

## Thin Layer Drying Study on Foamed Mango Pulp

P.Rajkumar<sup>1\*</sup>, R.Kailappan<sup>1</sup>, R.Viswanathan<sup>1</sup>, K.Parvathi<sup>1</sup>,  
G.S.V.Raghavan<sup>2</sup> and V.Orsat<sup>2</sup>

<sup>1</sup> Department of Food and Agricultural Process Engineering,  
Agricultural Engineering College and Research Institute,

Tamil Nadu Agricultural University, Coimbatore- 641 003, India.

<sup>2</sup>Department of Bioresource Engineering, McGill University, H9X 3V9, Canada  
[prajtnau@yahoo.co.in](mailto:prajtnau@yahoo.co.in)

### ABSTRACT

A thin layer dryer was used to dry the foamed mango pulp. The mango pulp (Totapuri variety) was foamed by the addition of egg albumen at different concentrations such as 5, 10 and 15% and the foam was stabilized with the addition of methyl cellulose at 0.5% concentration. The foamed pulp was dried at three drying temperatures viz., 60, 65 and 70°C with three foam thicknesses viz., 1, 2 and 3 mm in the batch type thin layer dryer. The drying time required for foamed mango pulp was lower than non-foamed pulp at all selected temperatures. The drying rate constant ' $k$ ' value increased with decrease in pulp thickness during drying. Biochemical analysis results showed a significant reduction in ascorbic acid, total soluble solids and  $\beta$ -carotene in the mango flakes dried at higher temperatures when compared to the flakes dried at 60°C. Also these biochemical changes were significantly higher in 2 and 3 mm than in 1 mm thick foam dried mango flakes. There was no significant change in other biochemical constituents such as pH, acidity and total sugar due to the increase in drying temperature and foam thicknesses. The thin layer drying study on foamed mango pulp concluded that the mango pulp treated with egg albumen (10%) and methyl cellulose (0.5%), dried at 60°C with one mm foam thickness retained significantly higher biochemical contents ( $P \leq 0.05$ ) than that of other foaming and drying treatments.

**Key words:** Thin layer dryer, Totapuri mango pulp, foam mat drying, drying rate constant.

### 1. INTRODUCTION

The mango (*Mangifera indica* L.) is a popular fruit with people around the world and it is grown extensively in India. Still India is the largest producer, with an area of 1.23 million ha with an annual production of 10.99 million tonnes, which accounted for 57.18 per cent of the total world production (Negi, 2000). The fruit has excellent flavour, attractive colour, and delicious taste with high nutritional value. Due to higher moisture content (85 %); it has very poor keeping quality and cannot with stand any adverse climatic conditions during storage. This results in loss of 30 per cent of fruits every year (Thind, 2002). To overcome this post harvest losses and to increase the shelf life, the surplus mango has to be processed into shelf stable products like sterilized pulp or dried flakes and powders (Saxena and Arora, 1997; Srinivasan *et al.*, 2000) for consumption.

Foam mat drying is carried out for the liquid or semi solid food by making them into foam with the addition of food foaming and stabilizing agents. The foam thus formed can be spread into a thin mat / sheet and dried by using hot air. Then, the dehydrated product is conditioned and converted into powder. Generally, drying rates are comparatively higher in foamed pulps because of increased surface area at the liquid-gas interface thus allowing rapid drying through internal moisture movement within the pulp. The dehydrated powder / flakes is superior to drum dried and spray dried products because of its honey comb structure and better reconstitution properties (Morgan *et al.*, 1961; Hart, *et al.*, 1963; Berry *et al.*, 1965; Chandak and Chivate 1972; Labelle 1984; Srinivasan, 1996). Selected fruit pulps such as mango (Srivastava, 1998), star fruit (Karim and Wai, 1999), papaya (Kandasamy, 2001) and banana (Sankat and Castaigne, 2004) have been dried to produce flakes by using foam mat drying technique.

Mango powder is generally required for certain food products like ice cream, yoghurt, mango fruit bar, mango cereal flakes, mango cake and mango for their production. Therefore, there is a great need to develop a non-caking and soluble / readily mixing mango flakes / powder (Chattopadhyay, 1996). As the information on foam mat drying of mango pulp is very little, a research study was conducted to dry the foamed mango pulp in the thin layer dryer at different temperatures with different foam thickness to produce mango flakes with a view to optimize the process parameters. The optimized design data can be used for the design of a continuous type foam mat dryer.

## 2. MATERIALS AND METHODS

### 2.1 Foaming Experiments

For the experimental work, totapuri mangoes having uniform colour and maturity were selected. The percentage of peel, stone and pulp present in the mangoes were determined. Flesh portions of mango were pulped using a pulper with a capacity of 0.6 kg per minute (Kifco, India) for conducting foaming and drying studies. Biochemical analyses of the non-foamed mango pulp namely acidity, pH, total soluble solids, total sugars,  $\beta$ -carotene and ascorbic acid contents were carried out to evaluate their relative loss during foam mat drying. Foaming and stabilizing agents were used within the limits stipulated in the Prevention of Food Adulteration Act (1955) and also based on the preliminary foaming tests conducted. The food foaming and stabilizing agents such as egg albumen (5, 10 and 15%) with methyl cellulose (0.5%) were selected and used for the foaming experiment on wet pulp weight basis. The densities of the fresh and foamed pulps (5, 10 and 15%) were 1.01, 0.60, 0.52 and 0.51 kg/m<sup>3</sup> w.b. over 0.36 m<sup>2</sup> surface area of the drying tray. For foaming and stabilizing the mango pulp, egg albumen and methyl cellulose were incorporated subsequently during whipping.

### 2.2 Foaming Properties

Foaming properties such as foam expansion, foam stability and foam density were determined at different concentrations and based on the foaming properties, the optimum level was identified.

### 2.2.1 Foam expansion

Mango pulp with foaming agent was foamed by operating a foaming unit attached with whipper/foaming blades at 1400 rpm to get maximum foam expansion with minimum density as described by Durian (1995):

$$\text{Foam expansion} = \left[ \frac{V_1 - V_0}{V_0} \right] \times 100 \quad (1)$$

Where,

$V_1$  = Final volume of foamed mango pulp,  $\text{cm}^3$

$V_0$  = Initial volume of mango pulp,  $\text{cm}^3$

During the foaming study, all the experiments were replicated thrice and the mean values were recorded. The whipping speed, which gives maximum foam volume with minimum density and the corresponding foaming time, was optimized for further foaming and drying study.

### 2.2.2 Foam stability

Foam stability of mango pulp was determined by taking 100 ml of the foamed pulp in a transparent graduated beaker and kept at room temperature for 3 hours. The reduction in foam volume was measured as an index for the foam stability for every 30 minutes by using the following relationship (Akiokato *et al.*, 1983):

$$\text{Foam stability} = V_0 \frac{\Delta t}{\Delta V} \quad (2)$$

Where,

$\Delta V$  is the change in volume of foam occurred during the time interval  $\Delta t$  and  $V_0$  is the volume of the foam at zero time.

### 2.2.3 Foam density

The density of the foamed mango pulp was determined in terms of mass by volume and represented as  $\text{g/cm}^3$  (Falade *et al.*, 2003):

$$\text{Foam density} = \rho \frac{V_0}{V_1} \quad (3)$$

Where,

$\rho$  is the density of the pulp.

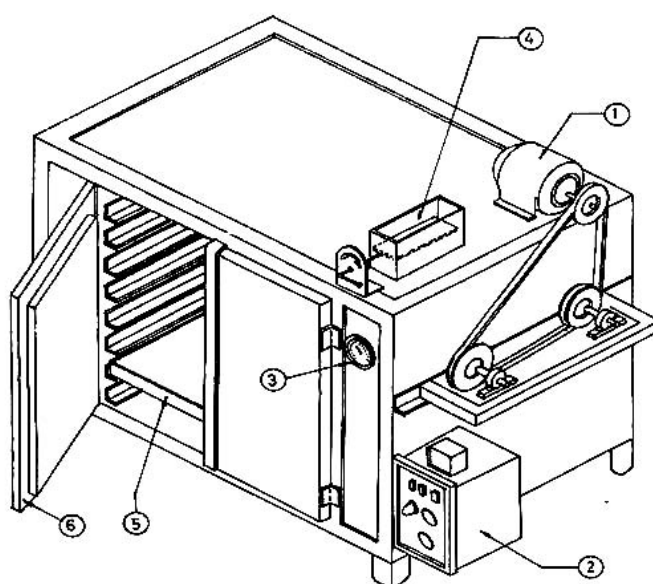
## 2.3 Colour Measurement

The colour of the non-foamed (control) and foamed mango pulps was measured by using color flex meter (Hunter lab, USA) at  $10^\circ$  observer and  $D_{65}$  illuminant. To measure the colour, the sample cup was filled with non-foamed and foamed mango pulps separately without any void space at the bottom. Then the deviation in colour of the samples to standard were observed and recorded in the computer interface in terms of L, a & b values. Here, luminance (L) forms the

vertical axis, which indicates whiteness to darkness. Chromatic portion of the solids is defined by a (+) redness and a (-) greenness, b (+) yellowness and b (-) blueness. Though all the 'L', 'a' and 'b' values were recorded, only the b (+) values, which represent the measure of yellowness of mango pulp and powder were considered for the study.

## 2.4 Foam Mat Drying

The thin layer batch type dryer (Kilburn, India) consists of heating coils, blower, drying chamber, air outlet openings and thermostat (Fig.1). The homogeneous foamed mango pulps were evenly spread on the food grade non-sticky Teflon lined trays of size (95 x 40 cm) at a foam thickness of 1, 2 and 3 mm. The foam thickness was arrived by multiplying the foam of known density (mass/volume) with drying area to get in terms of 'g/mm'. Similarly non-foamed mango pulps thickness were also arrived. The lined trays were then placed on the tray stand in position for drying. The temperature inside the drying chamber was measured by using thermometer. The foamed and non-foamed mango pulps were dried at different temperatures viz., 60, 65, and 70°C. At every 10 min interval, the trays were taken out of the drying chamber for mass loss determination. The drying was ceased when the mass of the samples recorded constant values. Thin layer dryer equations were used to calculate the drying rate constant (Liu and Bakker, 1999).



- |                          |                   |
|--------------------------|-------------------|
| 1. Motor                 | 4. Hot air outlet |
| 2. Control panel board   | 5. Drying tray    |
| 3. Temperature indicator | 6. Door           |

Figure 1. Schematic view of thin layer cabinet dryer

Drying rate constant 'k' was determined by using the relationship

$$\text{Moisture ratio (MR)} = \frac{M_{\theta} - M_e}{M_I - M_e} = ae^{-k\theta} \quad (4)$$

Where,

$M_{\theta}$	=	moisture content, dry basis (decimal) at $\theta$ time
$M_I$	=	initial moisture content, dry basis (decimal)
$M_e$	=	equilibrium moisture content, dry basis (decimal)
$a$	=	constant
$k$	=	drying rate constant ( $\text{min}^{-1}$ )
$\theta$	=	time, min

By linearising the equation (4)

$$\ln(\text{MR}) = \ln\left(\frac{M_{\theta} - M_e}{M_I - M_e}\right) = \ln a - k\theta \quad (5)$$

The drying rate constant 'k' ( $\text{min}^{-1}$ ) value was determined using the linearized equation (5) for each thickness of non-foam and foam dried mango flakes. Biochemical properties of mango flakes viz., acidity, pH, total soluble solids, total sugars,  $\beta$ -carotene and ascorbic acid were also determined by following standard procedures for the foam mat dried mango pulp after reconstituting the flakes to their original moisture content (Ranganna, 1979). The biochemical contents of the reconstituted, foam mat dried mango flakes with three replications were statistically analysed as factorial completely randomized block design (FCRD) using AGRES statistical package ( $P \leq 0.05$ ) and compared with non-foamed mango pulps to optimize the drying and foaming parameters.

### 3. RESULTS AND DISCUSSION

The physical property of the totapuri mango such as the percentage of peel, kernel and pulp recovery were found to be 13.7, 11.7 and 74.6%, respectively. Various biochemical contents of non-foamed mango pulps were determined as acidity (0.42), pH (4.37), total sugar (7.86%), total soluble solids (15.3°Brix),  $\beta$ -carotene (5960 $\mu\text{g}/100\text{g}$ ) and ascorbic acid (20.1 mg/100g). The results obtained on physical and biochemical properties are in comparison with the results reported by Chauhan *et al.* (1998) and Kansci *et al.* (2003).

#### 3.1 Foaming Properties of Totapuri Mango Pulp

##### 3.1.1 Foam expansion

The effect of whipping duration on foam expansion in mango pulp at different concentrations of egg albumen with 0.5% methyl cellulose is shown in the Table 1. From the table, it is seen that the percentage of foam expansion was increased with increase in the level of foaming concentrations. It is also observed from the table that all the treatments recorded increase in foam expansion up to 20 min of whipping operation and after that it became almost constant. Hence, it was decided to conduct the foaming study with whipping duration of 20 min.

Table.1. Effects of whipper duration on foam expansion (FE)

Foaming agent	Foaming Agent levels, %	FE after 5 min., %	FE after 10min., %	FE after 15min., %	FE after 20min., %	FE after 25min., %
Egg albumen with Methyl cellulose	5.0 + 0.5	10.1	25.8	55.3	70.5	70.9
	10.0 + 0.5	10.2	45.9	75.5	97.2	98.4
	15.0 + 0.5	5.7	40.9	78.0	101.2	102.2

Table.2. Characteristics of foamed mango pulp

Foaming agent	Concentration level, %	Wt. of non-foamed pulp, g	Vol. of non-foamed pulp, cm <sup>3</sup>	Bulk density of non-foamed pulp, g/cm <sup>3</sup>	Foam volume, cm <sup>3</sup>	Foam expansion, %	Foam density, g/cm <sup>3</sup>
Egg albumen with Methyl cellulose	5.0 + 0.5	263.8	258.6	1.02	440.9	70.5	0.60
	10.0 + 0.5	276.3	271.2	1.01	534.7	97.2	0.52
	15.0 + 0.5	288.6	284.2	1.01	571.8	101.2	0.51

The characteristics of foamed mango pulp is described in Table 2. From the table, it is seen that the density of mango pulp mix varied between 1.02 and 1.01 g/cm<sup>3</sup>. After whipping for 20 min, it lowered between the values of 0.60 and 0.51 g/cm<sup>3</sup> due to foam formation. The foaming study conducted using egg albumen with methyl cellulose (0.5%) recorded increase in foam expansion by 26.7 and 4.0 per cent, when the egg albumen addition was increased from 5 to 10, and 10 to 15 per cent, respectively. In the case of foam density, egg albumen with 10 and 15 per cent recorded 0.52 and 0.51 g/cm<sup>3</sup>, respectively. This increase in the egg albumen level from 10 to 15 per cent lowered the foam density only by 4.5 per cent. This might be due to the saturation point of egg albumen solubility under the given set of experimental conditions. Hart *et al.* (1967) stated that the foam density in the range of 0.2 - 0.6 g/cm<sup>3</sup> was highly suitable for foam mat drying. The present study also confirms the foam density within this range.

### 3.1.2 Foam stability

Foam stability studies were conducted by adding egg albumen to a level of 5, 10 and 15 per cent along with 0.5 per cent methyl cellulose for 3 h at room temperature and the result is shown in Fig.2. From the figure, it is seen that the foam stability was higher at higher level of egg albumen

with 0.5% methyl cellulose. However, the increase was higher when the level of addition of egg albumen was increased from 5 to 10 per cent and the increase was only 1%, when the egg albumen level was increased from 10 to 15 per cent. The increase in the egg albumen level from 10 to 15 %, increased the foam stability value from 97.1 to 98.2 % after 90 min and 96.4 to 97.6 % after 180 min of foam stability study period (Fig. 2). Hence, to reduce the addition of foaming agent and subsequently its cost of production, it was decided to add 10% of egg albumen with 0.5% of methyl cellulose for further foam mat drying studies. Similar result was reported by Patino *et al.* (1995) and Pernell *et al.* (2002) for egg albumen.

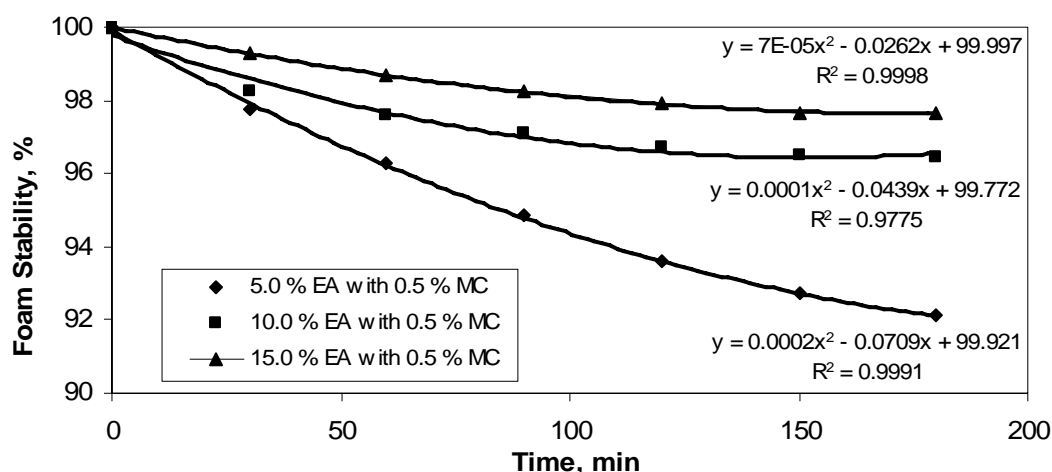


Figure 2. Foam stability of totapuri mango pulp treated with egg albumen (EA) and methyl cellulose (MC)

### 3.3 Colour values for the mango pulps

The colour values (L, a & b) of the non-foamed mango pulp was found to be 54.1, 15.4 and 60.4 and for the egg albumen (10%) with methyl cellulose (0.5%) treated foamed pulp; it was 59.4, 14.2 and 55.3, respectively. It is clear from the results that there was a little reduction in the colour of the pulp due to the incorporation of egg albumen and methyl cellulose as the 'b' value was decreased when compared to the non-foamed pulp. Similar study on colour values of dates Fadel *et al.* (2006) and quality of fruits by Irtwange (2006).

### 3.4 Drying characteristics of non-foamed and foamed mango pulp

Foam mat drying of foamed mango pulps was carried out using the optimized level such as egg albumen (10%) with methyl cellulose (0.5%) at three foam thicknesses *viz.*, 1, 2 and 3 mm and three drying temperatures of 60, 65 and 70°C in a batch type thin layer dryer. The biochemical contents of the foam mat dried mango flakes was determined and statistically analysed. The biochemical results of the foamed and non-foamed mango pulp dried at 60, 65 and 70°C are shown in Tables 3 and 4 for comparison.

From the biochemical analysis (Table 3), it was found that there was a significant reduction in total soluble solids (16.31 to 16.20 °Brix), β-carotene (3077 to 2907 μg/100g) and ascorbic acid (16.72 to 9.12 mg/100g) in the foam mat dried mango flakes due to heat sensitive nature of the

mango pulp during drying. Also, it was observed that the biochemical changes were comparatively higher in 2 and 3 mm thick foam dried at 65 and 70°C than in one mm thick foam dried at 60°C. But the variations in other biochemical contents such as acidity (0.39 to 0.43 %), pH (4.46 to 4.36), total sugar (7.87 to 7.98 %) were insignificant due to drying at higher temperatures with higher foam thickness.

Table 3. Biochemical composition of foam mat dried mango pulp

Biochemical compositions	60°C			65°C			70°C			CD(5%)
	Foam thickness			Foam thickness			Foam thickness			
	1 mm	2 mm	3 mm	1 mm	2 mm	3 mm	1 mm	2 mm	3 mm	
Acidity, %	0.40	0.39	0.39	0.42	0.43	0.43	0.42	0.41	0.41	0.05
pH	4.45	4.45	4.46	4.36	4.35	4.37	4.45	4.46	4.46	0.17
Total sugar, %	7.87	7.87	7.87	7.99	7.98	7.98	7.90	7.90	7.90	0.19
TSS, °Brix	16.45	16.35	16.31	16.45	16.31	16.25	16.30	16.20	16.20	1.02
β-Carotene, µg/100g	3077	3072	2987	3071	3067	2949	3062	2912	2855	9.31
Ascorbic acid, mg/100g	16.72	14.96	13.15	15.05	12.07	11.97	10.09	8.21	7.25	1.11

Table 4. Biochemical composition of control (non-foamed) dried mango pulp

Biochemical compositions	60°C			65°C			70°C			CD(5%)
	Pulp thickness			Pulp thickness			Pulp thickness			
	1 mm	2 mm	3 mm	1 mm	2 mm	3 mm	1 mm	2 mm	3 mm	
Acidity, %	0.41	0.41	0.40	0.39	0.41	0.41	0.40	0.40	0.39	0.03
pH	4.40	4.41	4.41	4.42	4.40	4.41	4.42	4.42	4.43	0.06
Total sugar, %	7.86	7.84	7.84	7.85	7.84	7.84	7.87	7.88	7.88	0.07
TSS, °Brix	15.17	15.1	15.0	15.15	15.10	15.10	14.45	12.1	11.1	1.61
β-Carotene, µg/100g	3115	3100	2905	3050	3055	2795	2925	2705	2603	10.0
Ascorbic acid, mg/100g	14.16	12.2	9.27	11.18	10.45	7.11	7.61	4.15	3.92	2.33

The results of the non-foamed pulp (control) showed that there was a highly significant reduction in the biochemical contents during drying due to high viscous nature with longer drying time (Table 4). Between the foamed and non-foamed mango pulp drying studies, it is observed that the biochemical changes were significantly lower in foamed mango pulps due to shorter drying times at all selected temperatures. Similar biochemical changes were reported by Srivastava, (1998) for mango and Kandasami, (2001) for papaya.



Based on the statistical analysis of foam mat dried totapuri mango flakes, it was found that one mm thick foam mat dried flakes at 60°C, retained significantly higher amount of biochemical / nutritional qualities than the other treatments.

### 3.4.1 Effect of thickness on drying of foamed and non-foamed mango pulp

The effect of foam thickness on the moisture content of foamed mango pulp during drying at 60°C is shown in Fig.3. From the figure, it is observed that the time taken for drying of foamed mango pulp from 451 to 5.3 per cent moisture content (d.b.) was 40, 60 and 80 min for 1, 2 and 3 mm foam thicknesses, respectively. While the time taken for drying of non-foamed mango pulp from 448 to 6.4 ± 0.2 per cent moisture content (d.b.) was 100, 130 and 190 min for 1, 2 and 3 mm thick pulp, respectively (Fig.4).

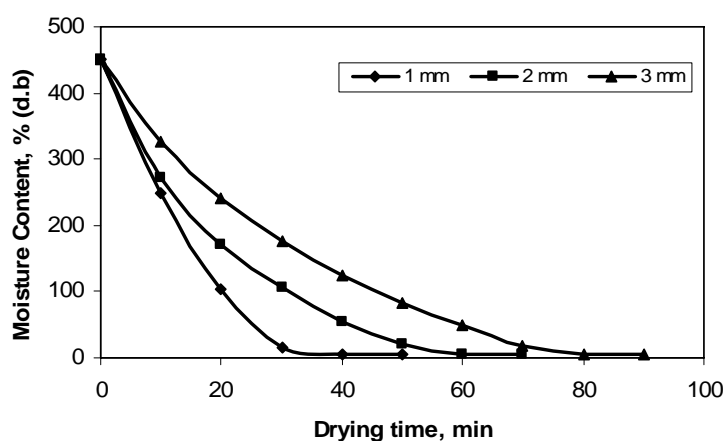


Figure 3. Relationship between moisture content and drying time of foamed pulp

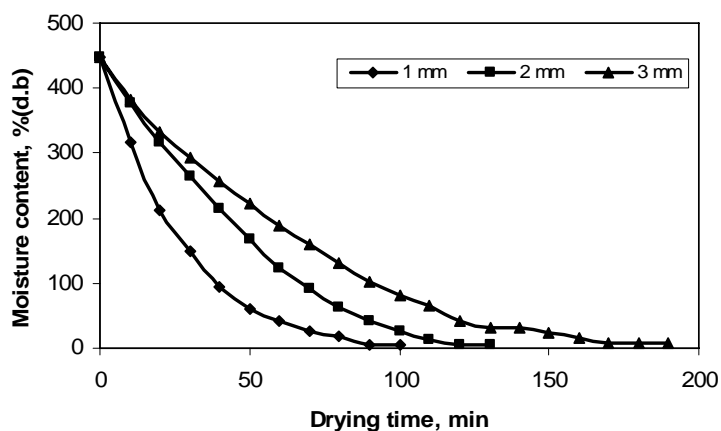


Figure 4. Relationship between moisture content and drying time of non-foamed pulp

The drying curves clearly indicated that the mango pulps dried with lower foam thickness dried at a faster rate as compared to the foamed mango pulps dried with higher foam thickness. This might be due to the complete exposure of mango pulps at lower foam thickness to the drying air. Rao *et al.* (1986) reported that the egg albumen took 10 min for drying at 60°C. The data in the present study also indicates faster drying of mango pulp in the presence of egg albumen thus portraying some similarity with the previous findings. It is also noted that the reduction in the moisture content of non-foamed mango pulp at any point of time during drying was lower when compared to the foamed mango pulps at all thicknesses studied. This might be due to high viscosity and bulk density of non-foamed pulp with less exposed surface area during drying. This result is similar to the drying data reported by Prakash *et al.*, (2004) for carrot.

### 3.4.2 Effect of thickness on drying rate of foamed and non-foamed mango pulp

From Figure 5, it is observed that the drying rate was 20.3, 17.9 and 12.4 g/min at the beginning of drying and the same was reduced to 1.0, 1.4 and 1.1 g/min at the end of the drying for 1, 2 and 3 mm thick foams, respectively.

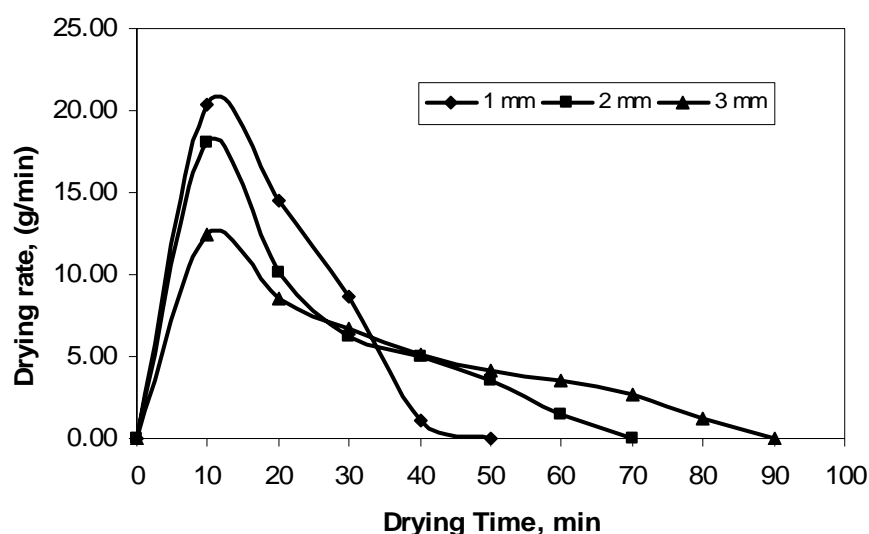


Figure 5. Rate of drying of foamed mango pulp at 60°C

It is also seen from the figure that the drying of foamed mango pulps at all thicknesses occurred at falling rate period because of the quick removal of moisture from thin surfaces of foams. The quantity of moisture removed is more in the three mm thick foam as compared to one mm thick foam due to the availability of higher moisture in higher thickness. But for the non-foamed pulp, the drying rate was 13.0, 7.2 and 6.4 g/min at the beginning of drying and the same was reduced to 0.7, 0.6 and 0.2 g/min at the end of the drying for 1, 2 and 3 mm thick pulps, respectively (Fig.6).

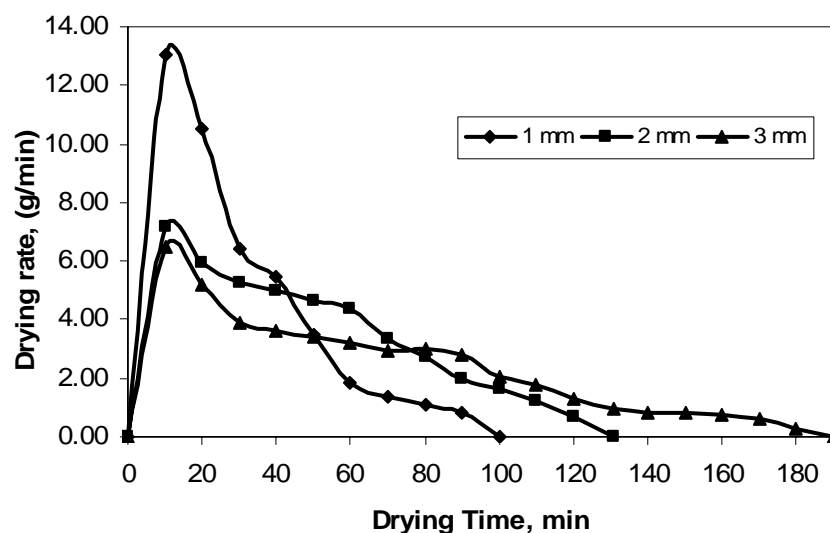


Figure 6. Rate of drying of non-foamed mango pulp at 60°C

The drying rate of the non-foamed mango pulps was lower than the drying rate of the foamed mango pulp at all thickness ranges studied due to less surface area exposed during drying. Also the result showed that due to foaming there is a beneficial effect in increasing drying rate and in turn reducing drying time. These drying results are in confirmation with the results reported in high moisture foods like tomato (Jayaraman *et al.*, 1975) and papaya (Levi *et al.*, 1983). The drying data at 65 and 70°C are shown in Tables 5 and 6 for comparison of the results with 60°C.

Table 5. Drying characteristics of non-foamed and foamed Totapuri mango pulps at 65°C

Treatments	Foam thickness, mm	Drying time, min	Initial moisture content, % (w.b.)	Final moisture content, % (w.b.)	Initial drying rate, g/min	Final drying rate, g/min
Egg albumen(10%) with Methyl cellulose (0.5%)	1 mm	40	81.87	5.07	0.186	0.020
	2 mm	60		5.07	0.308	0.020
	3 mm	80		5.07	0.320	0.024
Control (non-foamed)	1 mm	80	81.76	6.03	0.221	0.014
	2 mm	110		6.03	0.252	0.019
	3 mm	170		6.10	0.329	0.160

Table 6. Drying characteristics of non-foamed and foamed Totapuri mango pulps at 70°C

Treatments	Foam thickness, mm	Drying time, min	Initial moisture content, % (w.b.)	Final moisture content, % (w.b.)	Initial drying rate, g/min	Final drying rate, g/min
Egg albumen(10%) with Methyl cellulose (0.5%)	1 mm	30	81.87	4.64	0.207	0.035
	2 mm	50		4.63	0.316	0.029
	3 mm	60		4.60	0.357	0.043
Control(non-foamed)	1 mm	60	81.76	6.03	0.239	0.032
	2 mm	100		6.01	0.308	0.018
	3 mm	150		6.01	0.338	0.018

### 3.4.3 Drying rate constant

Based on the equation 5, the drying rate constant ' $k$ ' was determined at various pulp thicknesses. The result showed that the ' $k$ ' value decreased with increase in the pulp thickness. Also the ' $k$ ' value for foamed pup (0.023, 018 and 0.012 /min) was higher than the non-foamed pulp (0.019, 0.016 and 0.010 /min) at 1, 2 and 3 mm thicknesses, respectively. It is obvious that the drying rate is higher in foamed pulps due to larger surface area exposed when compared to non-foamed (control) mango pulps.

## 4. CONCLUSIONS

The optimum level of egg albumen was found to be 10% with the foaming time of 20 min for foam mat drying of mango pulp. Based on the foam mat drying study, it was observed that the time taken for drying of foamed mango pulp was 40, 60 and 80 min and for control samples (non-foamed), it was 100, 130 and 190 min at 1, 2 and 3 mm thick pulp thicknesses, respectively. The drying rate constant ' $k$ ' value decreased with increase in pulp thickness. Based on the overall foam mat drying study, it was concluded that the foamed mango pulp of one mm thick, dried at 60°C retained the maximum biochemical qualities when compared to all other treatments. The optimized drying study data can be used for the design of a continuous type foam mat dryer for drying mango pulp.

## 5. ACKNOWLEDGEMENTS

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