CHAPTER IV

RESULTS AND DISCUSSION

1. Introduction

Chili is one of the economic crops of Thailand. Normally, fresh chili after harvesting contains moisture content of 70-85% on wet basis. The high moist of chili is the important factors in drying process, because the moisture content is the factor for control the quality and price of chili in the market. This chapter study concentrate to chili drying using continuous fluidized bed in clean processes and study the effect of drying temperature, effect of drying air velocity, characteristics of chili. Finally, the dried chili have to be clean and good in quality for the market. First, study traditional method chili drying and drying using heat coil at different conditions. To study the effects of various influencing weight and moisture content of the pepper using continuous fluidized bed drying which can be show as follows.

2. Results of chili drying on traditional method

Experiment dried chili using sunlight consist of 5 samples of fresh chili(Jinda type). The initial condition in this experiment were weight of each group equal 1 kg., initial moisture content of 72.98% on wet basis, the average relative humidity of the air was 61.09% and the average environment temperature was 34 °C.

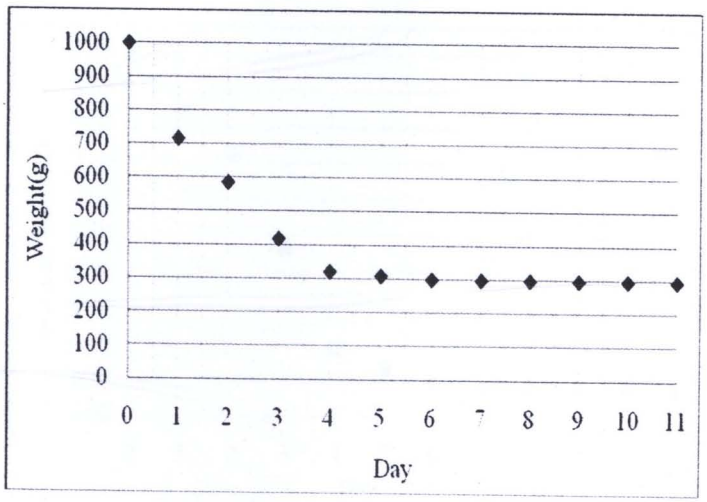

Figure 4.1 The change of chili weight on the Sun drying

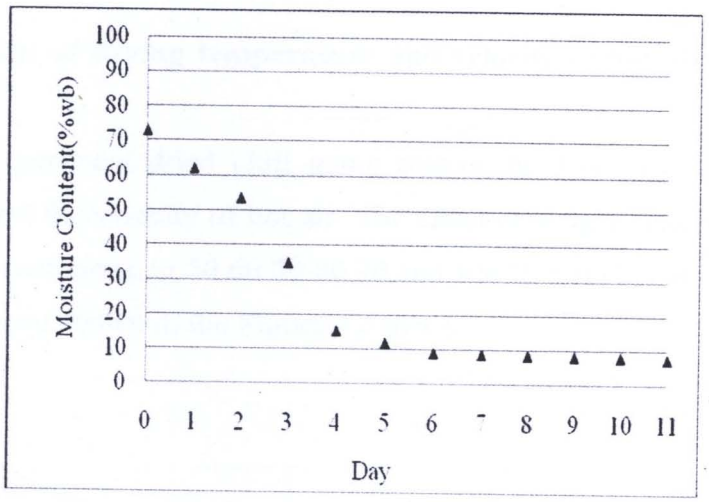

Figure 4.2 The change of moisture content on the Sun drying(%wet basis)

The results of this experiment can be shown in Figure 4.2 and 4.3 and found that in the range of 1 to 5 on the weight of chili decreased rapidly and after the 5th day found that the weight of the pepper that has been slowly reduced. All times are used to dry until constant weight of the chili starts was 11 days, the average weight was 292.87 grams. The weight lost is that pepper the moisture content decreased. The final moisture content of dried wet or equal to 7.74% 8.39% dry basis and the results can be shown in Figure 4.1, 4.2 and 4.3, respectively.

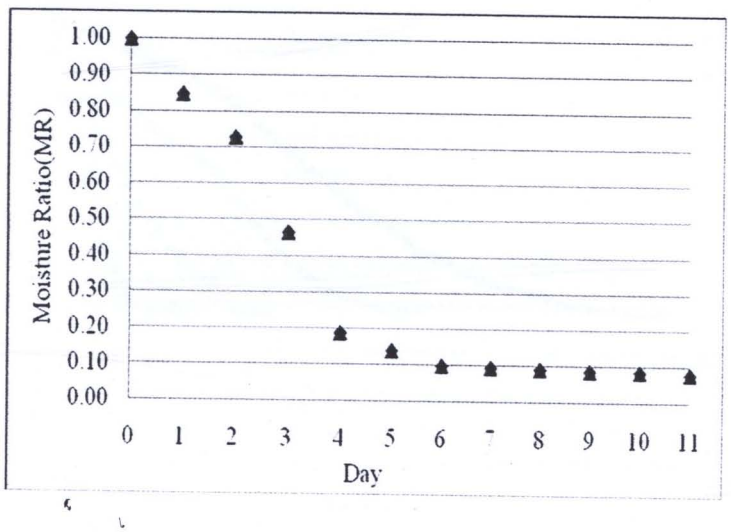

Figure 4.3 The change of moisture content ratio on the Sun drying (%wet basis)

3. Results of drying temperature and velocity of hot air that effect to the weight

The experiment dried chili using continuous dryer for study the effects of temperature and the velocity of hot air. The effect of weight change of pepper--under experimental conditions, at 50 60 70 80 90 and 100 °C with hot air velocity 4, 5 and 6 m/s. Results were shown in the Figure 4.4 to 4.6.

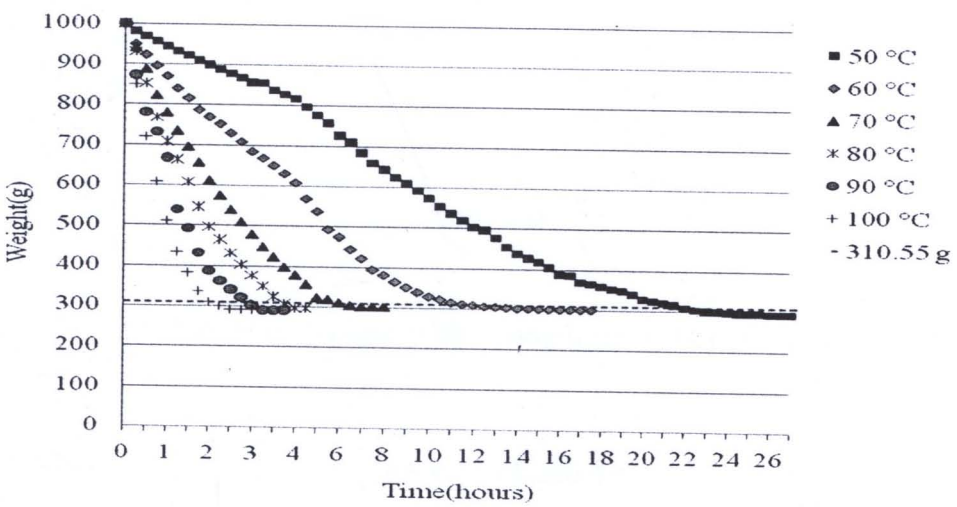

Figure 4.4 The change of weight with drying time on hot air velocity of 4 m/s

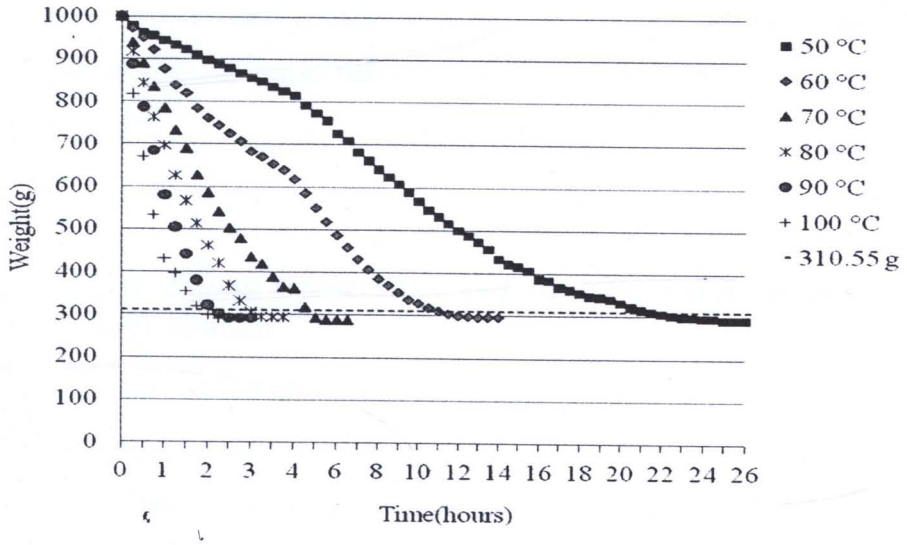

Figure 4.5 The change of weight with drying time on hot air velocity of 5 m/s

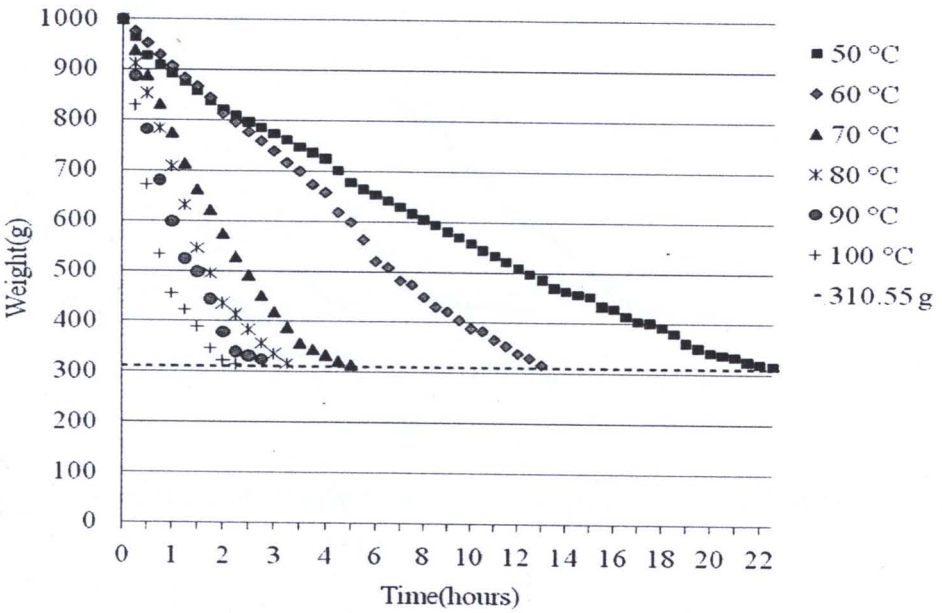

Figure 4.6 The change of weight with drying time on hot air velocity of 6 m/s

The results shown in Figure 4.4, 4.5 and 4.6 as a result, the drying temperature and velocity of hot air on the change of weight of pepper after drying process shows that the temperature of the hot air and increased the velocity of hot air would decrease

the weight of chili decreased continuously and even higher temperatures, drying time less. By weight in the drying in this experiment was 310.55 g. as weight is moisture was 13% wet basis.

4. Results of drying temperature and velocity of hot air that effect to the change of moisture content

Effects of drying temperature and velocity of hot air on the moisture content changes--under experimental conditions, at 50 60 70 80 90 and 100 °C with hot air velocity 4, 5 and 6 m/s. Results were shown in the Figure 4.7 to 4.9.

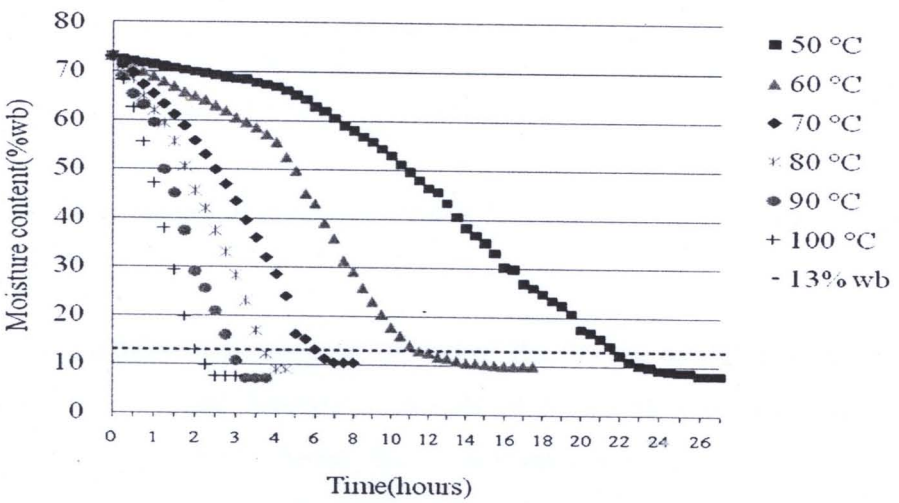

Figure 4.7 The change of moisture content with drying time on hot air velocity of 4 m/s

Changing of the moisture content of the drying air temperature of 50, 60, 70, 80, 90 and 100 °C and velocity of hot air of 4 m/s as shown in Fig.4.7 and found that—drying time equal 27 hours, the final moisture content of 8.19% on wet basis, drying time equal 17 hours 30 minute, the final moisture content of 9.96% on wet basis, drying time equal 8 hours, the final moisture content of 10.47% on wet basis, drying time equal 4 hours 30 minute, the final moisture content of 8.90% on wet basis, drying time equal 3 hours 45 minute, the final moisture content of 7.14% on

wet basis and drying time equal 3 hours, the final moisture content of 7.45% on wet basis respectively. And found that when the drying temperature increased the drying time is reduced. All results are final moisture content of less than 13% on wet basis--the standard moisture content of dried chili is sold in the market.

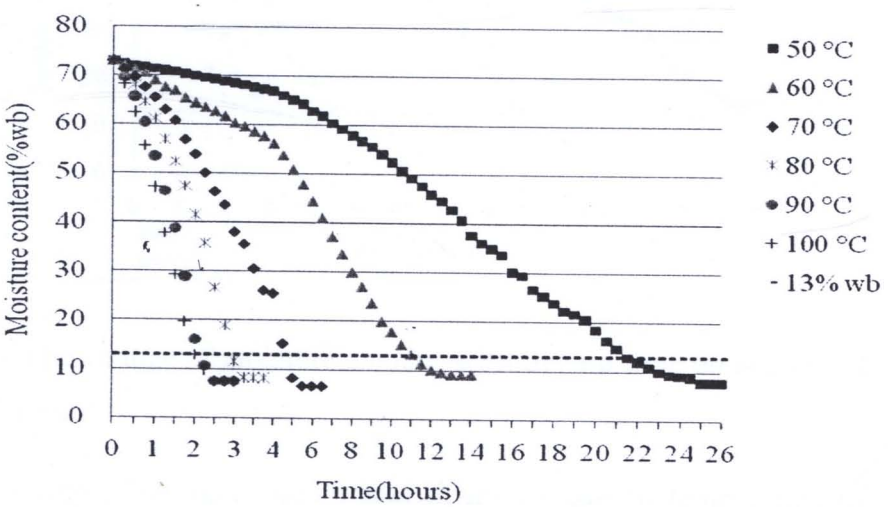

Figure 4.8 The change of moisture content with drying time on hot air velocity of 5 m/s

Changing of the moisture content of the drying air temperature of 50, 60, 70, 80, 90 and 100 °C and velocity of hot air of 5 m/s as shown in Fig.4.8 and found that—drying time equal 26 hours, the final moisture content of 7.79% on wet basis, drying time equal 14 hours, the final moisture content of 9.24% on wet basis, drying time equal 6 hours, the final moisture content of 6.53% on wet basis, drying time equal 3 hours 45 minute, the final moisture content of 8.17% on wet basis, drying time equal 3 hours, the final moisture content of 7.54% on wet basis and drying time equal 2 hours 45 minute, the final moisture content of 7.14% on wet basis respectively. And found that when the drying temperature increased the drying time is reduced. All results are final moisture content of less than 13% on wet basis--the standard moisture content of dried chili is sold in the market.

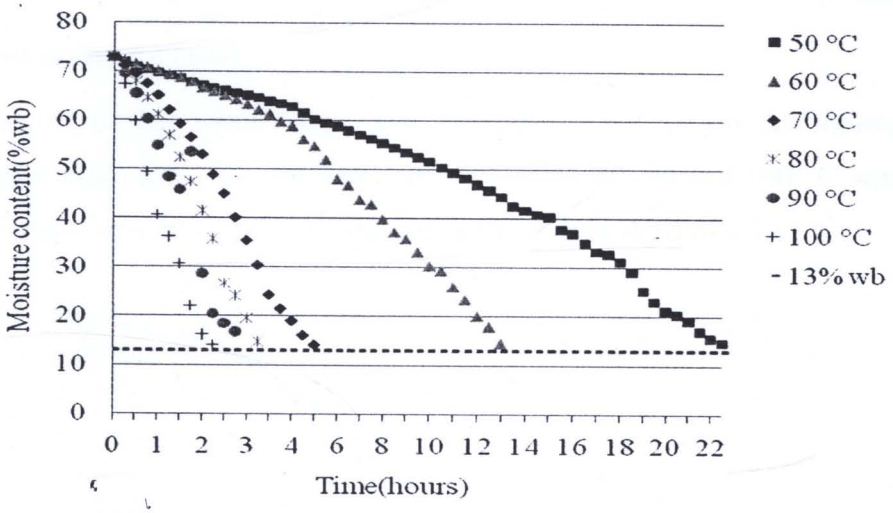

Figure 4.9 The change of moisture content with drying time on hot air velocity of 6 m/s

Changing of the moisture content of the drying air temperature of 50, 60, 70, 80, 90 and 100 °C and velocity of hot air of 6 m/s as shown in Fig.4.9 and found that—drying time equal 22 hours 30 minute, the final moisture content of 14.72% on wet basis, drying time equal 13 hours, the final moisture content of 13.37% on wet basis, drying time equal 5 hours, the final moisture content of 11.82% on wet basis, drying time equal 3 hours 15 minute, the final moisture content of 16.63% on wet basis, drying time equal 2 hours 45 minute, the final moisture content of 16.78% on wet basis and drying time equal 2 hours 15 minute, the final moisture content of 12.19% on wet basis respectively. It was found that when the drying temperature increased the time spent on drying is reduced in all experiments after that final moisture content was greater than the standard in contrast, at 70 ° C and 100 ° C with final moisture content lower than the standard moisture content. In this experiment also showed that hot air velocity of 6 m/s--resulting in the pepper move away from drying chamber before a final moisture content of less than or equal to the standard moisture content.

5. Results of drying temperature and velocity of hot air that effect to the change of moisture ratio

Effects of drying temperature and velocity of hot air on the moisture ratio changes--under experimental conditions, at 50, 60, 70, 80, 90 and 100 °C with hot air velocity 4, 5 and 6 m/s. Results were shown in the Figure 4.10 to 4.12.

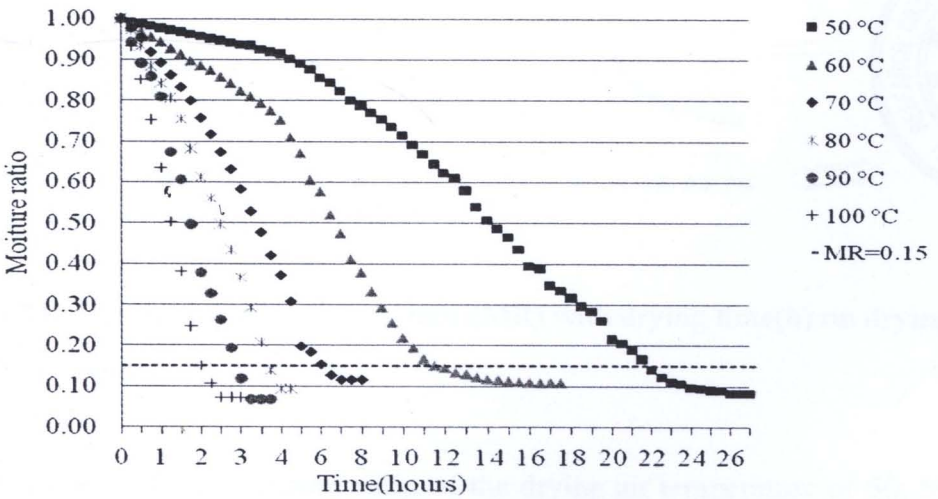

Figure 4.10 The change of moisture ratio(MR) with drying time(h) on drying air velocity of 4 m/s

Changing of the moisture ratio of the drying air temperature of 50, 60, 70, 80, 90 and 100 ° C and velocity of hot air of 4 m/s as shown in Fig.4.10 and found that—drying time equal 27 hours, the final moisture ratio of 0.083 on wet basis, drying time equal 17 hours 30 minute, the final moisture ratio of 0.108 on wet basis, drying time equal 8 hours, the final moisture ratio of 0.116 on wet basis, drying time equal 4 hours 30 minute, the final moisture ratio of 0.093 on wet basis, drying time equal 3 hours 45 minute, the final moisture ratio of 0.068 on wet basis and drying time equal 3 hours, the final moisture ratio of 0.073 on wet basis respectively. And found that when the drying temperature increased the drying time is reduced and shows the change of moisture ratio decreased continued. All results are final moisture ratio of less than 0.15 on wet basis.

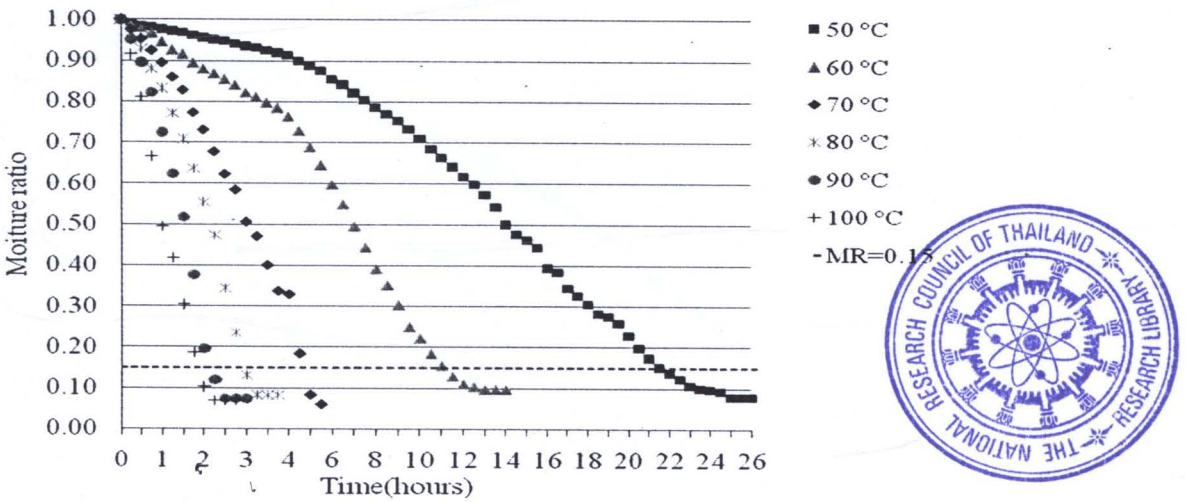

Figure 4.11 The change of moisture ratio(MR) with drying time(h) on drying air velocity of 5 m/s

Changing of the moisture ratio of the drying air temperature of 50, 60, 70, 80, 90 and 100 °C and velocity of hot air of 5 m/s as shown in Fig.4.11 and found that— drying time equal 26 hours, the final moisture ratio of 0.078 on wet basis, drying time equal 14 hours, the final moisture ratio of 0.098 on wet basis, drying time equal 6 hours, the final moisture ratio of 0.060 on wet basis, drying time equal 3 hours 45 minute, the final moisture ratio of 0.083 on wet basis, drying time equal 3 hours, the final moisture ratio of 0.074 on wet basis and drying time equal 2 hours 45 minute, the final moisture ratio of 0.068 on wet basis respectively. And found that when the drying temperature increased the drying time is reduced and shows the change of moisture ratio decreased continued. All results are final moisture ratio of less than 0.15 on wet basis. All results are final moisture content of less than 0.15 on wet basis-- the standard moisture ratio of dried chili is sold in the market.

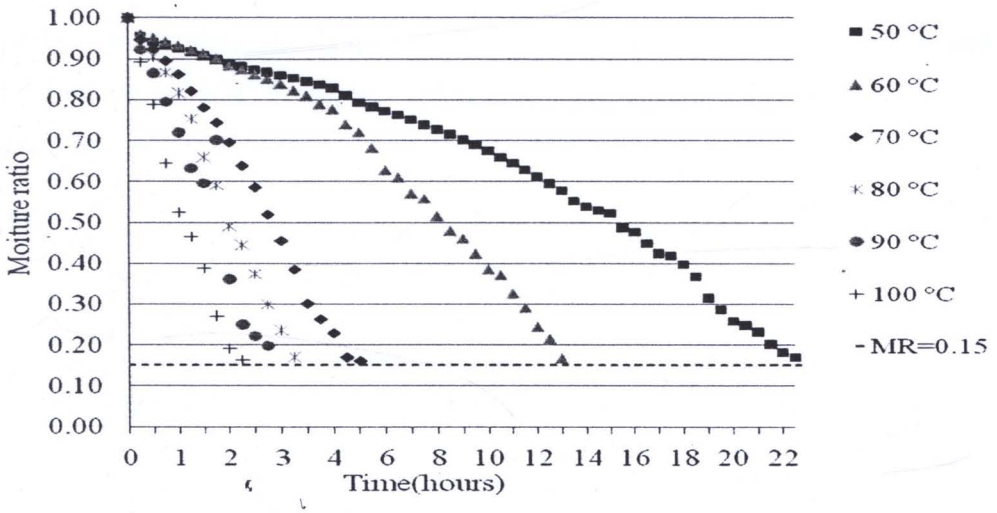

Figure 4.12 The change of moisture ratio(MR) with drying time(h) on drying air velocity of 6 m/s

Changing of the moisture ratio of the drying air temperature of 50, 60, 70, 80, 90 and 100 °C and velocity of hot air of 6 m/s as shown in Fig.4.12 and found that—drying time equal 22 hours 30 minute, the final moisture ratio of 0.017 on wet basis, drying time equal 13 hours, the final moisture ratio of 0.169 on wet basis, drying time equal 5 hours, the final moisture ratio of 0.161 on wet basis, drying time equal 3 hours 15 minute, the final moisture ratio of 0.171 on wet basis, drying time equal 2 hours 45 minute, the final moisture ratio of 0.199 on wet basis and drying time equal 2 hours 15 minute, the final moisture ratio of 0.162 on wet basis respectively. It was found that when the drying temperature increased the time spent on drying is reduced in all experiments after that final moisture ratio was greater than the standard in contrast.

The results from Figure 4.4 to 4.12. showed that the temperature on the reduction of weight of pepper, changes of moisture content and moisture ratio of chili. In this experiment to try to move until all of the pepper out of the dryer chamber. In fact pepper is the weight down to a weight that is considered a standard weight to moisture—13% wet basis or a few lower or moisture ratio of 0.15. From the weight of the chili was 1000 g. once through the dryer until the moisture content of

moisture was reported as 310.55 grams. So, the authors present data obtained from the experimental results of drying temperature during drying with 6 levels and 3 levels of hot air velocity, add to article 3, 4 and 5. The results can be displayed as shown in Table 4.1.

Table 4.1 Results of drying temperature with drying time(close to standard moisture content 13% wet basis and moisture ratio = 0.15)

Drying temperature(°C)	Moisture content(%wb)			Drying time(hours)		
	4 m/s	5 m/s	6 m/s	4 m/s	5 m/s	6 m/s
50	12.26	12.96	14.72	22.00	21.50	22.50
60	12.95	11.46	14.60	11.50	11.50	13.00
70	11.28	12.24	14.07	6.50	5.00	5.00
80	12.19	11.63	14.79	3.75	3.00	3.25
90	10.73	10.74	16.78	3.00	2.25	2.75
100	12.91	12.48	14.14	2.00	2.00	2.25

Table 4.1 showed that the period of drying chili will be decreased when the temperature of drying up. Moisture content of the pepper is decreased continuously and significantly lower than or close to 13% wb. At velocity of hot air of 4 and 5 m/s with similar results. Different from the results of hot air velocity 6 m/s. Chili will be reduced to less moisture, moisture content standard and drying over time as high-speed convection oven out of the chamber prior to the exchange of heat with chili. Therefore, the chili has a higher moisture content standards.

6. Results of drying temperature and velocity of hot air that effect to the change of moisture ratio at bed thickness of 2, 3, 4 and 5 cm

In addition to the drying experiment at 1000 g, drying temperature of 50, 60, 70, 80, 90 and 100 °C and hot air velocity 4, 5 and 6 m/s. Researchers have studied the effect of bed thickness on the changes in moisture content and moisture ratio. The experimental conditions bed thickness of 2, 3, 4 and 5 cm at drying temperature of 80, 90 and 100 ° C and hot air velocity 4, 5 and 6 m/s . The experimental results are shown in Figure 4.13 to 4.15.

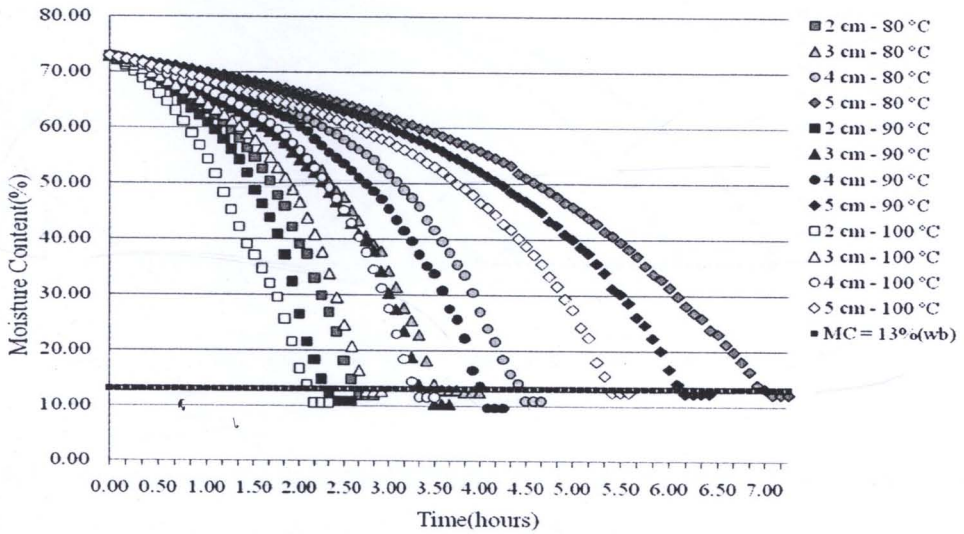

Figure 4.13 The change of moisture content with drying time on hot air velocity of 4 m/s at bed thickness of 2, 3,4 and 5 cm

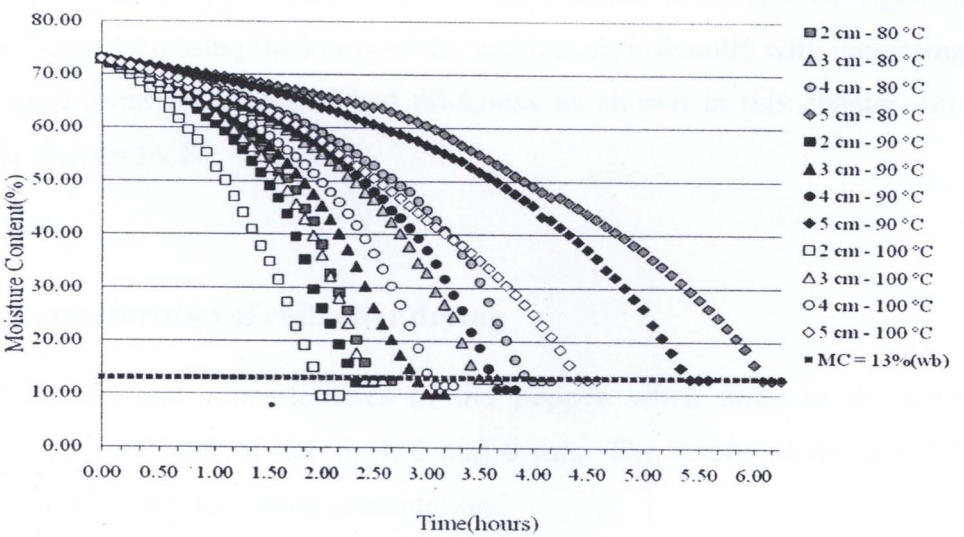

Figure 4.14 The change of moisture content with drying time on hot air velocity of 5 m/s at bed thickness of 2, 3,4 and 5 cm

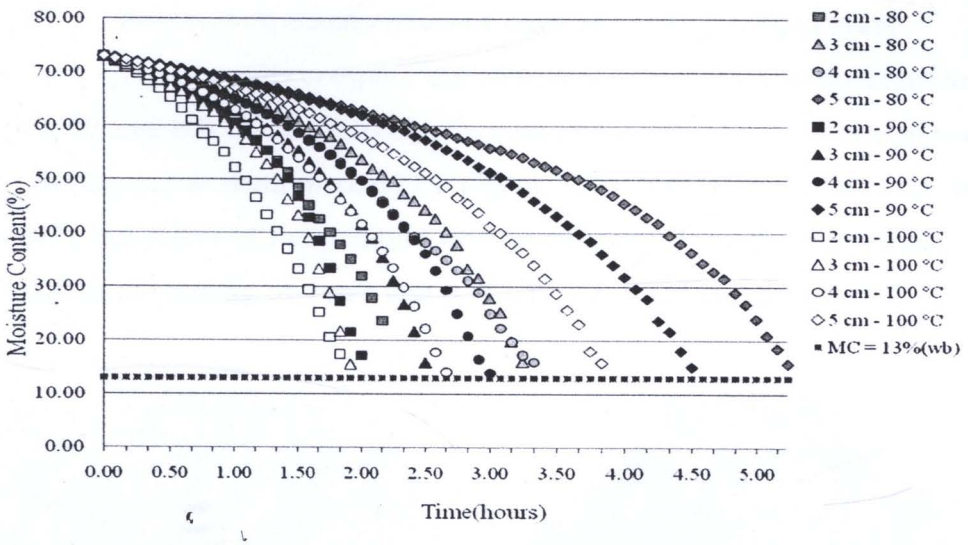

Figure 4.15 The change of moisture content with drying time on hot air velocity of 6 m/s at bed thickness of 2, 3, 4 and 5 cm

The results of bed thickness on the change of moisture content with drying time can be show in Figure 4.13, 4.14 and 4.15. It was found that when the bed thickness greater influence of humidity changes directly.The results were in a hot air velocity 4 m/s and 5 m/s--the final moisture content of the pepper that is lower than the standard 13% on wet basis which different from hot air velocity was 6 m/s. Final moisture content is higher than 13% wet basis which is considered higher than the standard. Also, increasing thickness of the bed has significantly with increasing drying time. Apart from the effect of bed thickness as shown in this chapter--the results shown in Appendix E.

7. Characteristics of chili after drying

The physical characteristics of the pepper when dried in the temperature conditions and velocity of hot air 4, 5 and 6 m/s. The results of the dried chili that looks different as the following presentation.

7.1 Physical characteristics of chili at various temperature

These results compare the change in temperature at different levels 50, 60, 70, 80, 90 and 100 °C respectively. Compares the physical characteristics of the pepper after drying as demonstrated by Figure 4.16 to 4.21. In this chapter the author present only the effect of temperature on the changes at the hot air velocity of 5 m/s and the results at velocity of 4 m/s and 6 m/s is presented in Appendix G.

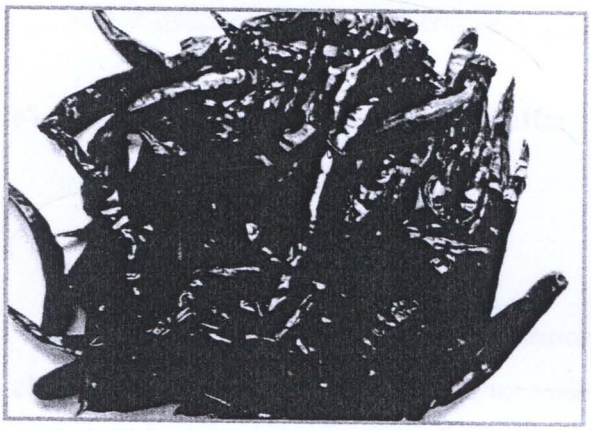

Figure 4.16 Characteristics of chili after drying at 50 °C

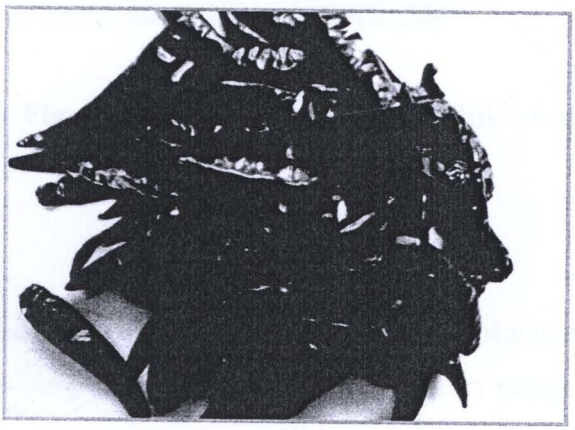

Figure 4.17 Characteristics of chili after drying at 60 °C

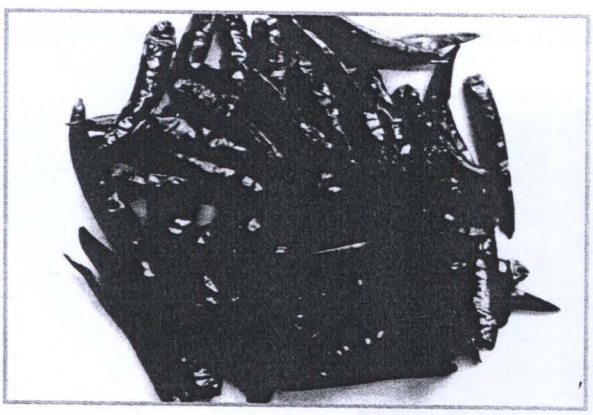

Figure 4.18 Characteristics of chili after drying at 70 °C

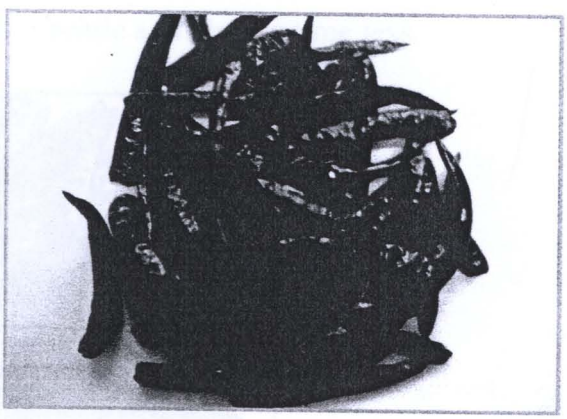

Figure 4.19 Characteristics of chili after drying at 80 °C

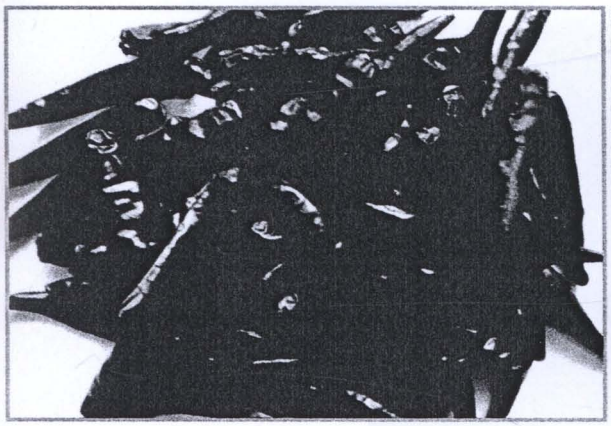

Figure 4.20 Characteristics of chili after drying at 90 °C

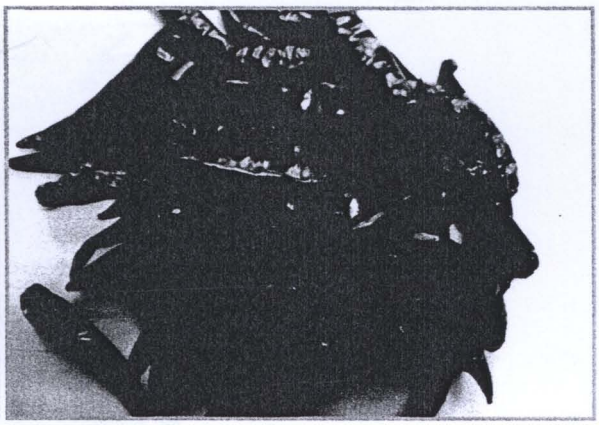

Figure 4.21 Characteristics of chili after drying at 100 °C

Figure 4.16 to 4.21 can be concluded that temperature affects the physical characteristics of the pepper such as color pepper, grain moisture content in pepper and Chili is not hard or brittle. If the drying temperature low will be seen that the red pepper seed and hard brittle but it will take longer to drying. If the temperature is too high, the color of the chili is dark red and hard and brittle with a burning smell. Therefore, based on physical characteristics of the treated dried chili in this study, the optimum temperature for drying chili was 90 °C. Because the color of the seed, red pepper, fresh and glossy surface, non-rigid or brittle and drying time less.

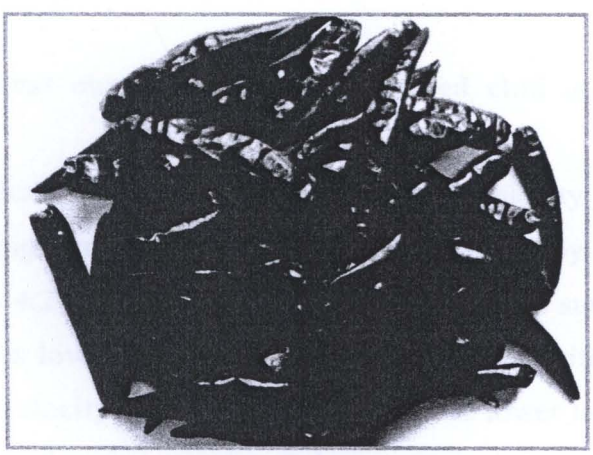

Figure 4.22 Characteristics of chili after drying at 90 °C and hot air velocity of 4 m/s

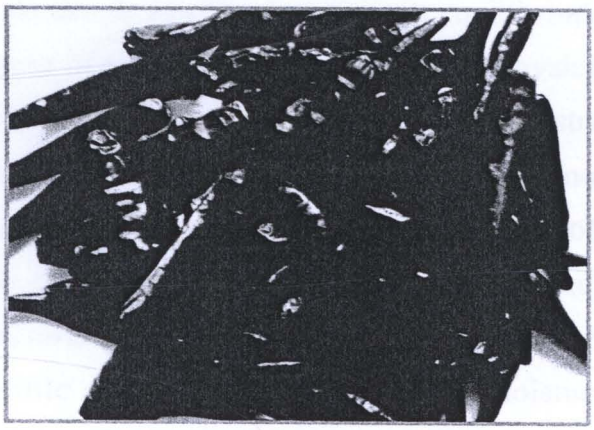

Figure 4.23 Characteristics of chili after drying at 90 °C and hot air velocity of 5 m/s

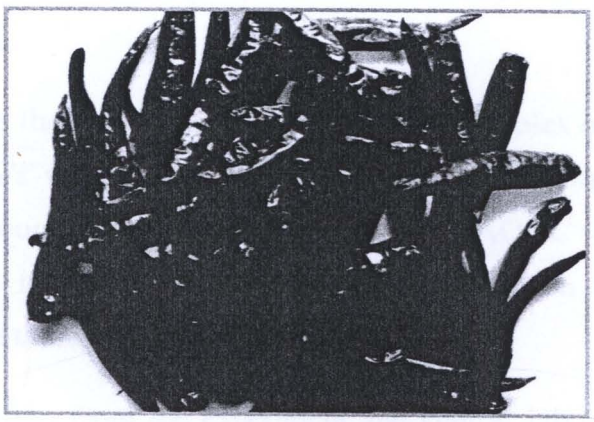

Figure 4.24 Characteristics of chili after drying at 90 °C and hot air velocity of 6 m/s

7.2 Physical characteristics of the dried chili at different of hot air velocity

Physical characteristics when hot air velocity of 4, 5 and 6 m/s respectively, at drying temperatures of 90 °C demonstrated by Figure 4.22, 4.23 and 4.24. Figure 4.22 to 4.24 showed that hot air will affect the surface of the pepper. If the hot air velocity is low the surface of the hot pepper is quite smooth, straight and shiny. If the hot air velocity of chili seed will not move lower from the chamber when the moisture content of grain pepper to balance. If the hot air speed is too high, hot pepper will make the skin will wrinkle. Chili in a less direct and humidity, it will remain because the hot air velocity is too high, pepper will move out of the chamber

before the moisture in the dried chili seed to reach equilibrium. Therefore concluded that the hot air velocity of 5 meters per second with the physical characteristics of the grain surface of the chili pepper best it can be quite smooth, straight and shiny. When the moisture balance and chili pepper to the point they are moving out of the drying chamber. In this study, criteria for determining the suitability of dried chili continuous using drying process must have a moisture content not exceeding 13% on wet basis. The physical characteristics are required by the market—red color, shiny skin, straight, not hard brittle and no burning smell. If the moisture content in grain and pepper to balance, chili will be moving out of the drying chamber and drying time is less.

7.3 The results of experiment and central laboratory (Thailand) Ltd., Khon Kaen branch

After the experiment(1 month ago), 6 samples of dried chili on drying air velocity of 5 m/s were determined the final moisture content (g/100 g) on wet basis and the compound capsaicin by HPLC based on AOAC (2005) 995.03 in house method. In central laboratory (Thailand) Ltd., Khon Kaen branch which the test results shown in the table.

Table 4.2 The results from the experiment and central laboratory (Thailand) Ltd., Khon Kaen branch

Drying Temperature(°C)	Moisture Content (g/100g) Central laboratory	Compound Capsaicin (g/100g) Central laboratory	Drying time (hours)		
			4 m/s	5 m/s	6 m/s
50	9.40	0.25	27.00	26.00	22.50
60	10.67	0.24	17.50	14.00	13.00
70	6.71	0.25	8.00	6.00	5.00
80	9.12	0.19	4.50	3.75	3.25
90	8.08	0.23	3.75	3.00	2.75
100	7.88	0.19	3.00	2.75	2.25

The result shown in Table 4.2 found that moisture content of dried chili(central laboratory) was higher as it was lower than 13%(standard moisture content of chili). Consequently, the decrease of moisture content affected the increase

of capsaicin quantity of dried chili compared to fresh chili. The experimental result showed drying time decreased with the increasing of drying temperature and drying air velocity as shown in Fig. 4.7, 4.8 and 4.9. The characteristics results as shown in Fig. 4.19-4.24, it also found that the suitable condition for drying process was 90°C of drying chamber's temperature and the drying air velocity at 5 m/s.

The result of drying of capsicum based on continuous fluidized-bed dryer revealed that the drying time decreased from 27 h (50°C and 4 m/s) to 2 h 25 min (100°C and 6 m/s) when drying air temperature increased from 50, 60, 70, 80, 90 to 100°C, and drying air velocity increased from 4-6 m/s, respectively(Table 4.2). The change of moisture content of chili on wet basis from the experiment using the dryer machine (Fig.1) showed that on drying air velocity of 4 m/s, 5 m/s and 6 m/s, the chili's initial weight was 1000 g, and final weight was 292.25 g. Moreover, it contained the moisture content of 7.54% (wb) from experiment and 8.08% (wb) from central laboratory. The capsaicin quantity of dried chili on drying air velocity of 5 m/s and drying temperature of 50, 60, 70, 80, 90 and 100 °C were 0.25, 0.24, 0.23, 0.19, 0.23 and 0.19 g/100 g, respectively. The capsaicin quantity of fresh chili on initial moisture content of 72.98% (wb) were 0.07 g/100 g. The result was certificated by Central Laboratory (Thailand) Ltd., Khon Kaen Branch: Nai Muang, Khon Kaen Thailand. The results about the amount of capsaicin substance at this during the drying temperature 50-70 °C -- dried chili is capsaicin concentration than in the higher temperature(80-100 °C). This is consistent with the findings of S. Kalleemulah and R. Kailappan(2005)--the experiment using a rotary dryer found that pepper is capsaicin concentration in large quantities at the drying temperature of 50-60 °C with drying time of 32 up to 23 hours.

In addition, with the duration of 3 h, the chili's physical characteristics would turn into red, flat and shiny, crispy and no burning smell-showed in Fig. 4.23. It was found that the drying temperature affected the decrease of chili's weight and moisture content. The drying air velocity affected on the fluidized bed particles movement and the chili's continuous migration outwards the drying chamber.