the constant weight was achieved. After that the sample pieces were washed in running tap water and blotted with the help of blotting paper. They were used immediately for tray drying.

F. Tray Drying

The osmotically dehydrated pieces were placed in glass dishes and the dishes were put in a tray dryer. The temperature was maintained at $6O^{O}$ C. The change in weight of pieces and the temperature was measured at 30 minutes interval. The drying was carried out till the constant weight was achieved.

The dried pieces were packed in polothylene bags and were stored at room temperature until quality evaluations were carried out.

G. Proximate Analysis

The proximate analysis of the sample was carried out for various parameters. The procedures followed are as follows-

H. Moisture Content

The initial and final moisture content after osmotic dehydration as well as vacuum drying was determined by oven drying method reported by Ranganna (1977) for fruit and vegetable products. A brief description of the method follows:

1) Two-three slices were kept in a tared moisture dish in duplicate. Tare weights were subtracted and weight of the sample recorded as w_1.
2) Dishes were uncovered and placed with covers beneath in a hot air oven at atmospheric pressure. The temperature maintained was 70^{O} C ± 1^{O} C.
3) The duration of drying is usually 18 hours.
4) After drying the covers were replaced and the sample was cooled in a desiccator to a room temperature. The sample with Petridish was weighed soon after they cooled to room temperature and weight of sample was recorded as w_2.

   The moisture content of the sample was calculated by using the equation:

$$\%\, moisture\ content\ = \frac{W_{1-}W_2}{W_1}\ x\ 100 \quad \ldots (3.2)$$

where,

w_1 = weight of original sample, g

w_2 =weight of sample after drying, g.

I. *Titratable Acidity*

The titratable acidity of papaya pieces before and after drying was determined by AOAC method. The procedure was as follows:

1) 10 g sample was taken and diluted to 250ml with distilled water. Out of this, 100 ml solution was taken in the beaker.
2) 0.3 ml phenolphthalein indicator was added.
3) The solution was titrated with 0.1 N sodium hydroxide (NaOH) till pink color persisting 30 seconds was appeared.
4) The titrable acidity was reported as ml o.1 N alkali/100 g of original material.

J. *Sensory Evaluation*

Dehydrated Papaya should have a typical taste, flavor, color and texture. To taste these organolaptic characteristics, sensory evaluation was carried out with the help of a taste panel consisting of 10 panelists having different eating habits. The sensory evaluation was done on the basis of a 9-point Hedonic scale defined as follows:

Grade	**Score**
Like extremely	9
Like very much	8
Like moderately	7
Like slightly	6
Neither like nor dislike	5
Dislike slightly	4
Dislike moderately	3
Dislike very much	2
Dislike extremely	1

The sensory evaluation was carried out for color, texture, flavor and overall acceptance. A sample of dehydrated Papaya was served for the evaluation of above parameters to ten panelists at a time. The score sheets were provided with the product and panelists were requested to mark the product according to their liking, then the average scores of all the panelists were computed for different characters. One sample was evaluated in a day.

K. *Data Analysis*

The data were analyzed for moisture loss per unit solid after 1,2 and 2.5 h. Drying rate was calculated based on moisture loss. Second order model was fitted in sensory analysis and titratable acidity. Optimization was carried out based on overall acceptability and titratable acidity. Design expert 8.06 trial version statistical software was used.

III. RESULTS AND DISCUSSION

Designed experiments were conducted to study the effect of various parameters on osmotic dehydration and tray drying of osmotic papaya. The parameters namely concentration (50,60 and 70^0 Brix), temperature(35,40 and 45^0C), solution to sample ratio(2,3.5 and 5) and agitation(0,100 and 200 rpm) were considered during osmotic dehydration of papaya in sugar solution and liquid jaggery. Further, drying of osmossed papaya was carried out in tray drying at 60^0C and sensory evaluation of the end product was done by semi-trained panel using hedonic scale. The results are given below.

A. *Drying Characteristics*

Moisture was removed during two stage drying – osmotic dehydration and tray drying. The moisture content of fresh and dehydrated samples is important in characterizing the drying. Initial and final moisture content along with weights of sample are given in Appendix I. It shows that the initial moisture content of papaya varied from 90.70 – 93.90% (w.b.) with an average of 92.03%. The moisture content after the osmotic treatment was in the range between 51.81 and 70.38% (w.b.). The lowest moisture content observed was at high levels of operating conditions (70^0 Brix, 45^0 C, ratio – 5 and agitation – 200 rpm) , while the highest was at low levels of parameters i.e. 50^0 Brix, 25^0 C, ratio – 2 and no agitation. The final moisture content after tray drying varied from 15.11 – 19.20% (w.b.). These values were observed for the samples treated osmotically at high levels and low levels of parameters, respectively.

The water loss was based on initial solid content at various time intervals and is given in Table 4.1. The minimum loss was reported to be 27.43% while maximum was 58.96%. This was observed at all low and high levels of parameters, respectively.

In the case of sugar solution, the minimum water loss was 4.42% and maximum was 56.51% during first hour over the entire experimental range. During second hour the minimum water loss was 16.57 % and maximum 75.40% and after two and half hour, it was 19.73% and maximum 76.55% respectively. In liquid jaggery, the minimum and maximum water loss was 4.66% and 37.03% during first hour was 9.59% and maximum 47.93% during second hour and 11.17% and 62.54% after the end of experiments respectively. It can be concluded that the loss of moisture from papaya in liquid jaggery is less as compared to that of in sugar solution. This may be attributed to various soluble substances that are present in jaggery which might have hindered the removal of moisture from papaya into the liquid jaggery. In case of sugar solution, single sucrose component is present. Osmotic pressure of different soluble solids is different from one another. Therefore, even if concentration of soluble solids (°Brix) is same, their potential for water removal is different and hence it is more in case of sugar as compared to liquid jaggery.

Table 3.1 Moisture loss kg per kg weight of solids (%) during osmotic dehydration

Expt. no.	Water loss (dry basis) in					
	sugar solution after			liquid jaggery after		
	1 h	2 h	2.5 h	1 h	2 h	2.5 h
1	20.04	24.00	24.55	33.53	44.01	49.90
2	22.61	30.52	31.23	37.03**	40.97	46.06
3	19.64	26.92	28.89	36.83	43.38	48.96
4	28.10	37.33	39.79	25.69	30.59	34.47
5	11.08	20.51	20.75	5.66	9.59*	11.17*
6	11.56	20.47	20.67	19.52	29.23	33.60
7	17.75	32.81	33.12	9.34	28.75	29.98
8	5.22	16.57*	26.61	17.56	42.36	47.80
9	9.68	24.46	26.76	7.49	30.16	36.15
10	4.42*	37.63	38.23	8.36	28.29	32.22
11	11.07	26.55	33.68	11.68	28.94	32.60
12	6.67	19.20	20.16	12.14	23.49	27.29
13	9.18	22.56	22.97	11.2	27.52	32.53
14	56.51	63.30	64.40	14.26	24.27	27.35
15	8.61	26.57	27.28	5.68	20.11	26.40
16	22.45	27.25	28.24	8.82	13.92	16.02
17	21.30	25.76	26.14	21.44	27.52	31.82
18	37.06	45.13	45.75	18.27	29.61	33.27
19	16.55	29.26	29.96	24.43	40.65	46.99
20	14.83	19.19	19.73*	4.66*	12.52	14.80
21	16.43	32.42	33.56	18.99	42.79	62.54**
22	55.63**	75.40**	76.55**	12.57	32.16	36.62
23	33.72	46.37	47.21	18.50	42.52	47.64
24	15.44	26.41	27.24	32.85	47.93**	54.17
25	20.28	37.52	38.42	11.37	24.92	28.02
26	21.42	37.04	37.37	24.39	41.58	46.58
27	21.60	34.72	34.88	18.90	33.33	37.60
28	21.28	39.45	40.82	14.45	31.92	35.92
29	17.33	33.06	33.26	23.21	38.69	43.67

* minimum ** maximum

B. Moisture Ratio

Moisture ratio which is $\frac{M-M_e}{M_{o-M_e}}$ where M -moisture content at time t, M_0 - initial moisture content and M_e - moisture content at equilibrium point was calculated and is given in Appendix II. The same has been shown in Figs. 4.1-4.6 for osmotic dehydration in sugar solution and in Figs. 4.7-4.12 for liquid jaggery. It can be seen from the figures that moisture ratio reduced drastically initially and then decreased gradually. It is also observed that these curves sometimes cross each other suggesting that papaya cuboids might be having different texture from each other and due to different experimental conditions used in osmotic dehydration.

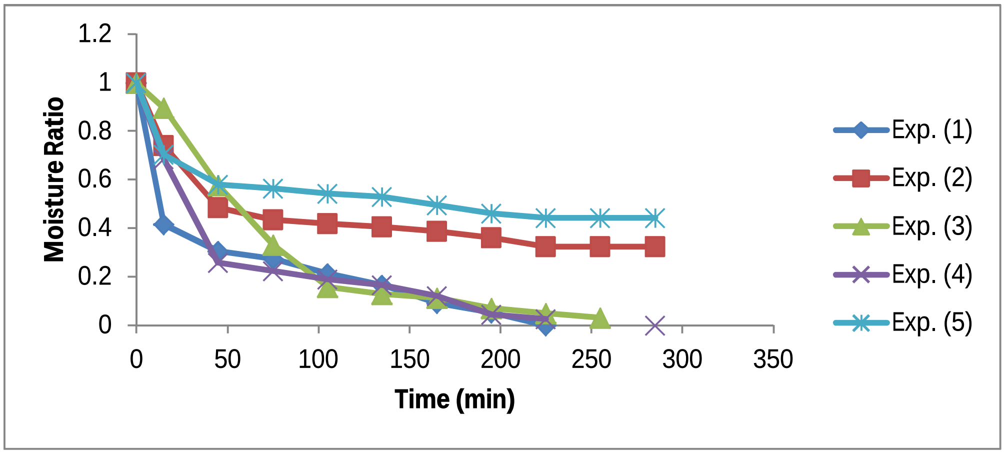

Fig 3.1 Variation of moisture ratio with drying time in sugar solution(Exp1-5)

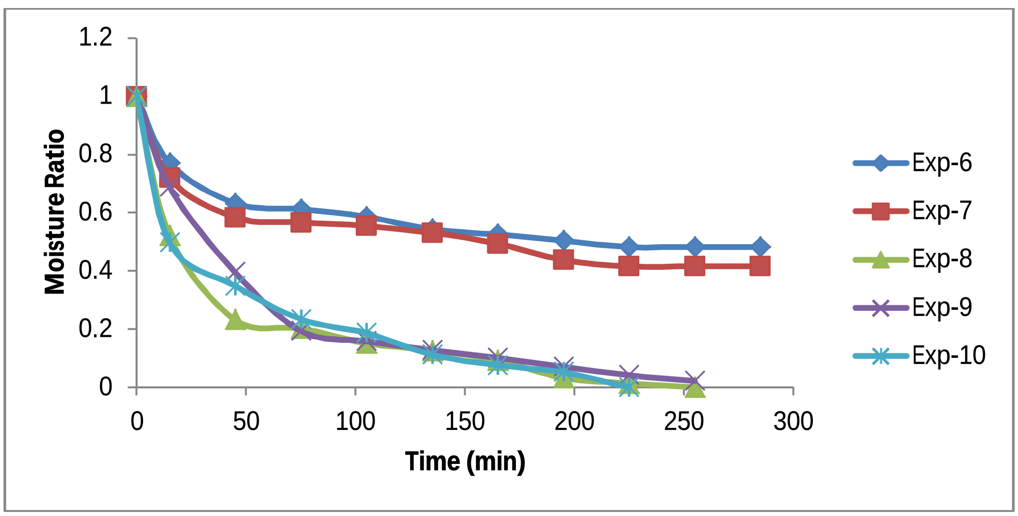

Fig. 3.2 Variation of moisture ratio with drying time in sugar solution(Exp6-10)

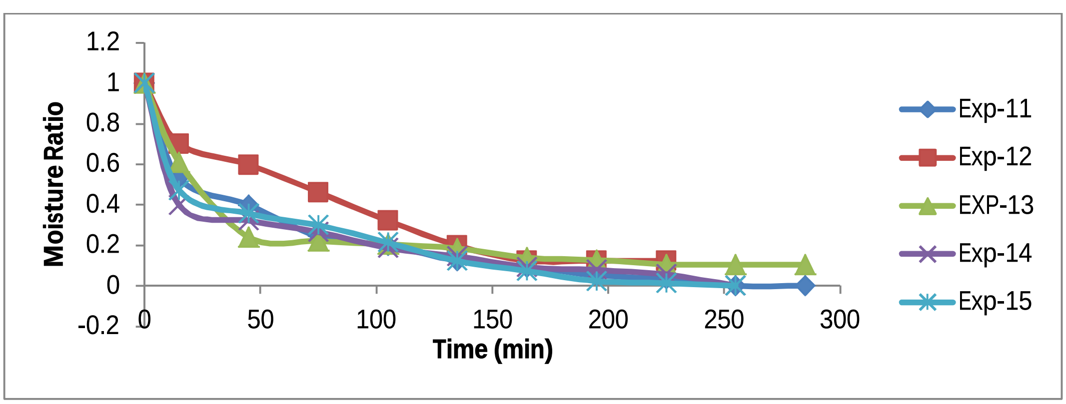

Fig 3.3 Variation of moisture ratio with drying time in sugar solution(Exp11-15)

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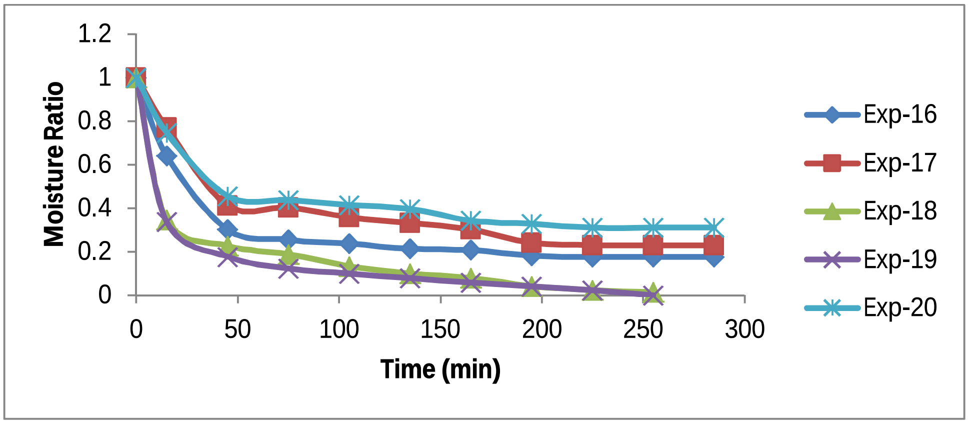

Fig3.4 Variation of moisture ratio with drying time in sugar solution(Exp16-20)

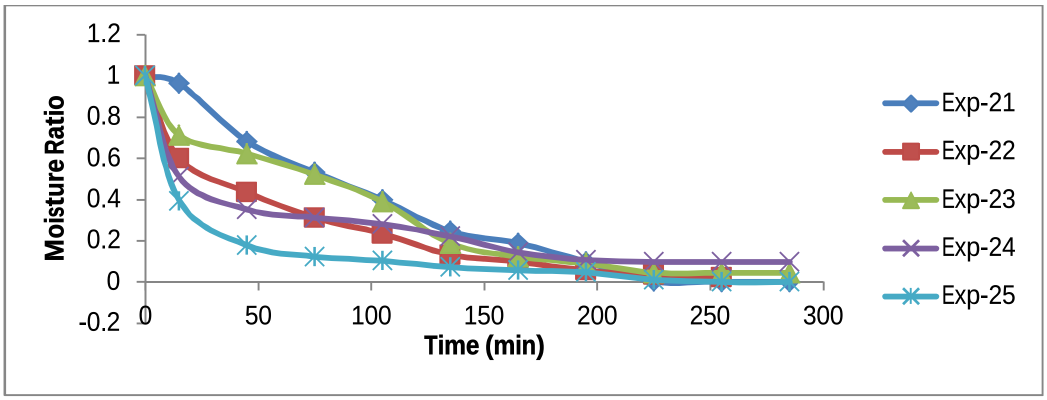

Fig. 3.5 Variation of moisture ratio with drying time in sugar solution (Exp21-25)

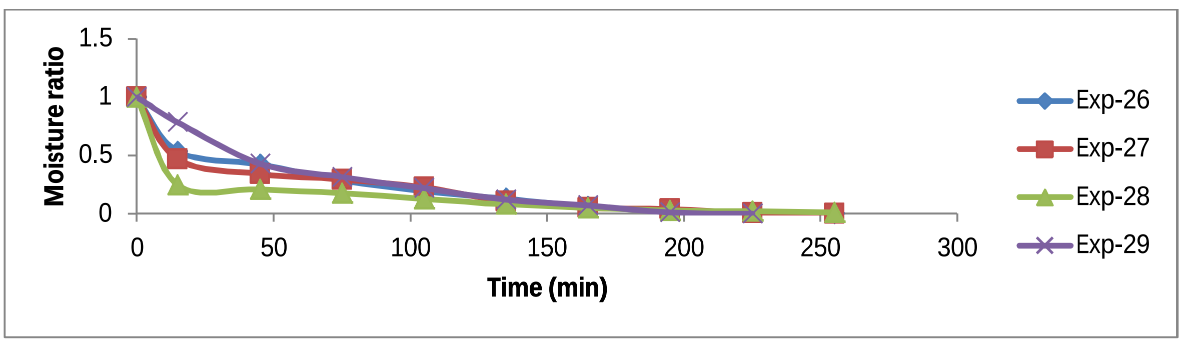

Fig. 3.6 Variation of moisture ratio with drying time in sugar solution(Exp26-29)

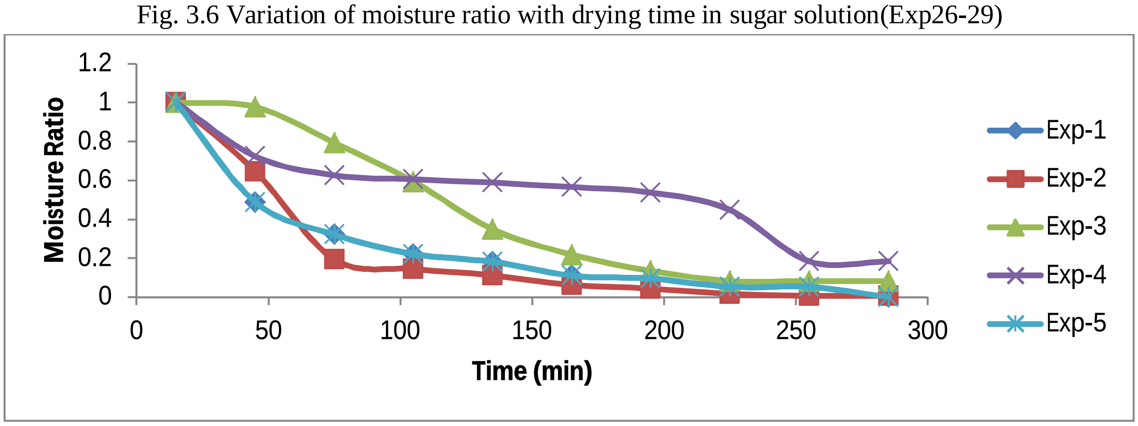

Fig. 3.7 Variation of moisture ratio with drying time in jaggery solution (Exp1-5)

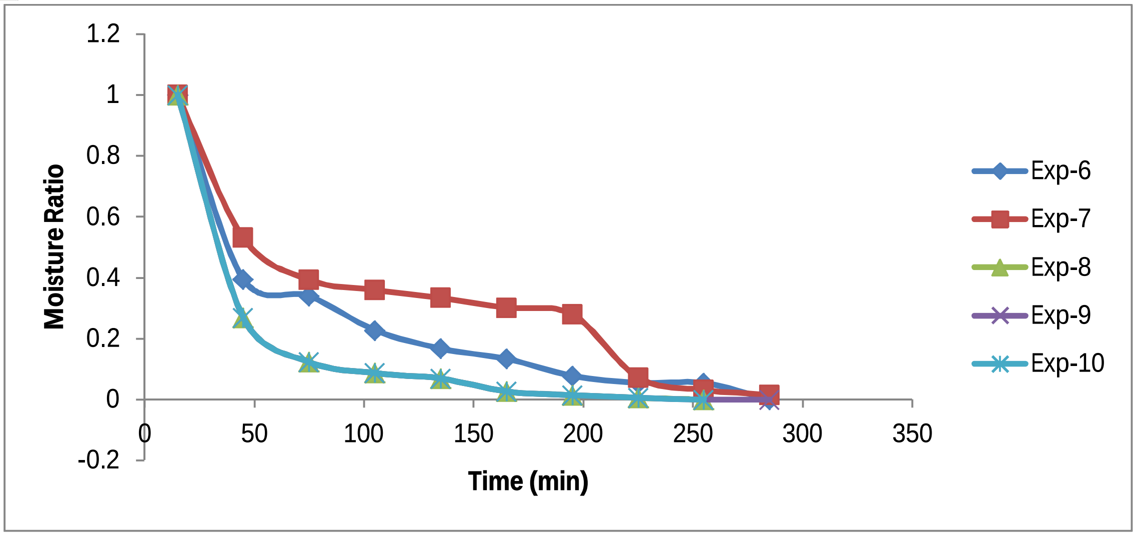

Fig 3.8 Variation of moisture ratio with drying time in jaggery solution(Exp6-10)

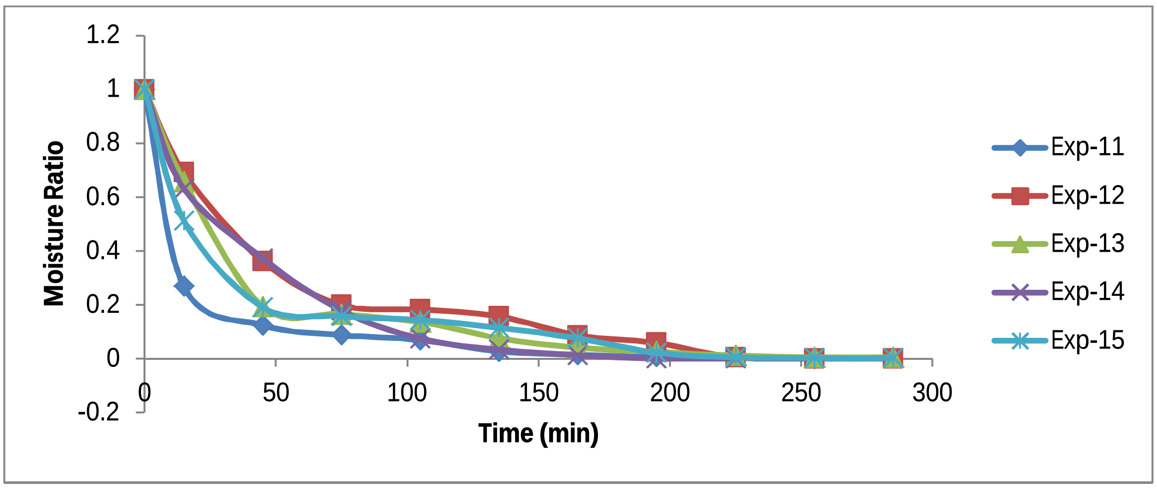

Fig 3.9 Variation of moisture ratio with drying time in jaggery solution(Exp11-15)

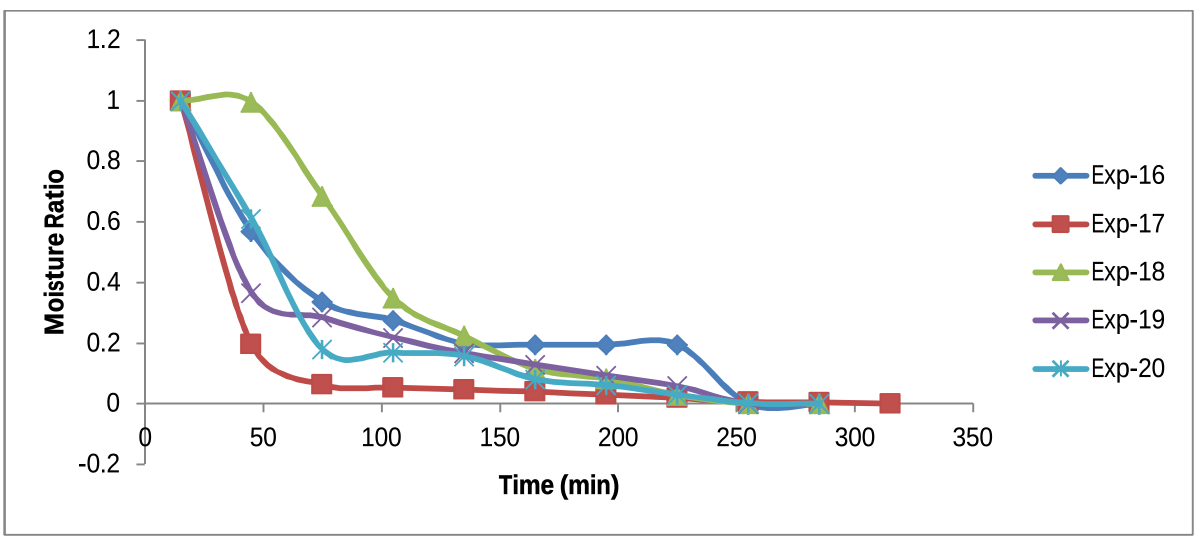

Fig. 3.10 Variation of moisture ratio with drying time in jaggery solution(Exp16-20)

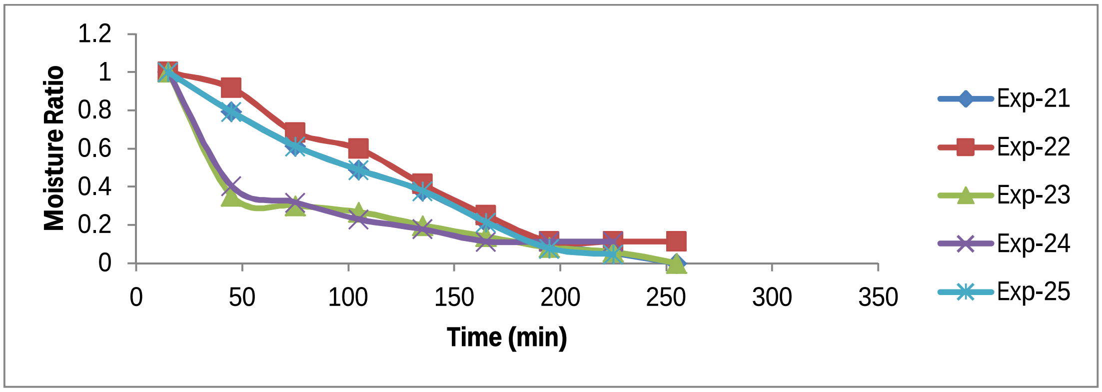

Fig 3.11 Variation of moisture ratio with drying time in jaggery solution(Exp21-25)

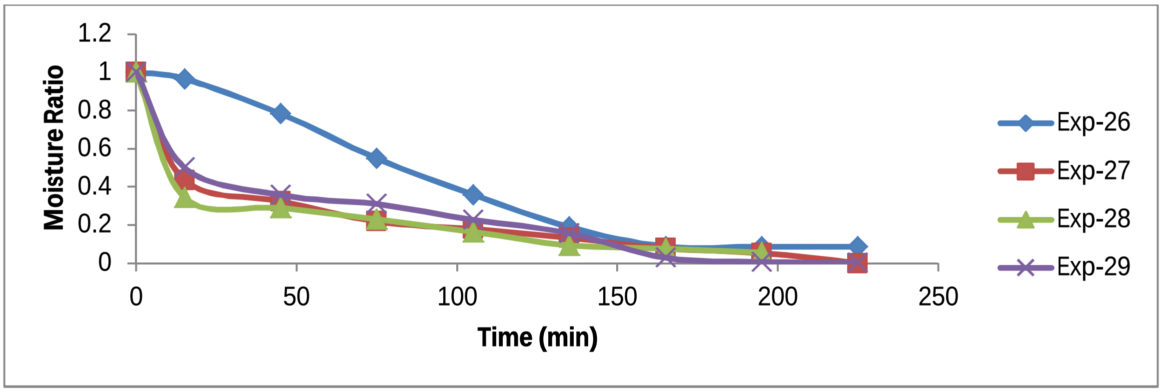

Fig 3.12 Variation of moisture ratio with drying time in jaggery solution(Exp26-29)

C. Drying Rate

Drying rate that is $\frac{d_m}{dt}$ was calculated and is shown in Figs. 4.13-4.18 and 4.19-4.24 for osmotic dehydration in sugar solution and liquid jaggery, respectively under various experimental conditions. Figs. 4.13 to 4.24 show that osmotic dehydration took place in falling rate period. No constant rate drying period was observed. It is generally assumed that the drying of high moisture food materials takes place in constant and falling drying rate periods. In the present osmotic dehydration process, constant rate drying might have taken during small time period. This could have been obtained by continuous recording of the sample weight. However, it becomes difficult to have continuous weighing of material in a solution.

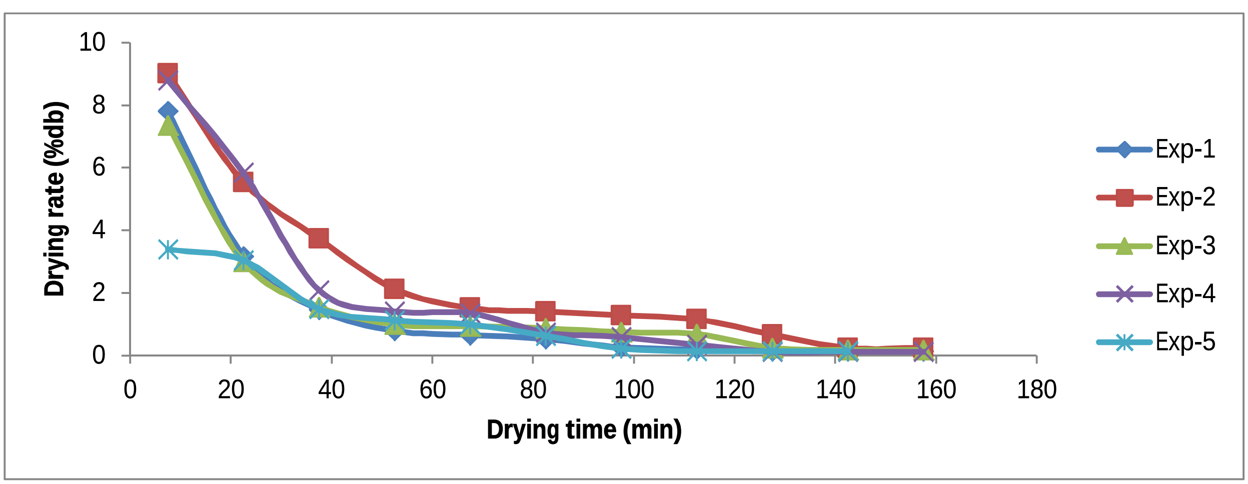

Fig. 3.13 Variation of drying rate with drying time in sugar solution (Exp 1-5)

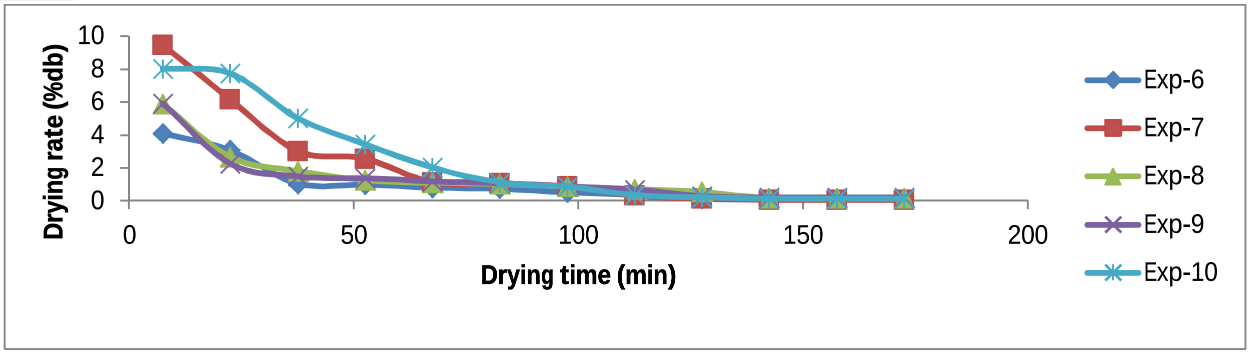

Fig 3.14 Variation of drying rate with drying time in sugar solution(Exp 5-10)

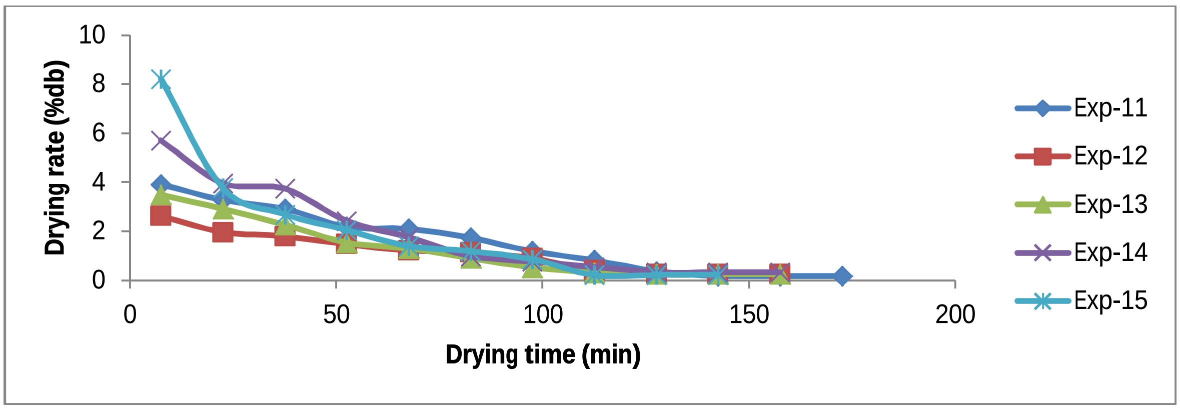

Fig. 3.15 Variation of drying rate with drying time in sugar solution(Exp11-15)

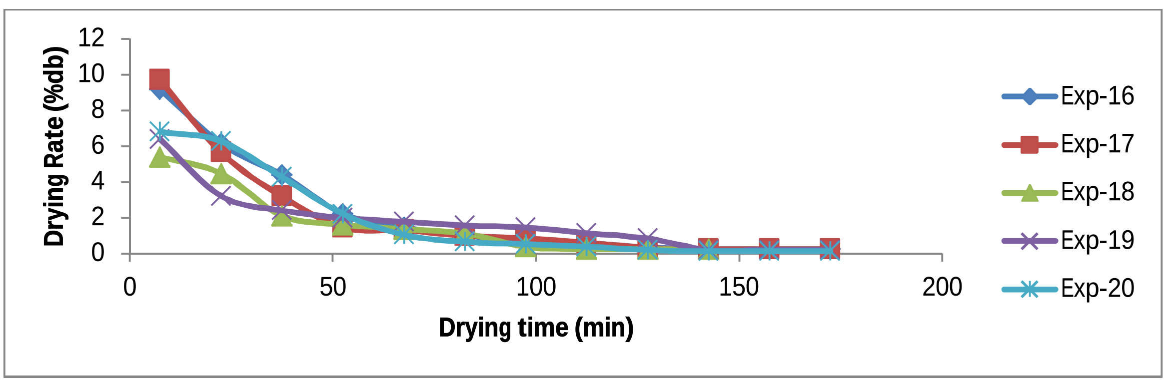

Fig. 3.16 Variation of drying rate with drying time in sugar solution(Exp16-20)

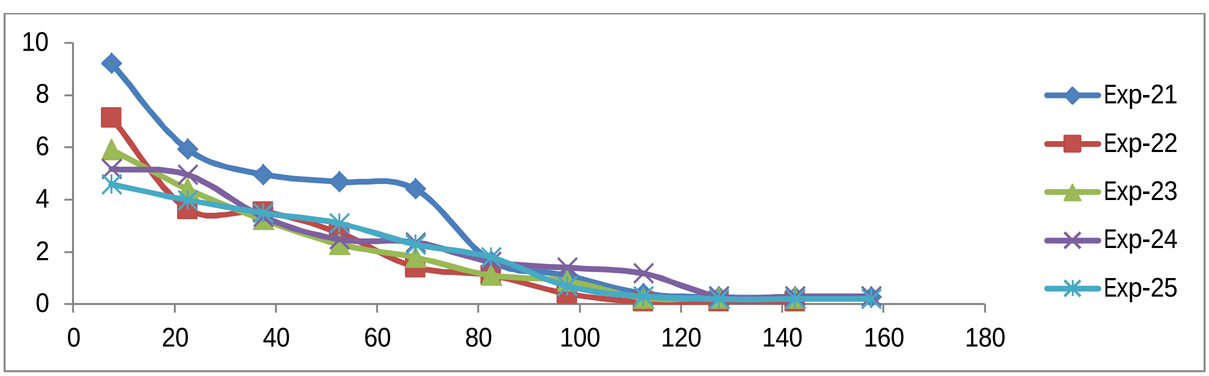

Fig 3.17 Variation of drying rate with drying time in sugar solution(Exp21-25)

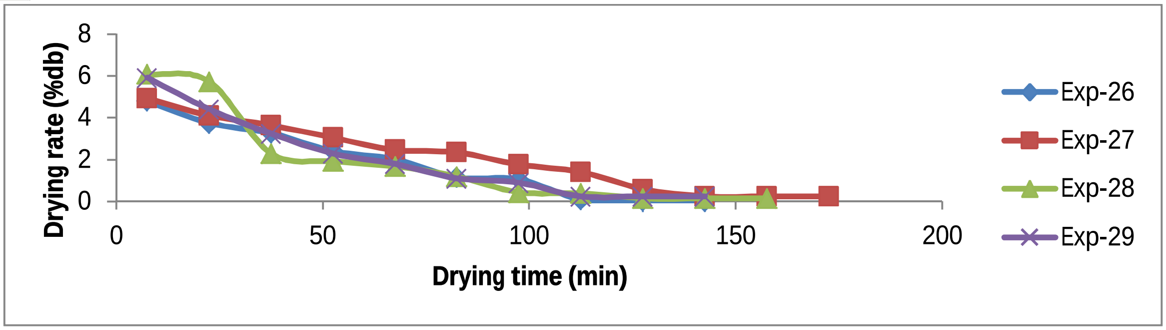

Fig 3.18 Variation of drying rate with drying time in sugar solution(Exp26-29)

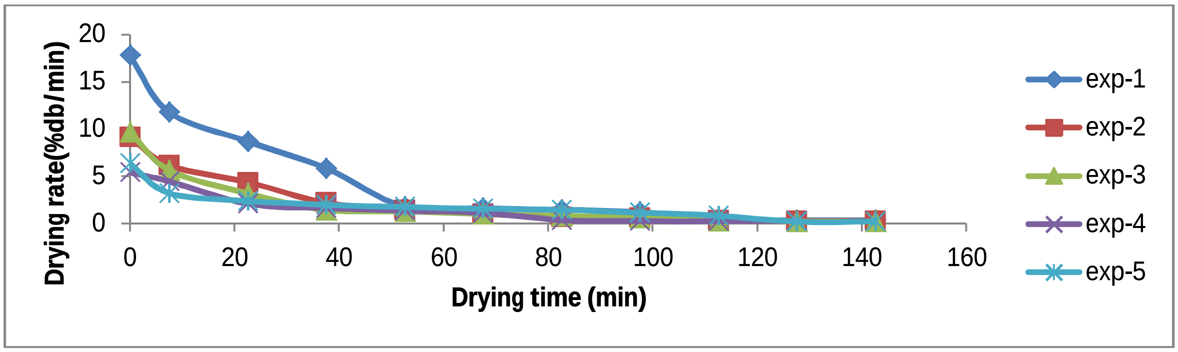

Fig 3.19 Variation of drying rate with drying time in jaggery solution(Exp1-5)

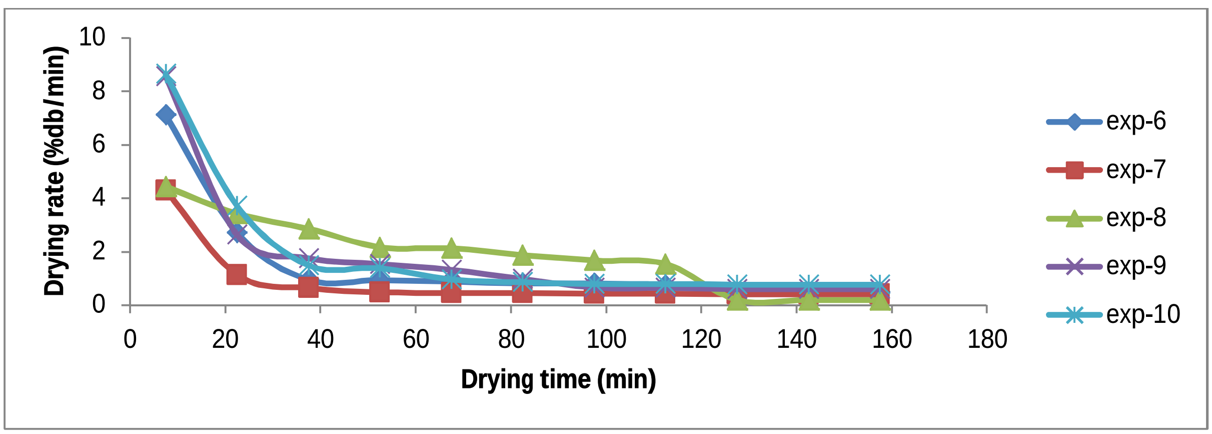

Fig. 3.20 Variation of drying rate with drying time in jaggery solution(Exp6-10)

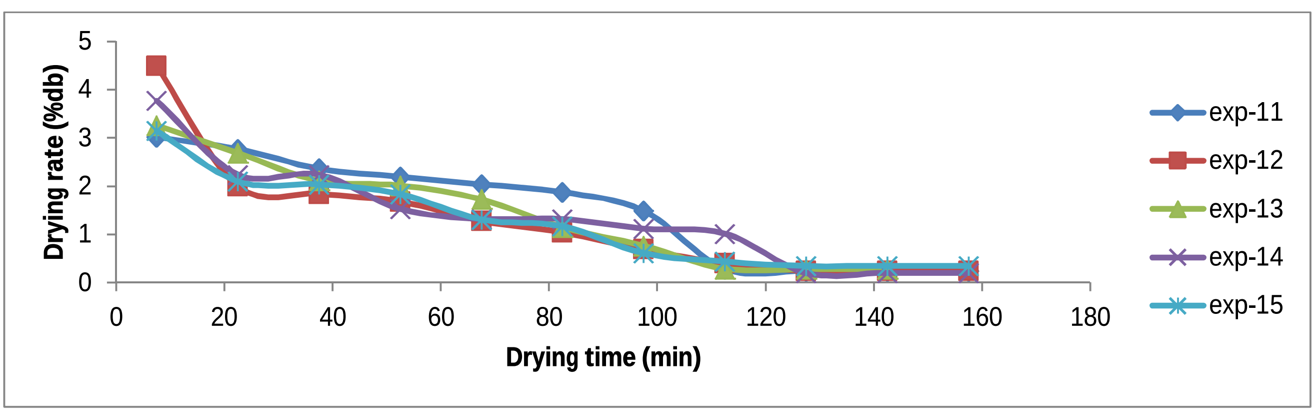

Fig. 3.21 Variation of drying rate with drying time in jaggery solution(Exp11-15)

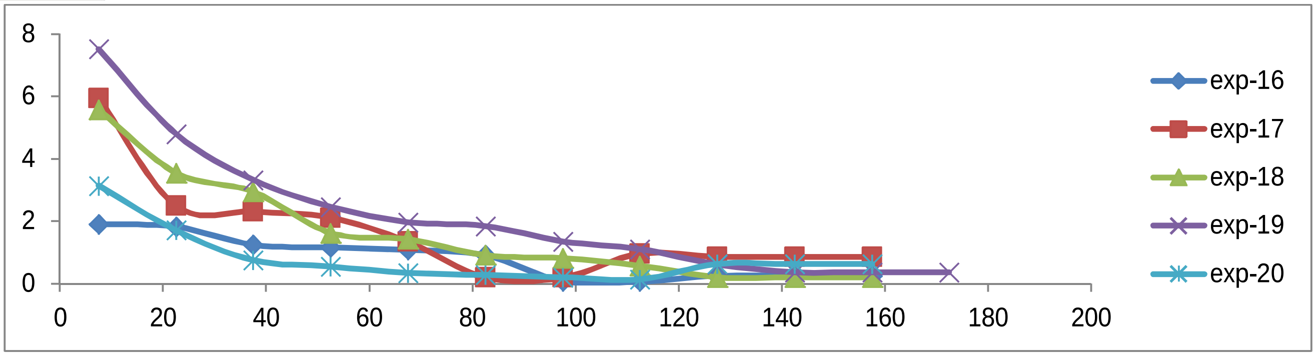

Fig 3.22 Variation of drying rate with drying time in jaggery solution(Exp16-20)

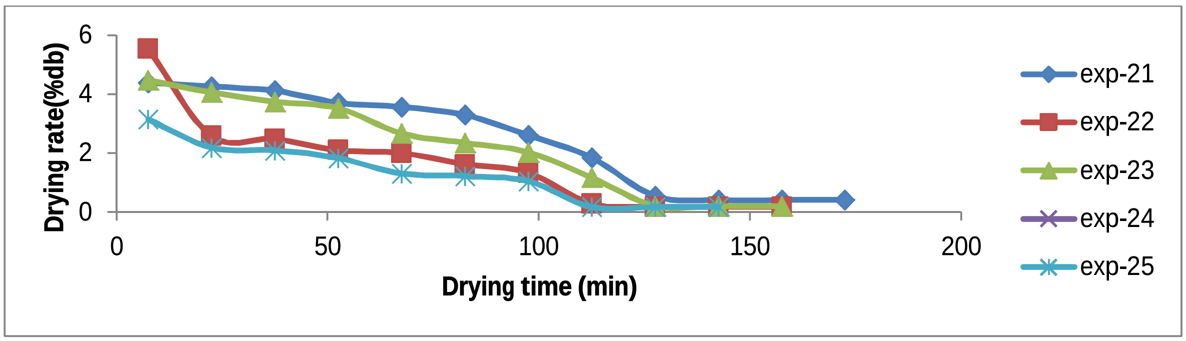

Fig 3.23 Variation of drying rate with drying time in jaggery solution(Exp21-25)

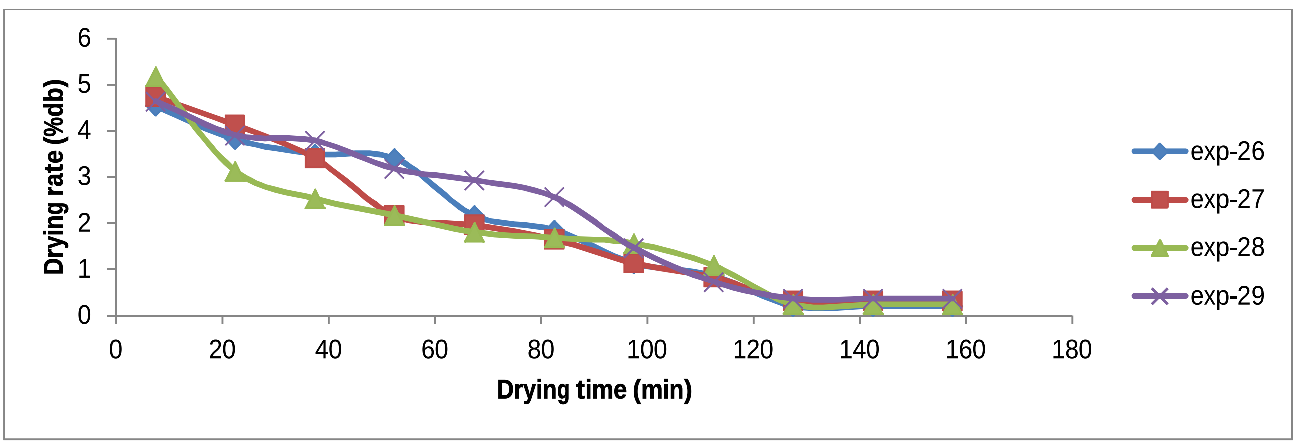

Fig 3.24 Variation of drying rate with drying time in jaggery solution(Exp26-29)

IV. SUMMARY AND CONCLUSIONS

Experiments were conducted to study the effect of processing parameters on osmotic dehydration of Pant-2 Papaya to evaluate the quality of the osmotically dehydrated product after tray drying. The independent parameters were concentration, temperature, solution to sample ratio and agitation. The concentration was 50^0-70^0 Brix and temperatures were 35^0 -and 45^O C. The solution to sample ratios was 2-5. Agitation (100-200 rpm) and no agitation were also used. The experiments were designed using Box-Behnken design for four variables, namely, concentration, temperature, solution to sample ratio and agitation at three levels each. Sugar solution and liquid jaggery were used for osmosis. Moisture loss and drying rate were determined. Osmotically dehydrated papaya was subjected to tray drying at 60^0C for 2.5 h. Sensory evaluation of the dehydrated papaya was done for colour, flavor, texture and overall acceptability. Acidity of papaya was also measured.

The optimization of the process parameter was carried out by using RSM (Response Surface Methodology) with fixing the goal as maximum overall acceptability of the product and processing parameters in their range. Design Expert 8.0.6 trial version was used for data analysis.

Results of the study indicated that the average initial moisture content of papaya was 92.0%. The moisture content after the osmotic treatment ranged between 51.81 and 90.38% (w.b.). The moisture loss during osmotic dehydration was 76.55% and 62.54% in the case of sugar solution and liquid jaggery respectively.
Osmotic dehydration took place in falling rate with two distinct falling rate periods. No constant rate period was observed. Second order mathematical model did not describe colour, flavor and texture score adequately. Acidity also could not be represented by the mathematical model well. Overall acceptability was predicted reasonably well and was used for optimization

From the drying characteristics and quality evaluation results, the following conclusions could be drawn.

1) Acceptable product can be produced using osmotic dehydration and tray drying.
2) Weight of the material could be reduced by more than 50% using osmotic dehydration.
3) Agitation had maximum effect on water loss.
4) Interaction of concentration with temperature, solution to sample ratio and agitation was significant.
5) Overall acceptability of the papaya osmotically dehydrated in sugar solution was better than the product osmotically dehydrated in liquid jaggery.
6) Optimization of osmotic dehydration process in sugar solution obtained the optimum operating conditions as 69.5 % concentration, 44.5 ^{0}C temperature, solution to sample ratio was 2 and agitation speed was 185 rpm.
7) Optimization of osmotic dehydration process in liquid jaggery solution resulted in the optimum operating conditions as 59.5 % concentration, 38 ^{0}C temperature, solution to sample ratio was 5 and 185 rpm was agitation speed.

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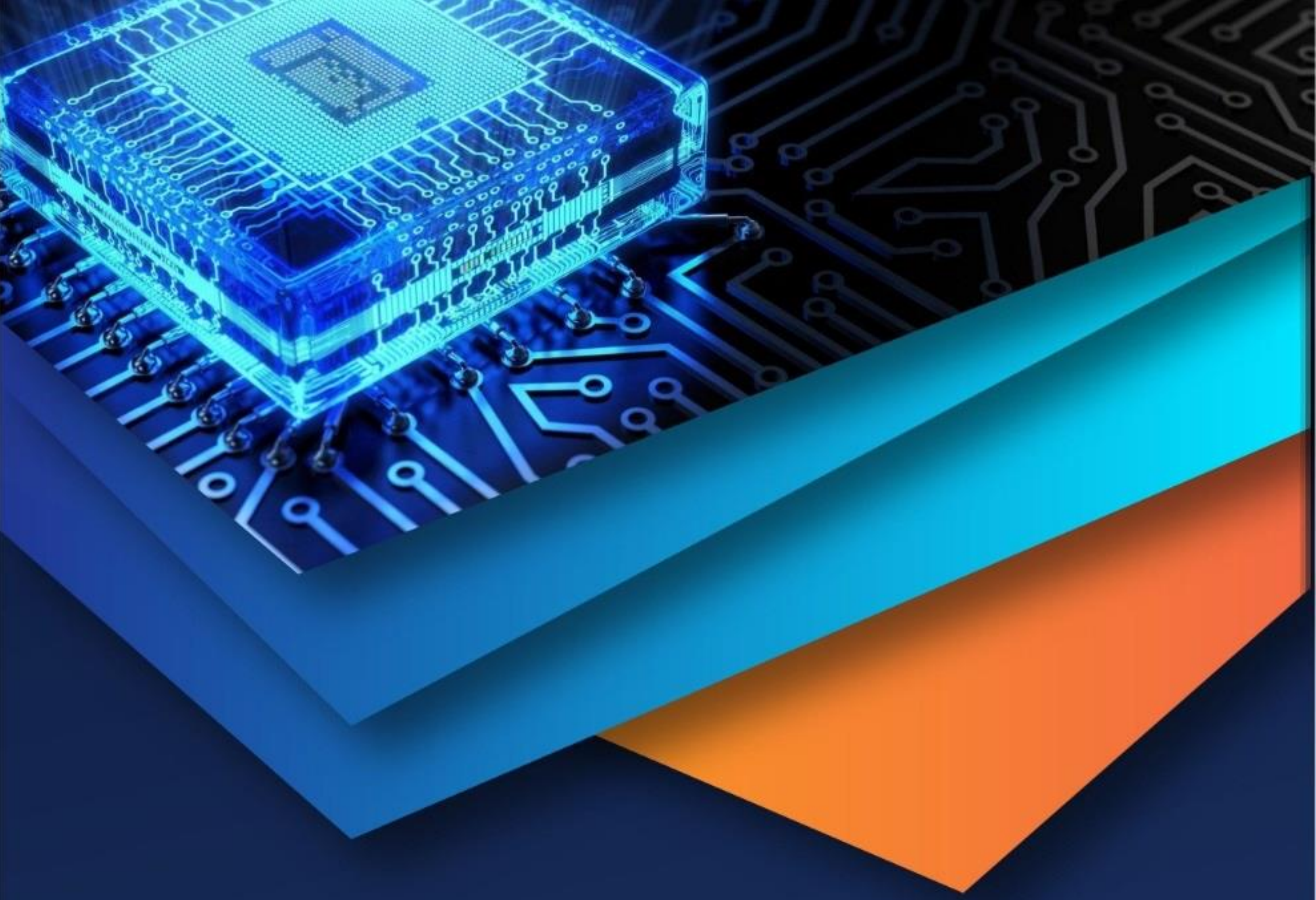

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