Comparative study of Conventional tray and Advanced tray in Tray Drying

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Abstract

This paper compares performance of conventional tray and advanced tray (i.e., Porous tray) used in Batch dryer, in terms of drying time. The flat plate was used as conventional tray with Hexamine powder as test material and the porous tray was considered as advanced tray with similar Hexamine powder as test material, for drying. The drying was carried out with equal material in each plate spread uniformly until material was bone dry for both types of plates and results were noted. The result of drying curve show that for constant rate period, the rate of drying of advanced tray is greater than that for flat plate (1.45 times); And for falling rate period the curve is steeper for Flat plate. However, in case of porous tray the constant rate period is up to greater extent of drying (0.03gm/gm) than for flat plate (0.04 gm/gm). This is reflected as greater span of the constant rate period for the porous tray curve than for the flat plate curve. The observation concludes that the total drying time is 2.26 times for porous tray than for flat plate. Thus, porous tray shows increased rate of drying with less energy consumption.

Keywords*: Tray Dryer, Flat Plate, Porous Plate, Cross-Flow, Through Circulation, Rate of Drying, Energy saving in dryer, Batch Dryer*

1. Introduction

Tray dryers are also called Cabinet dryers, compartment or shelf dryers [1] and are used for drying of the solids like pasty materials from filter cake, lumpy solids of wet powder and other wet crystals and for other application. The general design of tray dryer includes a cabinet containing removable trays on which wet solid material is placed in plates and hot air is blown from across and bottom of the tray in cross-circulation manner to evaporate moisture from solids. After reaching desired drying state dried solid product is removed. The general batch drying cycle in Tray dryer is 4-48 hrs [2]. This dryer is useful when the production rate is small and in batch and have lower moisture to be removed. However, solid with higher moisture content can also be dried in this dryer but takes very long time and high energy is required for drying. Therefore, a novel tray is tried and tested for the similar equipment to overcome the drawback of conventional dryer i.e., long time requirement for higher moisture removal and high energy required for drying for material with higher moisture content. The findings are interesting and are explained in subsequent section.

1.1 Construction and working of Tray Dryer:

The Tray dryer consists of rectangular chamber of sheet metal containing racks on which solid material is kept for drying (refer fig 1). At the bottom of the section, fan is provided to distribute the air and heated air is circulated with the help of fans. The air is generally heated by electric heater or fin tube heat exchanger. The air is then circulated inside chamber. At top of the chamber vent is provided so as to remove moist air and fresh air is introduced at bottom [3].

1.1.1 Working

The wet solid material is placed on Trays or plates inside Tray Chamber. The air is heated in heater and is circulated with the help of fan provided at bottom of chamber. The air is circulated in cross-flow to the solids. The moist air is partly vent out through the vent provided above and make up fresh hot air is added continuously.

The main disadvantage in tray drying is that the moisture content of finished product is uneven [2]. This is due to uneven distribution of air inside the chamber of dryer. This can be eliminated by using Through circulation drying operation rather than cross-flow. In that the air is passed through entire bed of solid removing moisture

from all the solid and is coming out. Thus, the through circulation has advantage of increased drying area and therefore increase rate of drying than that of in cross-flow.

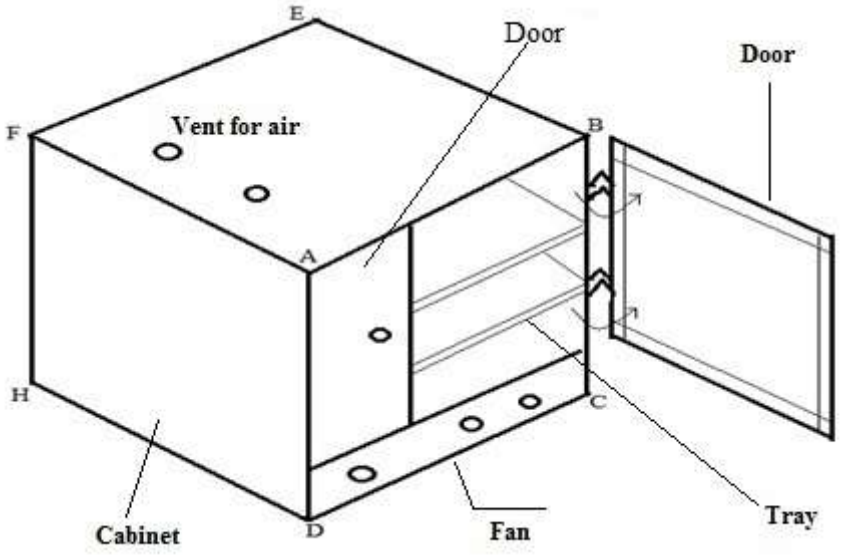

Fig 1 Schematic of Tray Dryer

The drying rate for Batch drying is calculated by equation [1]

$$N = \left(\frac{Ws}{A}\right)\left(\frac{dX}{dt}\right) \quad (1)$$

Where, N is drying rate, (gm/ m^2min)
W_s is weight of dry solid, (gm)
A is available area of drying, (m^2)

The drying time is calculated as follow[3]

$$t = \left(\frac{ms}{A*Nc}\right)\left[(X1 - Xc) + \left(Xc * \ln\left(\frac{Xc}{X2}\right)\right)\right] \quad (2)$$

Where, t = total drying time (min)
N_c = constant rate drying (gm/m^2*min)
X_1, X_c, X_2 are initial, critical and final moisture content of solid material respectively, (gm moisture/gm dry solid).

2. Experimental work

The experiment was carried out using wet hexamine powder supplied by 'M/S Simalin Industries P.Ltd., Nandesari'. The two plates with the following dimensions were used:

Flat plate
- Size: 30 cm X 20 cm
- Weight: 820 gm

Porous Plate
- Size: 30 cm X 20 cm (open area, 31 cm X 20 cm)
- Weight: 1085.5 gm

Material
- Hexamine Powder
- Mesh size: +250, -400 (Tyler Standard Screen)
- Weight of sample taken: 145 gm per tray
- Drying Temperature: 65^0C

Initial moisture content: 0.074 gm moisture/gm dry solid

The drying was carried out till material was bone dry. It took 2 days for complete experimentation.

3. Results and Discussion

3.1 Flat Plate results:

The drying was started with ambient air at 65^0C

Dry Bulb Temperature: 35^0C

Wet bulb temperature: 30^0C

Relative Humidity (%): 69.98%

Table 1 Results of Drying with Flat Plate

Total Drying Area = 0.060 m^2

Time (min)	Weight of sample+Flat plate (gm)	Weight of sample (gm)	Weight of moisture(gm)	Moisture content X (gm mosture/gm dry solid)
0	965	145	10	0.0741
3	964.5	144.5	9.5	0.0704
6	964.5	144.5	9.5	0.0704
9	964.5	144.5	9.5	0.0704
12	964	144	9	0.0667
15	964	144	9	0.0667
18	964	144	9	0.0667
21	964	144	9	0.0667
24	964	144	9	0.0667
27	964	144	9	0.0667
30	964	144	9	0.0667
33	964	144	9	0.0667
36	964	144	9	0.0667
39	964	144	9	0.0667
42	964	144	9	0.0667
45	964	144	9	0.0667
48	964	144	9	0.0667
51	963.5	143.5	8.5	0.0630
54	963.5	143.5	8.5	0.0630
57	963.5	143.5	8.5	0.0630
60	963.5	143.5	8.5	0.0630
63	963.5	143.5	8.5	0.0630
66	963.5	143.5	8.5	0.0630
69	963.5	143.5	8.5	0.0630
72	963.5	143.5	8.5	0.0630
75	963.5	143.5	8.5	0.0630
82	963.5	143.5	8.5	0.0630
85	963.5	143.5	8.5	0.0630
95	963.5	143.5	8.5	0.0630
98	963.5	143.5	8.5	0.0630
101	963.5	143.5	8.5	0.0630

104	963.5	143.5	8.5	0.0630
107	963.5	143.5	8.5	0.0630
110	963.5	143.5	8.5	0.0630
113	963.5	143.5	8.5	0.0630
118	963.5	143.5	8.5	0.0630
123	963.5	143.5	8.5	0.0630
128	963.5	143.5	8.5	0.0630
133	963.5	143.5	8.5	0.0630
138	963	143	8	0.0593
225	962.5	142.5	7.5	0.0556
312	962	142	7	0.0519
399	961.5	141.5	6.5	0.0481
486	961	141	6	0.0444
571	960.5	140.5	5.5	0.0407
660	960.5	140.5	5.5	0.0407

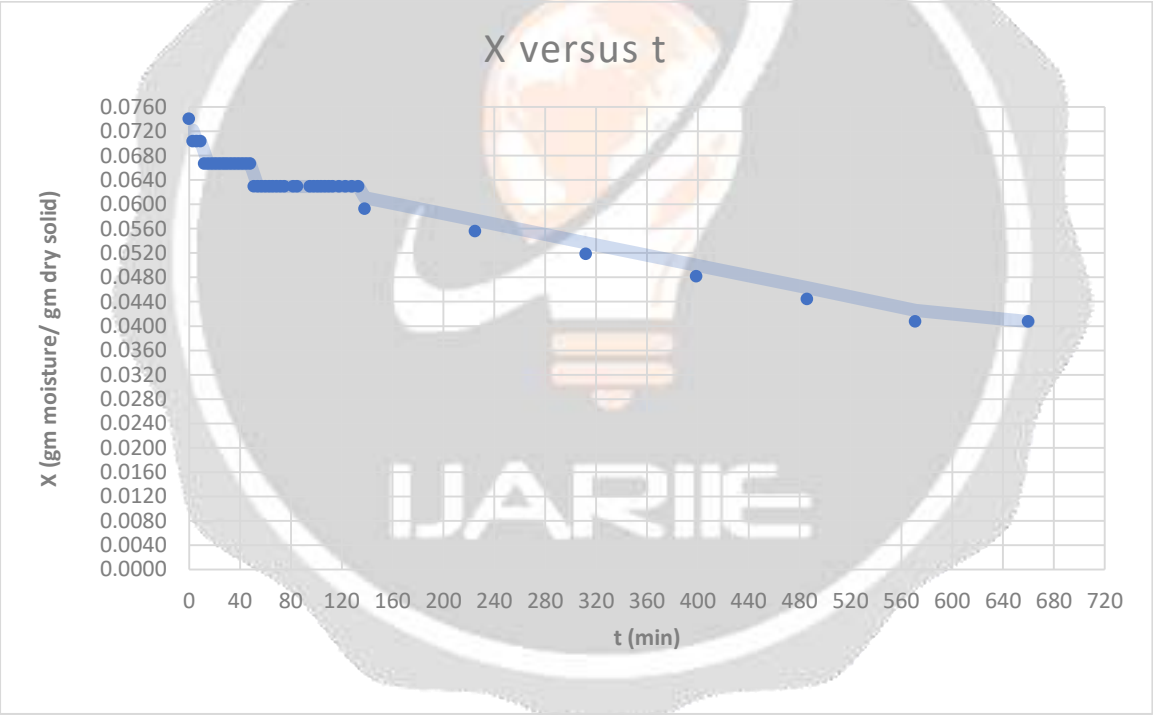

Fig 2 Plot of X versus t for Flat plate

Using plot of 'X versus t', dX/dt was calculated for different values of X. Subsequently, N was calculated using equation .1. The results are tabulated below.

Table 2 'Rate of Drying N' for Flat Plate

X(from graph) (gm moisture/ gm solid)	dX/dt (gm/min)	N (gm/m^2*min)
0.069	0.000115	0.25875
0.066	0.000083	0.18675
0.063	0.000075	0.16875
0.06	0.000053	0.11925

0.058	0.00005	0.1125
0.056	0.00005	0.1125
0.054	0.00005	0.1125
0.0525	0.00005	0.1125
0.049	0.00005	0.1125
0.048	0.00005	0.1125
0.047	0.00005	0.1125
0.045	0.00005	0.1125
0.044	0.00005	0.1125
0.042	0.000013	0.02925
0.041	0	0
0.041	0	0
0.041	0	0

The rate of drying, N is plotted against moisture content of solid, X, and is plotted. The constant rate drying **N_c is 0.11 gm/m^{2}min** and critical moisture content **X_c 0.041 gm moisture/gm dry solid.**

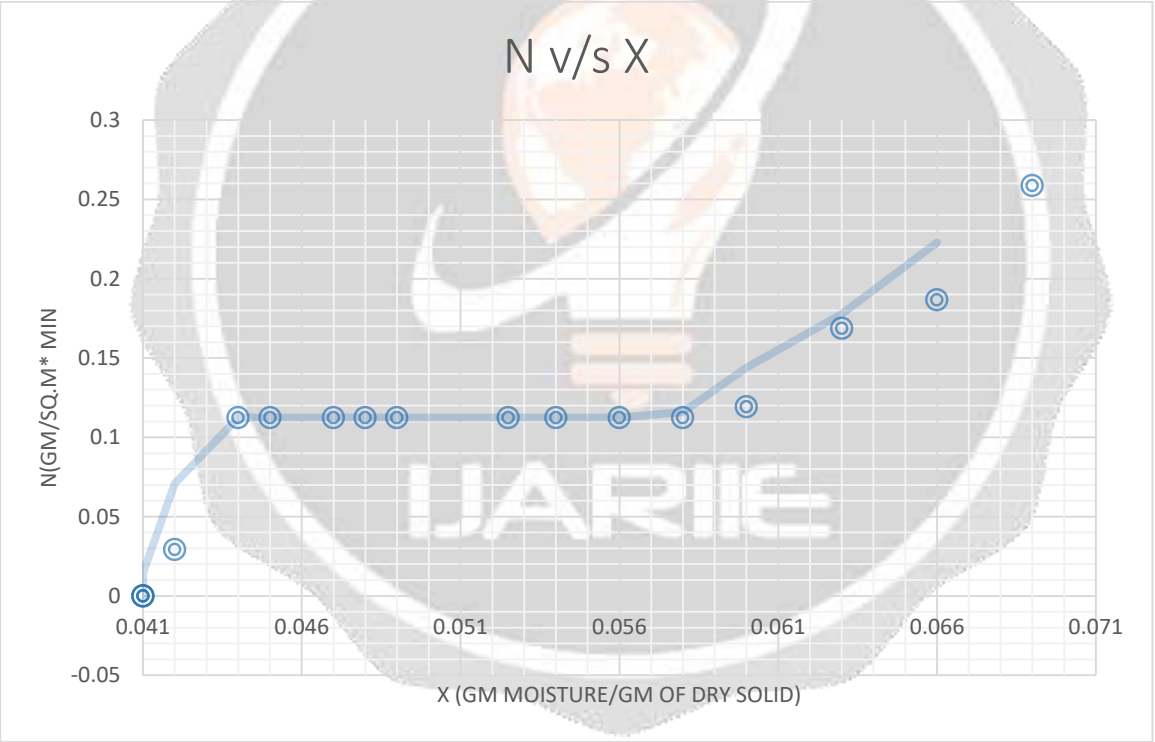

Fig 2 Plot of N Vs X for Flat Plate

3.2 Porous plate

Table 3 Results of Drying with Porous plate

Total drying area = 0.085 m^2

Time(min)	weight of sample+Porous plate (gm)	weight of sample (gm)	weight moisture(gm)	Moisture content X (gm moisture / gm dry solid)
0	1230.5	145	10	0.0741
3	1230	144.5	9.5	0.0704

6	1229.5	144	9	0.0667
9	1229	143.5	8.5	0.0630
12	1229	143.5	8.5	0.0630
15	1229	143.5	8.5	0.0630
18	1228.5	143	8	0.0593
21	1228	142.5	7.5	0.0556
24	1228	142.5	7.5	0.0556
27	1228	142.5	7.5	0.0556
30	1228	142.5	7.5	0.0556
33	1228	142.5	7.5	0.0556
36	1228	142.5	7.5	0.0556
39	1228	142.5	7.5	0.0556
42	1228	142.5	7.5	0.0556
45	1228	142.5	7.5	0.0556
48	1228	142.5	7.5	0.0556
51	1228	142.5	7.5	0.0556
54	1228	142.5	7.5	0.0556
57	1228	142.5	7.5	0.0556
60	1228	142.5	7.5	0.0556
63	1227.5	142	7	0.0519
66	1227.5	142	7	0.0519
69	1227.5	142	7	0.0519
72	1227.5	142	7	0.0519
75	1227.5	142	7	0.0519
82	1227.5	142	7	0.0519
85	1227.5	142	7	0.0519
95	1227	141.5	6.5	0.0481
110	1227	141.5	6.5	0.0481
125	1227	141.5	6.5	0.0481
140	1226.5	141	6	0.0444
185	1226	140.5	5.5	0.0407
230	1225.5	140	5	0.0370
275	1225	139.5	4.5	0.0333
320	1224.5	139	4	0.0296
365	1224.5	139	4	0.0296
410	1223	137.5	2.5	0.0185
455	1222.5	137	2	0.0148
500	1222	136.5	1.5	0.0111
545	1221.5	136	1	0.0074
590	1221	135.5	0.5	0.0037
635	1220.5	135	0	0.0000
680	1220.5	135	0	0.0000

Using plot of 'X versus t', dX/dt was calculated for different values of X. Subsequently, N was calculated using equation .1. The results are tabulated below.

Table 4 'Rate of Drying N' for Porous plate

X(from graph) (gm moisture/gm dry solid)	dX/dt (gm/min)	N (gm/m^2*min)
0.066	0.00015	0.238235
0.054	0.00013	0.206471
0.058	0.0001	0.158824
0.044	0.0001	0.158824
0.0398	0.0001	0.158824
0.0362	0.0001	0.158824
0.0326	0.0001	0.158824
0.029	0.0001	0.158824
0.0252	0.0001	0.158824
0.0216	0.0001	0.158824
0.0184	0.0001	0.158824
0.0152	0.0001	0.158824
0.01135	0.0001	0.158824
0.0074	0.0001	0.158824
0.0042	0.000065	0.103235
0.0024	0.00006	0.095294

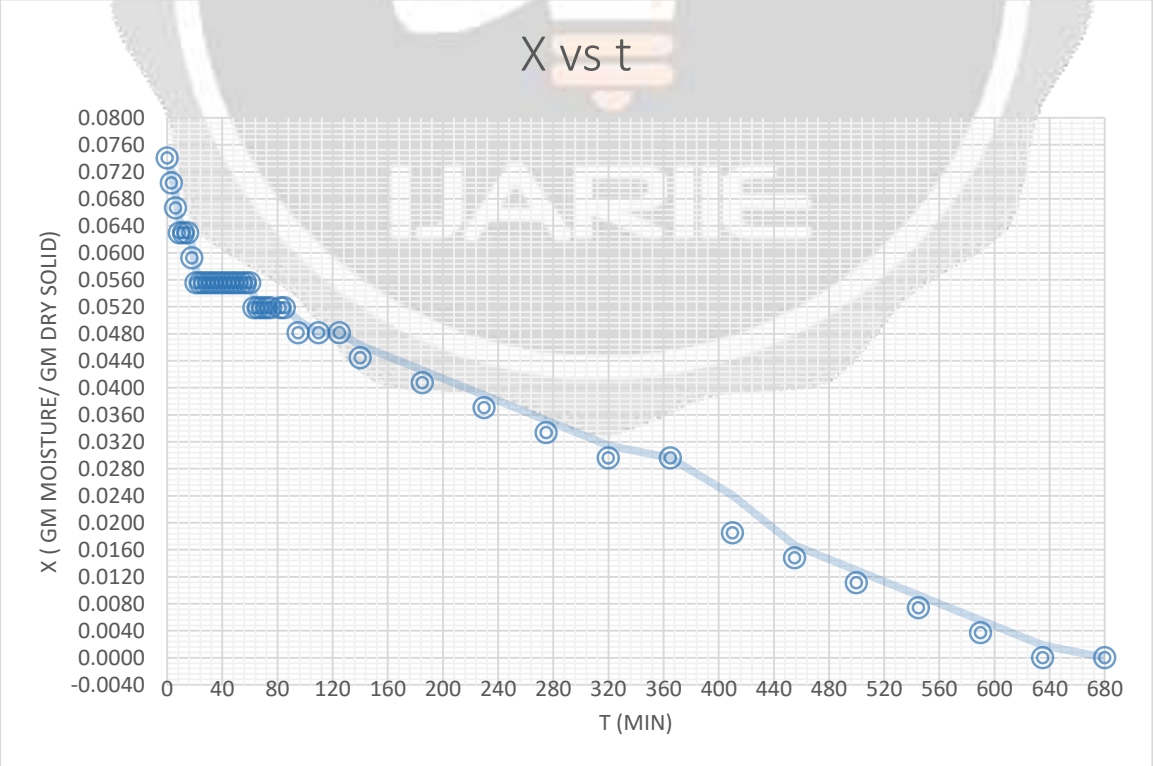

Fig 3 X vs t for porous plate

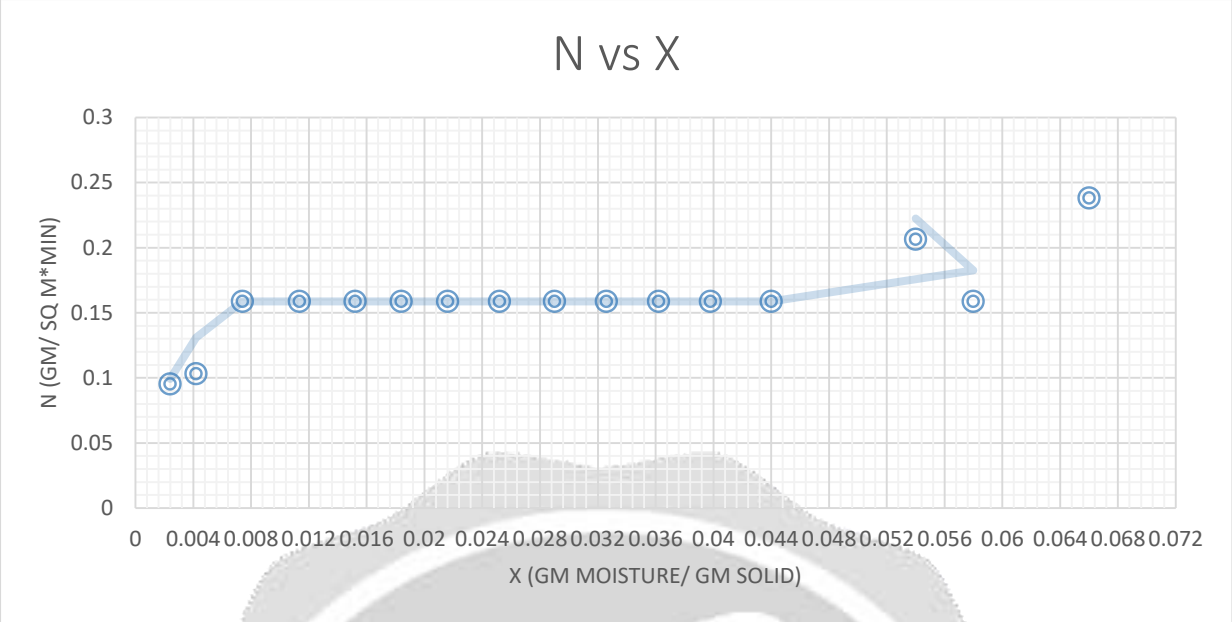

Fig 4 N vs X porous plate

From the graph constant rate drying is $\mathbf{N_c = 0.16\ gm/m^2*min}$ and critical moisture content is $\mathbf{X_c = 0.003}$ gm moisture/gm dry solid. The relative performance for conventional tray and advanced tray is plotted on the same graph to have the comparative study. Refer Fig 5.

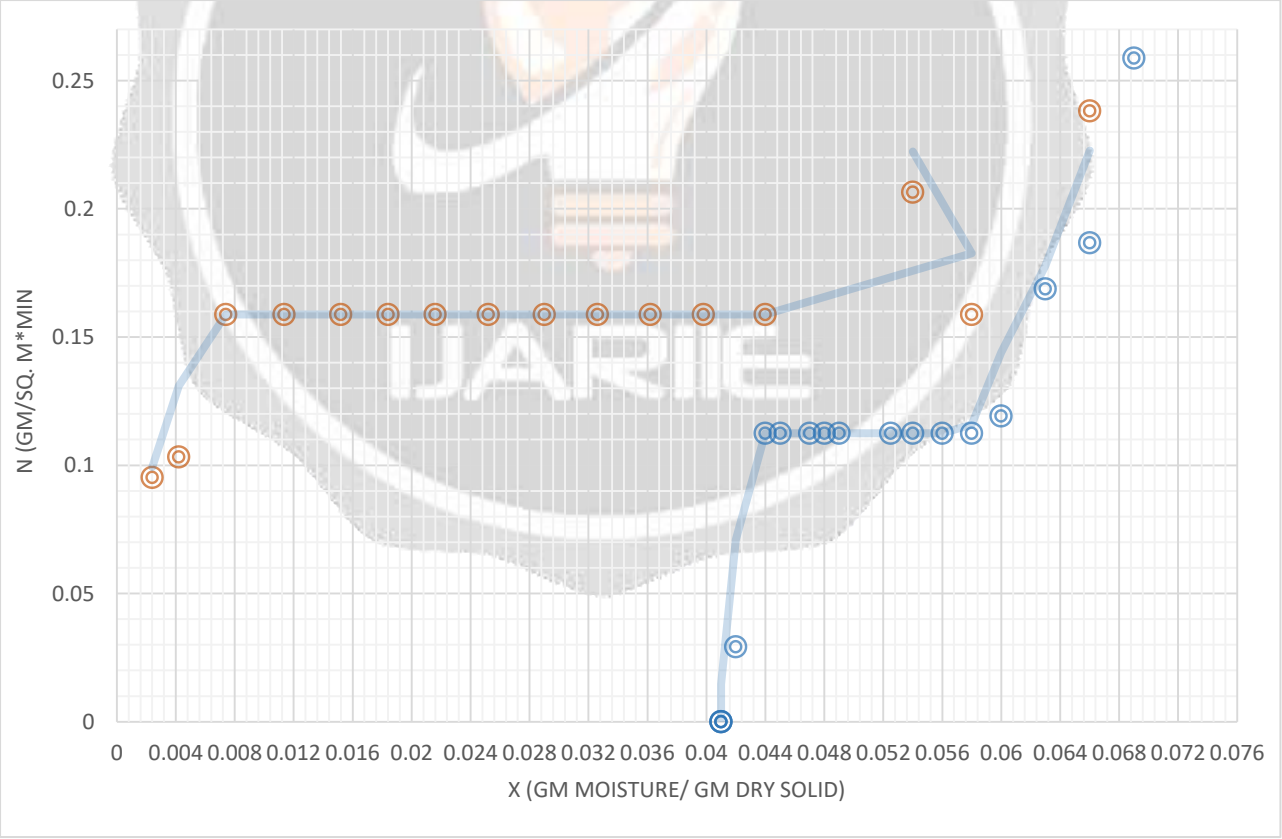

Fig 5 N vs X plot showing comparison of Flat Plate and Porous Plate

4. Conclusion

The constant drying rate obtained for Flat Plate is N_c = 0.11 gm/m^2min and for porous plate is 0.16 gm/m^2min. The critical moisture for flat plate X_c = 0.040 gm/gm and porous plate X_c = 0.003 gm/gm.

For initial and final moisture content, 0.074 gm moisture/gm dry solid and 0.041 gm moisture/gm dry solid, respectively, and for 135 gm of bone dry solid, various results obtained are listed below:

Table 5 Comparison of Flat and Porous Plate Drying Performance

Plate	Nc (gm/m^2min)	X_1 (gm/gm)	X_2 (gm/gm)	t (Hrs)
Flat plate	0.11	0.074	0.041	11.26
Porous plate	0.16	0.074	0.041*	5.45
Flat plate	0.11	0.5	0.005	187.33
Porous plate	0.16	0.5	0.005	82.36

*Drying can go up to X_2 =0.0036 for porous plate

From above results it is concluded that, using flat plate with of cross flow, time taken for drying is 2.6 times than that for porous plate under same conditions of drying. This is due to through circulation available in porous plate. The porous plate offers greater drying area and hence faster drying rate and therefore reduction in total drying time. The constant rate drying, Nc, for Porous plate is 1.45 times than that of flat plate.

5. References

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