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Studies on effect of various operating parameters & foaming agents- Drying of fruits and vegetables

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Abstract: *The foam mat drying is a good way of dehydrating liquids foods in short times. Due to the porous structure of the foamed materials, mass transfer is enhanced leading to shorter dehydration times. This technique can be successfully employed for drying a variety of fruit juice concentration and pulps. The dried powders have good reconstitution characteristics. These studies are particularly applicable for drying of fruit and vegetable pulps drying such as guava, bananas and tomato etc. with some of the commonly used foaming agents like egg albumin and soya protein.*

The drying studies are carried out in a tray drier. The drying curves are drawn with different operating parameters and foaming agents. Falling rate is observed for the foam at different timings. Drying rates are compared and the drying time is evaluated by drying the foam at 55^oC to 80^oC. These studies are helpful for evaluating best drying to get good quality dried powders.

Keywords: *mass transfer, foaming agents, falling rate, reconstitution characteristics*

I. INTRODUCTION

Drying is a process of moisture removal due to simultaneous heat and mass transfer from the surrounding environment .the transfer of energy depends on the air temperature, air humidity, air flow rate and pressure. Rate of moisture transfer is governed by some of factors such as physical nature of the food, temperature, composition and initial moisture content. Foam mat is drying is one the very effective methods employed for the removal of moisture from the fruit pulps to obtain a free flowing powder that have good reconstitutions characteristic. it is the simplest method of drying in which a liquid food concentrate along with a suitable foaming agent is whipped to form a stable foam and is subjected to dehydration in the form of a mat of foam [1,2].rate of drying in this process comparatively very high because of enormous increase in liquid-gas interface, in spite of the fact that the heat transfer is impeded by a large volume of gas present in the foamed mass [3].

NanjunaSwamy et al [4] reported on the drying of fruit juice and pulps. Glycerol monostearate , egg albumin, ground nut protein isolate, gur gum and carboxy methyl cellulose (CMC) were employed in the preliminary trials as foaming agents.. Anjaria and chivate [5] reported that foam mat drying of certain model system multiple constant rate periods and falling rate periods foam mat drying was ideally suitable for drying of sticky and viscous slurries. Bolin and salunke [6] reported the physicochemical and volatile flavor changes occurring in fruit juices during concentration and foam mat drying.over the years, the foam-mat drying have been applied to many fruits including banana, guava, apple [7], tomato juice[8]. Lewicki and Konopacka [9] reported the mass transfer and volatile retention during the foam mat drying.
Drying occurs in multiple constant rate periods due to periodic bursting of successive layers of foam bubbles, thus exposing new surfaces for heat and mass transfer as the drying progresses [10, 11]. The foam-mat dried products have better reconstitution properties because of their honeycomb structure and are superior to drum and spray dried products [12]

II. Materials and methods

2.1. Materials
The fruits and vegetables Viz., guava, banana and tomato were procured from the local market.

2.2. Foaming agents:
1. Egg albumin
2. Soya protein isolate

2.3. Methods
Studies were conducted with different concentrations of foaming agents at temperature ranging from 55^oC to 75^oC.they are as follows:

a. Guava pulp foamed with egg albumin
b. Guava pulp foamed with soya protein isolate
c. Guava pulp foamed with egg albumin and water
d. Banana pulp foamed with egg albumin
e. Banana pulp foamed with soya protein isolate
f. Banana pulp foamed with egg albumin and water.
g. Tomato pulp foamed with egg albumin.
h. Tomato pulp foamed with soya protein isolate
i. Tomato pulp foamed with egg albumin and water.

2.3.1. Preparation of pulps: Guava pulp was prepared by scooping out the pulp along with seeds from fruits. Then these seeds were separated from pulp by rubbing the mixture on 14mesh sieve where the most of the pulp is passed through the mesh leaving seeds. This pulp was then smoothly blended in a mixer. Creamy white pulp was obtained which was ready for analysis. In the same way banana pulp and tomato pulp were prepared.

2.3.2. Preparation of foam:
1. Preaparation of guava foam

Guava pulp was foamed by dispersing initially 0.25% to 1% of the foaming agent in a known quantity of water of 50%.the mixture was then stirred at 300rpm using magnetic stirrer for about 15minutes.stable foam was thus prepared in a stable form previously weighed amount of guava pulp was slowly added . Homogeneous foam slurry was thus prepared and the foam slurry was ready for carrying out the foam mat drying process. In the first case of foaming agent used was egg albumin followed by soya protein isolate. Along with egg albumin and soya protein isolate sometimes water was also added which acted as a stabilizer of the foam for different cases. Stability of the foam played an important role while foam was subjected to drying. During drying they should not be any damage to the foam structure. The same process was done for the preparation of Banana and tomato pulp.

2.3.3. Determination of initial moisture content of the foam: The moisture content was determined by AOAC method [6]. A small amount of this sample (approx. 2 gm) was taken in a pre-weighed petri dish. A sample in the petri dish was dried in an oven for overnight or until the constant weight is reached at 1000^{o}C. The difference in the weight of the sample gave the amount of moisture content and percentage of moisture content was calculated.

% moisture = (Wt of moisture) / (Wt of sample – Wt of moisture) * 100

2.3.4. Preparation of soya protein isolate: Soya bean isolate can be defined as major proteineous fraction of soya bean prepared from superior quality, clean soya bean by removing preponderance of non protein components by physical and chemical process. Food grade, defatted soya bean flour was the basic raw material for the preparation of soya protein isolate. Soya protein isolate was prepared by mixing soya flour and water in the ratio of 1:20. The pH of this mixture adjusted to 9 to 10 by adding 0.1 N NaOH drop by drop. The mixture was centrifuged for 20 min at 5000rpm. Supernatant was adjusted to the pH 4.5 by slowly adding 1N Hcl drop by drop. This was again centrifuged to separate the precipitate to get the soya protein isolate. It was then stored in cool and dry place preferable below 28^{o}C at a relative humidity of 65% or less. The flow sheet for the process of preparing soya protein isolate is shown in the figure1.

Defatted soya flour (100 g)
↓
Water (200 ml) soya flour (1: 20)
↓
Add 0.1N NaOH slowly to adjust the pH of the slurry 9 to 10
↓
Centrifugation
↓
Supernatant
↓
Add 1N Hcl to adjust the pH of the supernatant to 4.5
↓
Centrifugation
↓
White precipitate is separated as residue
↓
Soya protein isolate

Figure 1: Flow sheet for the preparation of soya protein isolate

2.4. Drying studies: known quantity of the foam was taken into a tray kept in a tray drier. The tray was kept in tray drier until the foam gets dried. This process was carried at different temperatures ranging from 550^{o}C to 800^{o}C. The weights of the sample were taken for every 5minutes, till the foam gets dried. Initial moisture content was determined by AOAC method [13]. Final moisture content of the dried foam in sample in tray drier was also determined. A fine crispy powder was obtained and flakes were observed after some samples which were due to the foaming agent. Considering the experimental samples the good and the best suited foaming agent for these fruits were observed. The same procedure was followed for tomato, banana and guava pulp.

2.5. Rate Curves: A free flowing powder was obtained after drying. However for some samples, the powders were not free flowing. This is due to the foaming agent. The powder is then stored in poly ethylene covers and thus can be used for flavor.

From the data obtained after foam mat drying, curves of moisture content as a function of time were plotted. This was useful directly in determining the time required for drying. Much information were obtained if the data were converted into rates of drying expressed as –dX/ dt and plotted against moisture content **X.** for this purpose the smooth curves for moisture content versus drying time data tangents were drawn for different point to obtain the values for drying rates and drying rate curves were drawn.

III. Results and Discussions

Dried powders were made from tomato, banana and guava by using foam mat drying technique. The tangents were drawn for drying curves and –dx/dt was determined and converted into rate of drying for which the values are shown in the tables 4.1.a to 4.3.b.Maximum moisture (X) for guava, banana and tomato foamed with soya protein isolate and egg albumin against time was determined. From the data available from experiments conducted, it can be observes that the moisture content was decreasing with time. Similarly data was also collected for banana and tomato.

Rate of drying was evaluated from drying curves. The drying curves were drowning with the data on rate of drying versus moisture content at any time. Multiple constant rate periods was observed for different fruits foamed agents because of periodic bursting of successive layers of foam bubbles giving rise to new layer each time.

Data for moisture content of foam dried of guava, banana and tomato samples with time from initial moisture constant to final moisture content are shown in the table 4.1.a. variation of moisture content were shown and the drying curves in figure 4.7, 4.8, 4.9 for guava , banana and tomato with soya protein isolate as a foaming agent for which values are shown in table 4.3a. In the case of foam mat drying of fruit and vegetables pulps constant rate periods falling the rate periods were obtained. The pulp of fruit and vegetables does not change the behavior of the foam mat drying.

Drying was fast in all the above model systems considered. Higher drying resulted in less drying times of the pulp of any fruit and vegetables. The foam mat dried guava powder was in cream color where as a pleasant red color was observed. These powders were highly reconstitutable in water.

Multiple constant rate periods were not observed in control process unlike in the case of foam mat drying. Drying rates were not higher in these cases. Consequently more time was required when compared to the foam mat drying method. As can be seen figures 4.1, 4.2, 4.3, which were drawn from table 4.1a shows the drying data and observed that the initial moisture content decreases with time at 65^{o}C.The drying data for foam mat drying of guava, tomato and banana samples were done under 12mesh size with egg albumin as a foaming agent and water is converted into drying rate vs moisture content are shown in table 4.1.b.

As can be seen figures 4.4, 4.5, 4.6, which are drawn from table 4.2.a shows the drying data and observed the initial moisture content decreases with time at 65^{o}C. Here guava, tomato and banana samples were done under 14 mesh size with egg albumin as a foaming agent dried. The drying data for foam mat drying of guava, tomato and banana samples under 14 mesh with egg albumin as a foaming agent is converted into drying rate vs moisture content are shown in table 4.2.b. From the figures 4.10, 4.11 and 4.12 we can observe the particles of smaller diameters have more drying rates than that of larger particles for the guava, tomato and banana samples with foaming agent as 1 weight percent egg albumin and water because the drying depends on the particle size and specific surface of drying material. The larger particles and uneven surface of drying material takes more time to drying. From the figure 4.13, 4.14 and 4.15 we can observe the particles of samples with egg albumin gives larger drying rates than the samples with 1 weight percent of foaming agent. The drying of material depends on the density of the particles. The less dense particles gives larger drying rates. The foam with egg albumin as a foaming agent ha less density than the foam with soya protein isolate as a foaming agent.

IV. Conclusion

Studies on foam mat drying of the guava, tomato and banana were carried out. The creation of foam has resulted increased surface area for drying with the increase in surface area exposed for drying, increased the rate of drying. Where the low density foams dried at relatively low temperature in an ordinary forced circulation drier. Foam mat drying has results in fruit leathers or powders which otherwise would not have been possible by normal drying. The mat dried powders were good quality and were highly reconstitubel in water.

The foaming agent has effect on rate of drying. Of the various foaming agents dried. Egg albumin was found to be the best. Hence the foam mat drying method is highly feasible in producing fruit and vegetable powders of acceptable quality at reasonable cost under the experimental conditions employed.

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S.No	Time, t (min)	Moisuture content , X (g moisture/g dry solid)		
		Guava	Tomato	banana
1	0	10.08	30	8.7
2	5	9.76	22	7.8
3	10	8.16	17.66013.33	7
4	15	6.9	9.33	6.8
5	20	6.25	7	6.6
6	25	5.25	3.66	6.4
7	30	4.5	3.66	5.7
8	35	3.83	3.66	5.5
9	40	3.5	2.33	5.4
10	45	3.3	0.33	4.8
11	50	1.8	0	4.4
12	55	1.5	0	3.4
13	60	1.08	0	3.0
14	65	0.75	0	2.2
15	70	0.416	0	2.1
16	75	0.33	0	1.9
17	80	0	0	0
18	85	0	0	0

Table 4.1.a: drying data for the samples under 12 mesh size

S.No	Guava		tomato		Banana	
	Moisture content, X (g moisture/g dry solids)	Drying rate N (g/ cm^2min)	Moisture content, X (g moisture/g dry solids)	Drying rate N (g/ cm^2min)	Moisture content, X (g moisture/g dry solids)	Drying rate N (g/ cm^2min)
1	6.9	0.0367	26	0.13565	7.5	0.031
2	5.3	0.0366	19.5	0.111	5.5	0.024
3	3.8	0.0354	12	0.0827	4.8	0.016
4	2.3	0.0278	5	0.056	3.4	0.014
5	0.7	0.0240	3	0.034	2.2	0.006

Table4.1.b: drying data for the samples under 12 mesh size

S.No	Time, t (Minutes)	Moisture content , X (g moisture / g dry solid)		
		guava	Tomato	Banana
1	0	4	24.5	1.8
2	5	3.8	20.5	1.68
3	10	3.46	18.5	1.54
4	15	2.93	17	1.45
5	20	2.3	9	1.18
6	25	1.93	5	0.9
7	30	1.26	1	0.54
8	35	0.93	1	0.5
9	40	0.8	1	0.4
10	45	0.46	0.5	0.318

11	50	0.2	0	0.045
12	55	0.13	0	0
13	60	0.13	0	0
14	65	0	0	0
15	70	0	0	0

Table 4.2.a: drying data for foam- mat drying of samples using egg albumin as a foaming agent under 14 mesh sizes.

S.No	Guava		tomato		Banana	
	Moisture content, X (g moisture/g dry solids)	Drying rate N (g/ cm^2min)	Moisture content, X (g moisture/g dry solids)	Drying rate N (g/ cm^2min)	Moisture content, X (g moisture/g dry solids)	Drying rate N (g/ cm^2min)
1	6.9	0.01236	26	0.06656	7.5	0.04168
2	5.3	0.00957	19.5	0.05112	5.5	0.0361
3	3.8	0.00697	12	0.03329	4.8	0.0342
4	2.3	0.00434	5	0.01656	3.4	0.0303
5	0.7	0.015	3	0.00002	2.2	0.02704

Table 4.2.b: drying rate data for the samples under 18 Mesh size

S.No	Time, t (Minutes)	Moisture content , X (g moisture / g dry solid)		
		guava	Tomato	Banana
1	0	5.25	8.6	20.5
2	5	4.75	8.4	15
3	10	3.125	8.0	13.5
4	15	3.02	7.4	12
5	20	2.875	6.6	11.5
6	25	1.965	6	11
7	30	0.625	3.4	10.5
8	35	0.52	2.4	9.5
9	40	0.25	1.4	8.5
10	45	0	0.4	8
11	50	0	0	7
12	55	0	0	6
13	60	0	0	5
14	65	0	0	3
15	70	0	0	1.5
16	75	0	0	0
17	80	0	0	0

Table 4.3.a. Drying rate for foam-mat drying of samples using soya protein isolate a foaming agent under 18 Mesh

S.No	Guava		tomato		Banana	
	Moisture content, X (g moisture/g dry solids)	Drying rate N (g/ cm^2min)	Moisture content, X (g moisture/g dry solids)	Drying rate N (g/ cm^2min)	Moisture content, X (g moisture/g dry solids)	Drying rate N (g/ cm^2min)
1	6.9	0.01236	26	0.06656	7.5	0.04168
2	5.3	0.00957	19.5	0.05112	5.5	0.0361
3	3.8	0.00697	12	0.03329	4.8	0.0342
4	2.3	0.00434	5	0.01656	3.4	0.0303
5	0.7	0.0015	3	0.00002	2.2	0.02704

Table 4.3.b: drying data for the samples under 14 Mesh size.

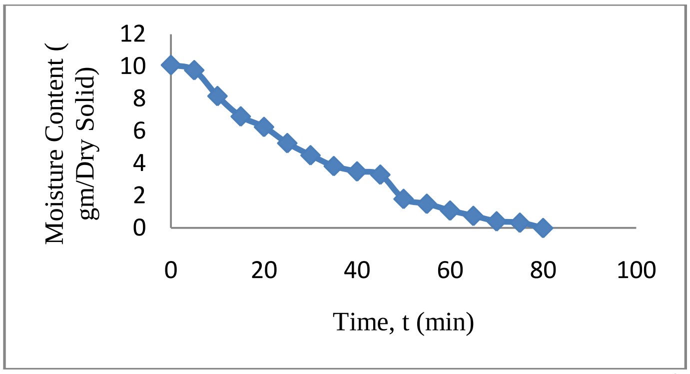

Fig: 4.1. Drying curve for guava (12 meshes) with Egg albumin as a foaming agent at 65°C

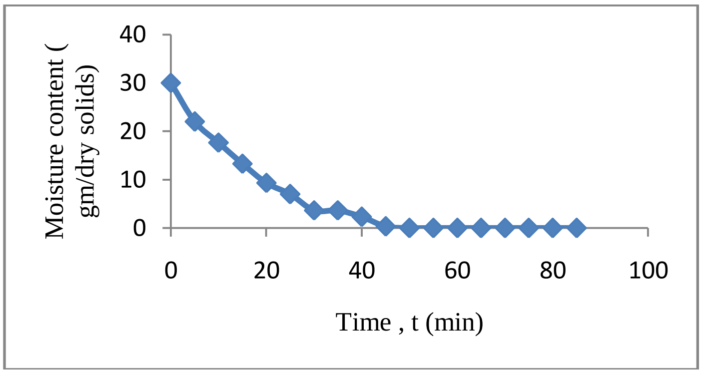

Fig: 4.2. Drying curve for Tomato (12 mesh) with Egg albumin as a foaming agent at 65°C

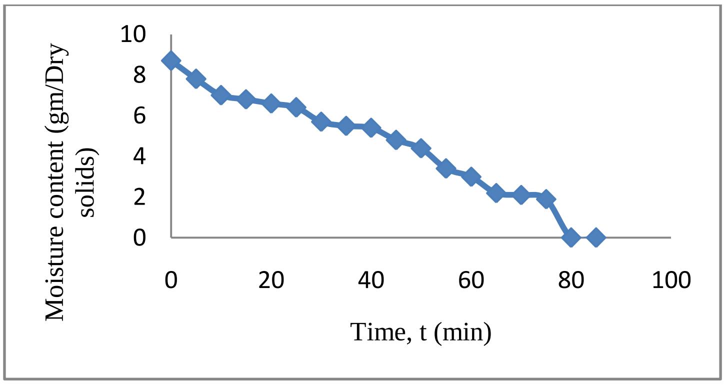

Fig: 4.3. Drying curve for Banana (12 mesh) with Egg albumin as a foaming agent at 65°C

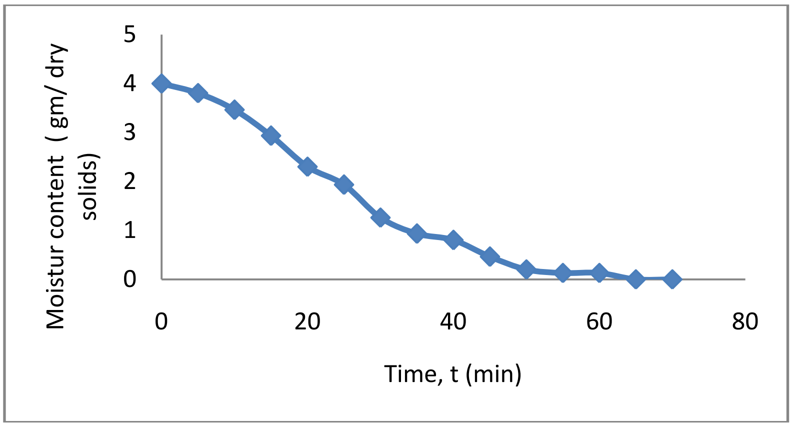

Fig: 4.4. Drying curve for Guava (18 mesh) with Egg albumin as a foaming agent at 65°C

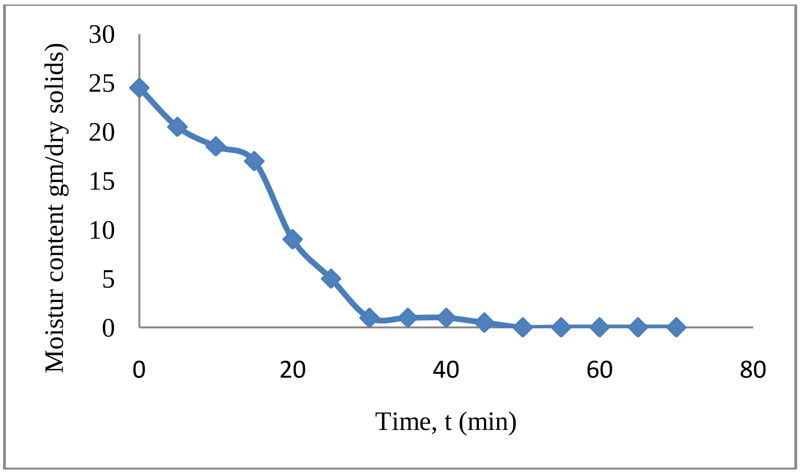

Fig: 4.5. Drying curve for Tomato (18 mesh) with Egg albumin as a foaming agent at 65°C

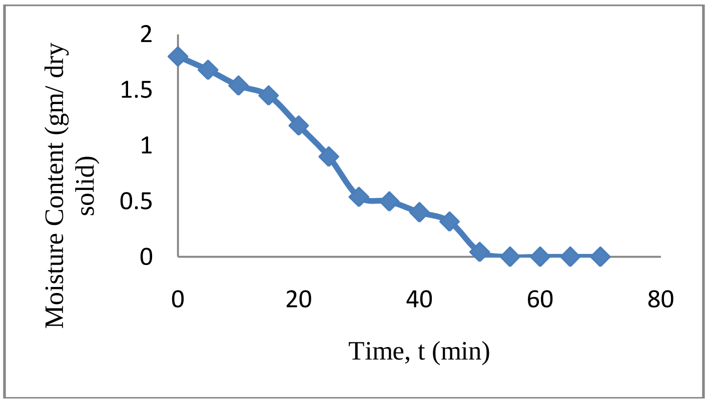

Fig: 4.6. Drying curve for Banana (18 mesh) with Egg albumin as a foaming agent at 65°C

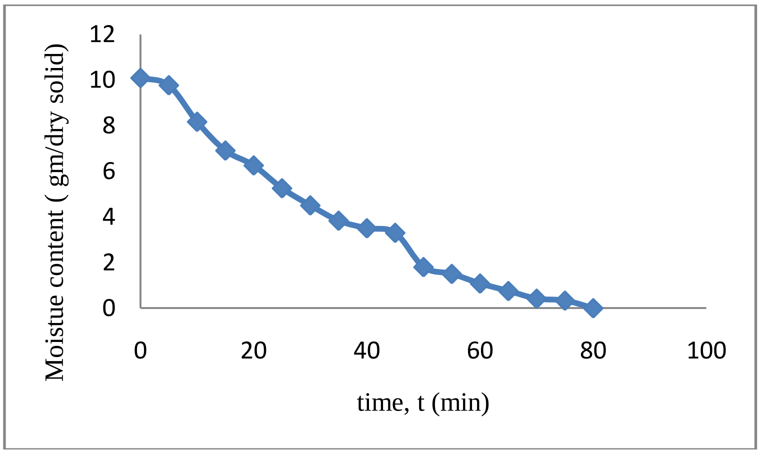

Fig: 4.7. Drying curve for banana (18 mesh) with Soya protein as a foaming agent at 65°C

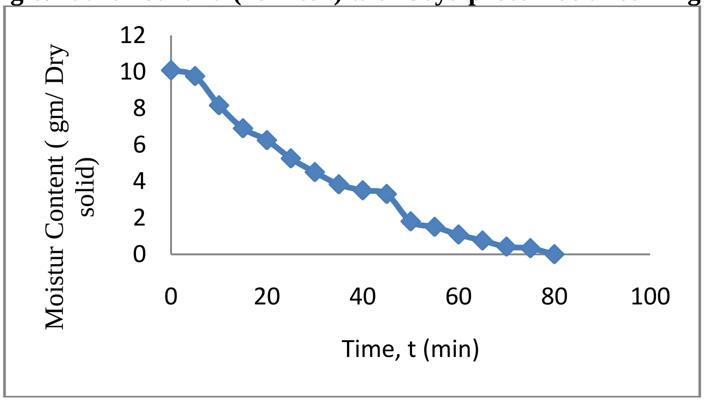

Fig: 4.8. Drying curve for Tomato (18 mesh) with Soya protein as a foaming agent at 65°C

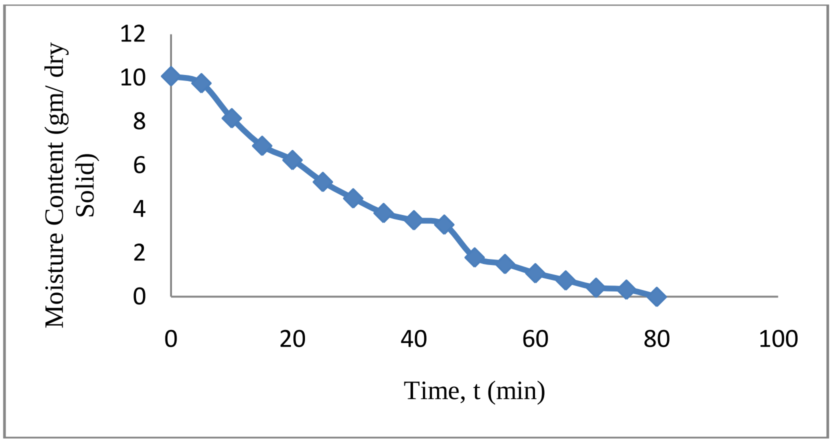

Fig: 4.9. Drying curve for Banana (18 mesh) with Soya protein as a foaming agent at 65^{o}C

Nomenclature:

Moisture content, X (g moisture/g dry solids)
Drying rate N (g/ cm^{2}min)
Time t (min)
Temperature ^{o}C
Carboxy methyl cellulose (CMC)