CHAPTER VII

QUALITY VARIATION MANAGEMENT IN DRYING PROCESS WITHIN A CONSTANT DRYING RATE PHASE

After heating the raw materials within the first drying phase, the heated raw materials are transferred to the second phase of the drying process. The heated raw materials are dried to reduce the moisture content to the target shown in Chapter 3. They are dried with a constant drying rate. Thus, quality variation management in the drying process within a constant drying rate phase is studied in this chapter as Figure 7.1. The first aim of this chapter is to find the optimal temperature levels for drying the heated raw materials within a constant drying rate phase. Furthermore, the second aim is to construct the mathematical models for representing the behavior of the moisture content during the drying with a constant rate phase.

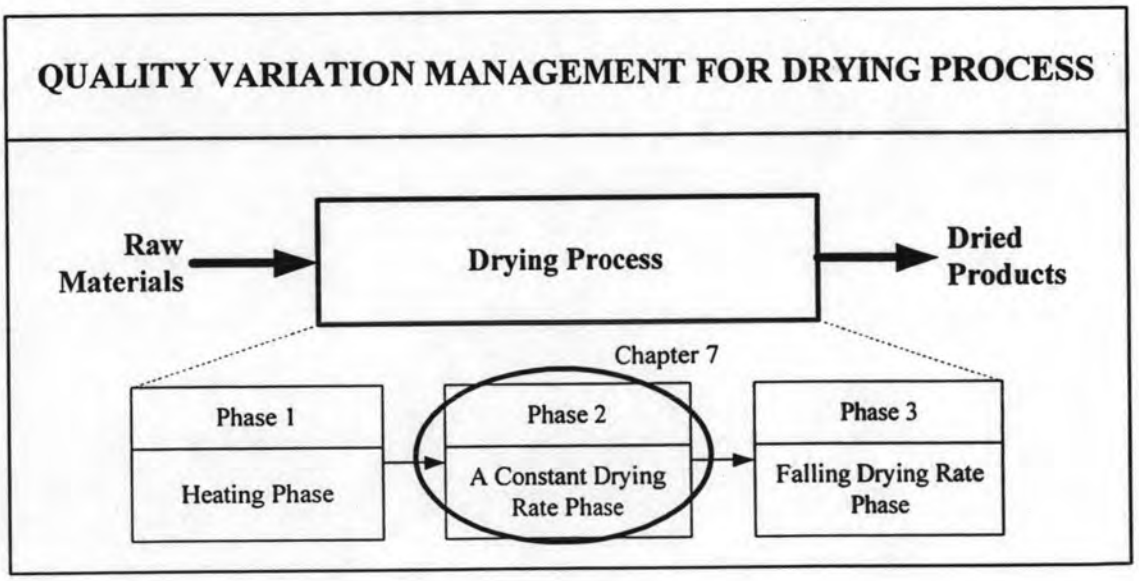

Figure 7.1 Scope of quality variation management in drying process within a constant drying rate phase

The outline of this chapter is organized into five sections. In Section 7.1 to 7.4, experimental results of paddy rice, cassava chip, tobacco, and longan are explained and discussed respectively. In each section, drying temperature is varied to find the optimal drying temperature level; moreover, the mathematical models are constructed to represent the relationship between the moisture content and drying time. In the last section 7.5, all experimental results are concluded and summarized.

7.1 Experimental Results of Paddy Rice

In this phase, paddy rice is dried within five minutes by varying levels of drying temperature. The target of the moisture content after drying is desired to 19.0% w.b. The experimental results are shown as following clustering of the raw materials.

7.1.1 Low Moisture Content

Paddy rice within low moisture content is sampled at an average initial moisture content of 23.9% w.b. It is dried with varying levels of temperature at 100, 110, and 120°C. The experimental results are explained as below.

(1) Drying Temperature Level at 100°C

From Figure 7.2, the moisture content of paddy rice is reduced continuously with a constant drying rate. The constant drying rate of this drying temperature level is an average of 0.8% w.b./minute. However, the moisture content after drying is 19.5% w.b. It is not equaled to 19.0% w.b. Moreover *MSD* is equaled to 0.361 (% w.b.)^2.

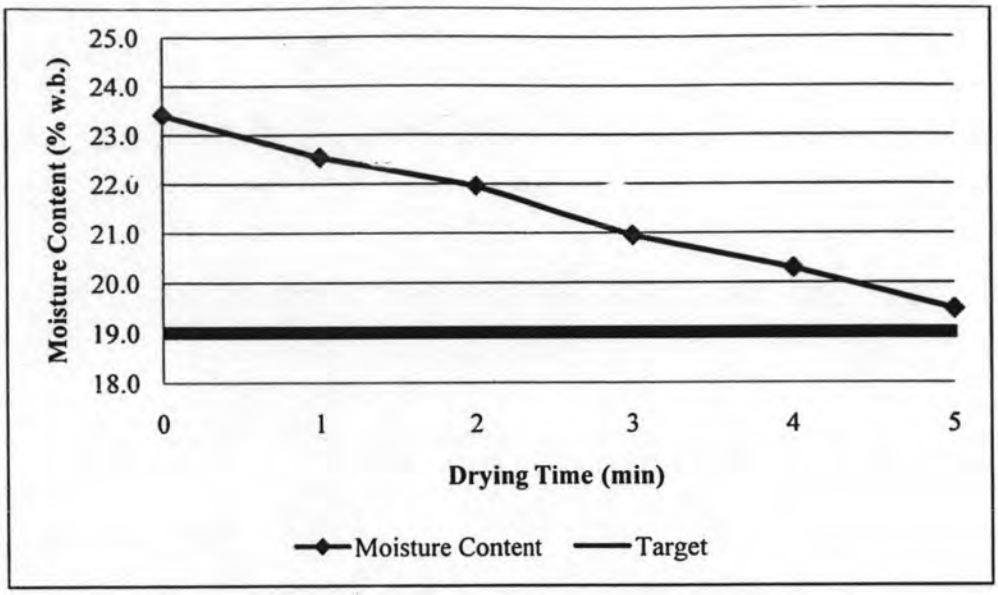

Figure 7.2 Drying result of paddy rice within low moisture content at 100°C

(2) Drying Temperature Level at 110°C

From Figure 7.3, the moisture content of paddy rice is reduced continuously with a constant drying rate. The constant drying rate of this drying temperature level is an average of 0.9% w.b./minute. After drying, the moisture content is 19.1% w.b. It is near to 19.0% w.b. Moreover *MSD* is equaled to 0.095 (% w.b.)^2.

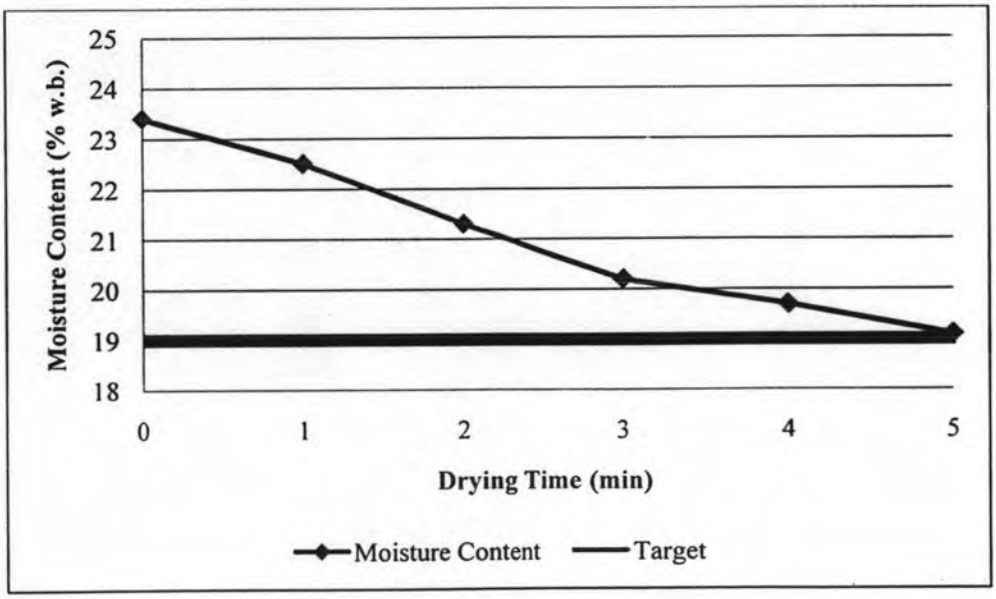

Figure 7.3 Drying result of paddy rice within low moisture content at 110°C

(3) Drying Temperature Level at 120°C

From Figure 7.4, the moisture content of paddy rice is reduced continuously with a constant drying rate. The constant drying rate of this drying temperature level is an average of 1.0% w.b./minute. However, the moisture content after drying is 18.8% w.b. It is less than 19.0% w.b. Moreover *MSD* is equaled to 0.204 (% w.b.)^2.

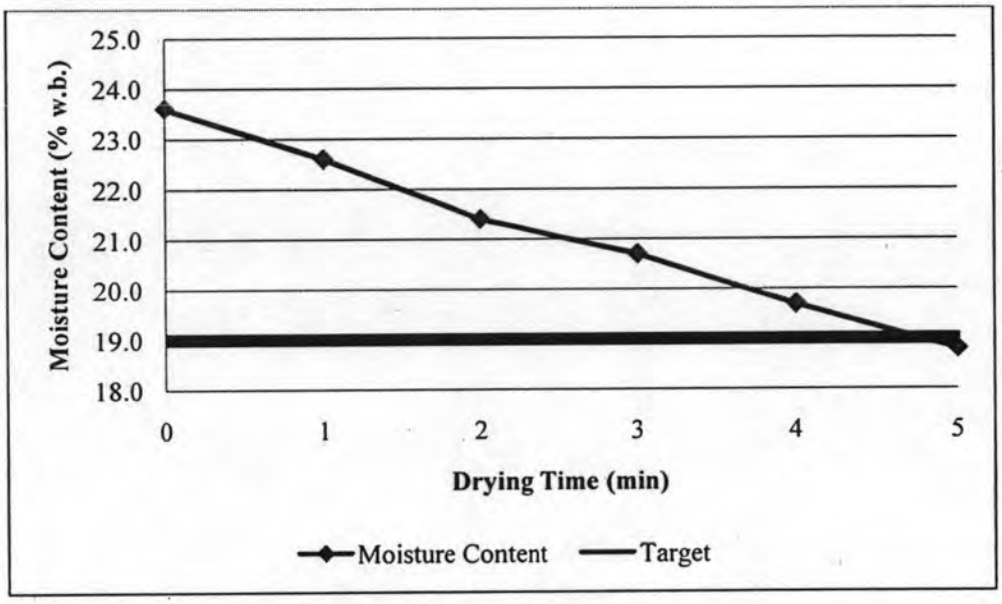

Figure 7.4 Drying result of paddy rice within low moisture content at 120°C

(4) Selecting Optimal Drying Temperature Level

Minimum *MSD* is a criterion to select the optimal drying temperature level. From all experimental results, their *MSD*s are plotted in Figure 7.5. It shows that minimum *MSD* is from drying temperature level at 110°C. Therefore, the optimal temperature level for drying paddy rice within low moisture content is at 110°C.

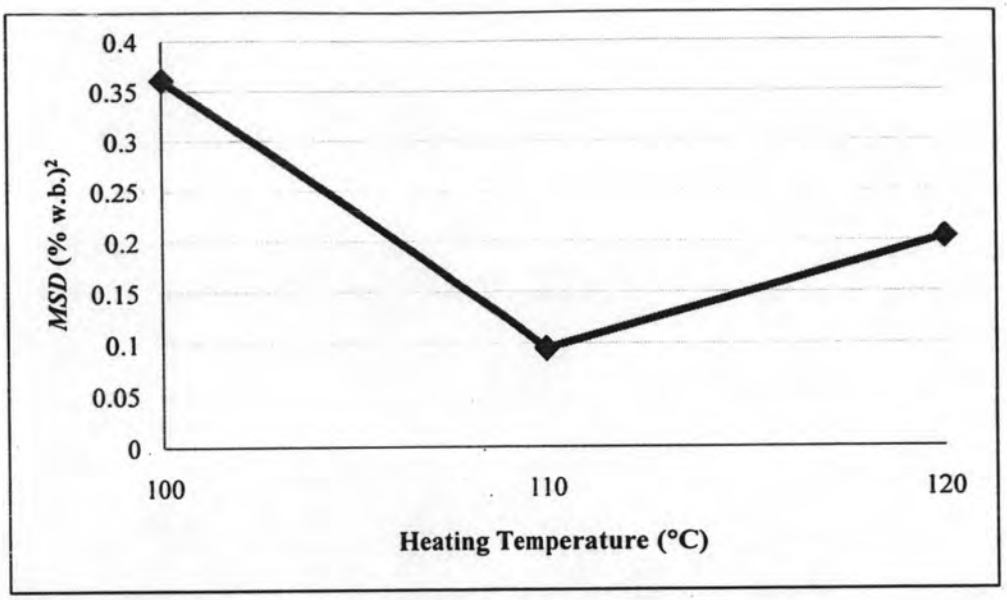

Figure 7.5 *MSD* from drying paddy rice with a constant drying rate within low moisture content

(5) Constructing Mathematical Model

After selecting the optimal drying temperature level, the mathematical model for drying paddy rice within low moisture content is constructed by Matlab program with function *polyfit*. As a result, the mathematical model is shown as Equation (7.1).

$$M(t)_2 = 23.4 - 0.919t, \qquad 0 \le t \le 5 \qquad (7.1)$$

where

$M(t)_2$ = the moisture content during a constant drying rate phase at time t

t = drying time in minutes

7.1.2 Medium Moisture Content

Paddy rice within medium moisture content is sampled at an average initial moisture content of 27.6% w.b. It is dried with varying levels of temperature at 115, 120, and 125°C. The experimental results are explained as below.

(1) Drying Temperature Level at 115°C

From Figure 7.6, the moisture content of paddy rice is reduced continuously with a constant drying rate. The constant drying rate of this drying temperature level is an average of 1.4% w.b./minute. However, the moisture content after drying is 19.5% w.b. It is not equaled to 19.0% w.b. Moreover *MSD* is equaled to 0.305 (% w.b.)^2.

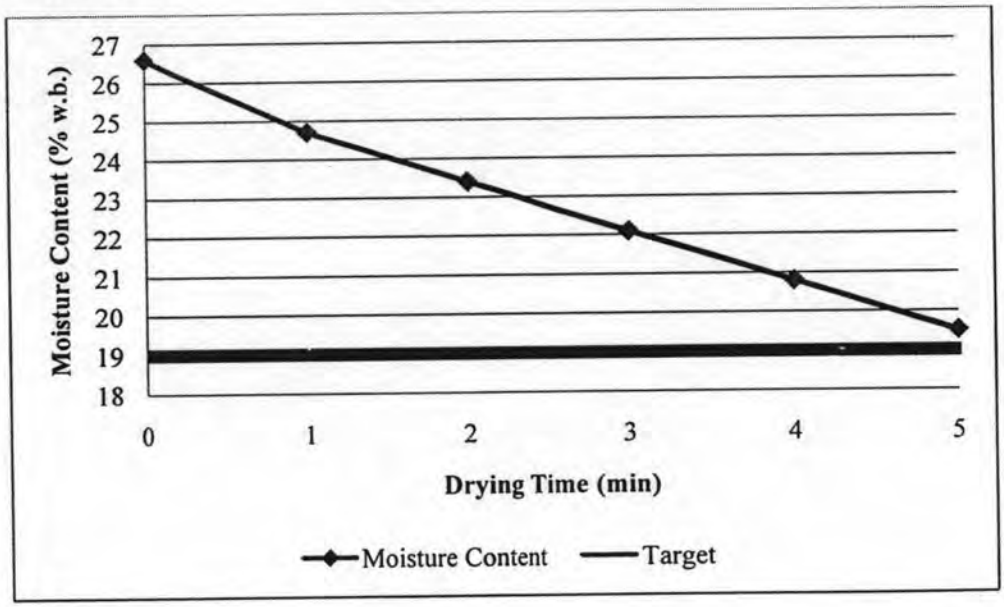

Figure 7.6 Drying result of paddy rice within medium moisture content at 115°C

(2) Drying Temperature Level at 120°C

From Figure 7.7, the moisture content of paddy rice is reduced continuously with a constant drying rate. The constant drying rate of this drying temperature level is an average of 1.5% w.b./minute. However, the moisture content after drying is 19.1% w.b. It is near to 19.0% w.b. Moreover *MSD* is equaled to 0.060 (% w.b.)^2.

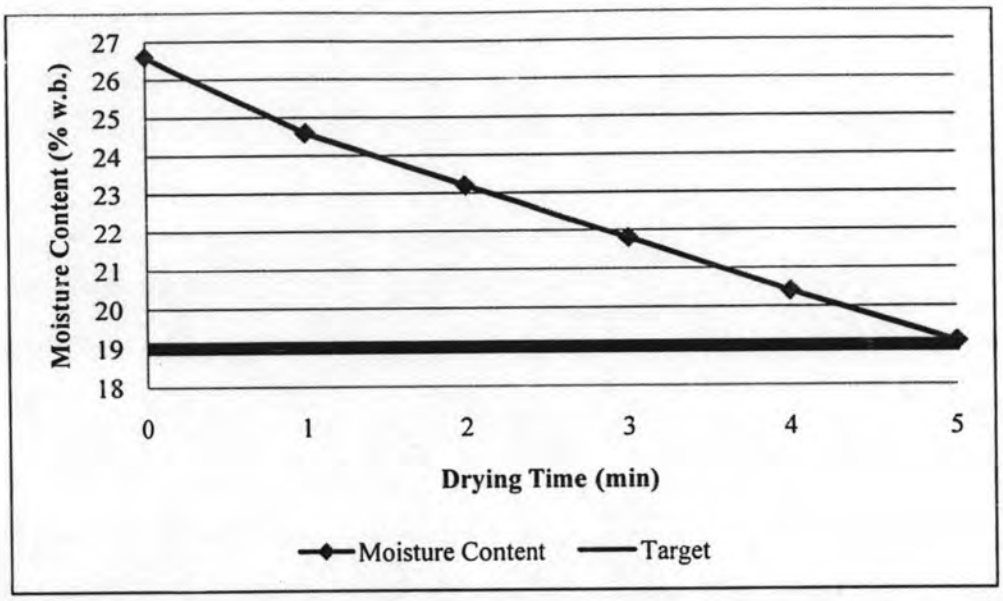

Figure 7.7 Drying result of paddy rice within medium moisture content at 120°C

(3) Drying Temperature Level at 125°C

From Figure 7.8, the moisture content of paddy rice is reduced continuously with a constant drying rate. The constant drying rate of this drying temperature level is an average of 1.6% w.b./minute. However, the moisture content after drying is 18.4% w.b. It is less than 19.0% w.b. Moreover *MSD* is equaled to 0.370 (% w.b.)^2.

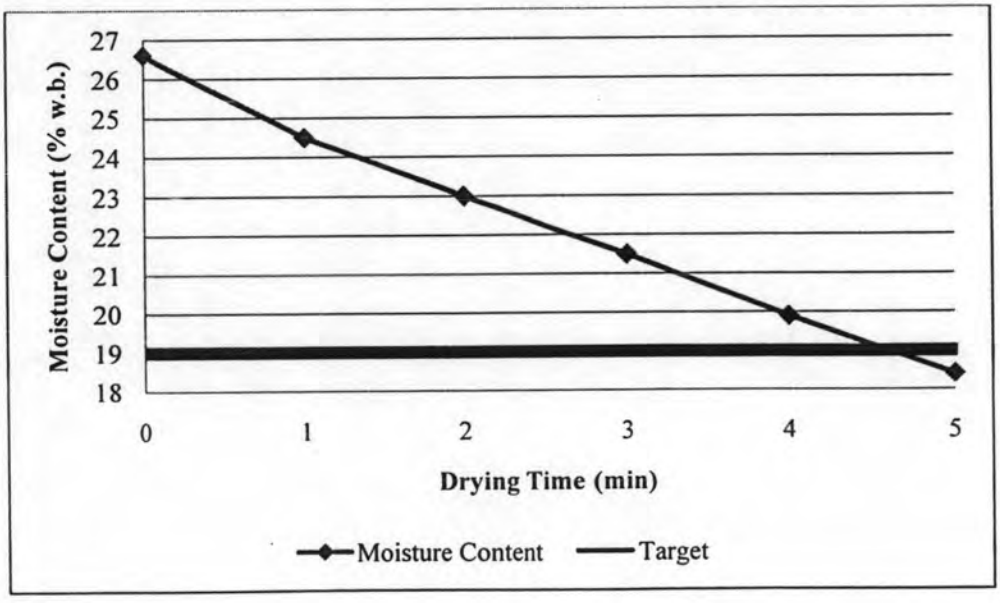

Figure 7.8 Drying result of paddy rice within medium moisture content at 125°C

(4) Selecting Optimal Drying Temperature Level

Minimum *MSD* is a criterion to select the optimal drying temperature level. From all experimental results, their *MSD*s are plotted in Figure 7.9. It shows that minimum *MSD* is from drying temperature level at 120°C. Therefore, the optimal temperature level for drying paddy rice within medium moisture content is at 120°C.

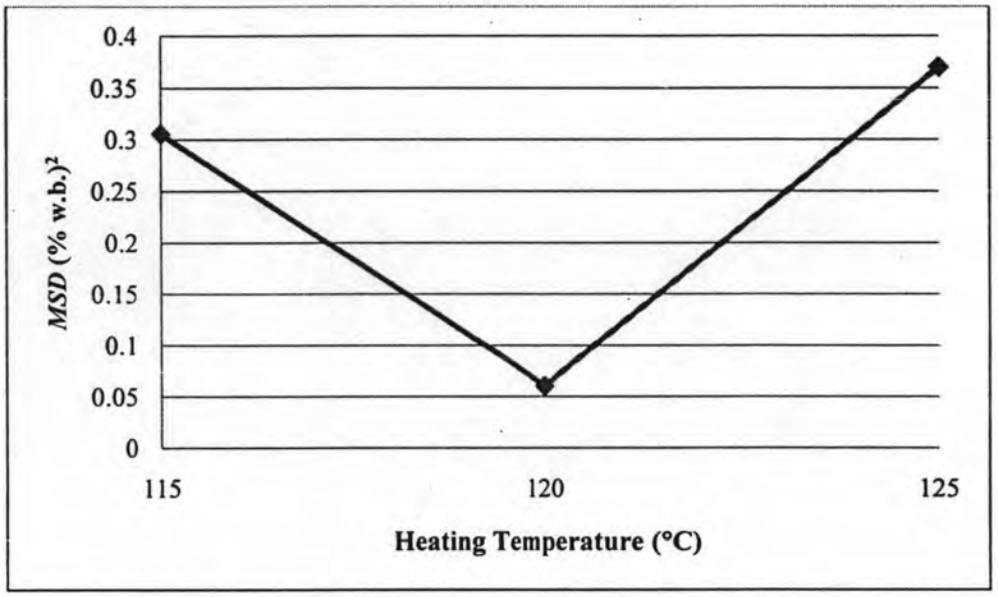

Figure 7.9 *MSD* from drying paddy rice with a constant drying rate within medium moisture content

(5) Constructing Mathematical Model

After selecting the optimal drying temperature level, the mathematical model for drying paddy rice within medium moisture content is constructed by Matlab program with function *polyfit*. As a result, the mathematical model is shown as Equation (7.2).

$$M(t)_2 = 26.1 - 1.42t, \qquad 0 \le t \le 5 \qquad (7.2)$$

7.1.3 High Moisture Content

Paddy rice within high moisture content is sampled at an average initial moisture content of 27.8% w.b. It is dried with varying levels of temperature at 120, 125, and 130°C. The experimental results are explained as below.

(1) Drying Temperature Level at 120°C

From Figure 7.10, the moisture content of paddy rice is reduced continuously with a constant drying rate. The constant drying rate of this drying temperature level is an average of 1.7% w.b./minute. However, the moisture content after drying is 19.1% w.b. It is near to 19.0% w.b. Moreover *MSD* is equaled to 0.032 (% w.b.)^2.

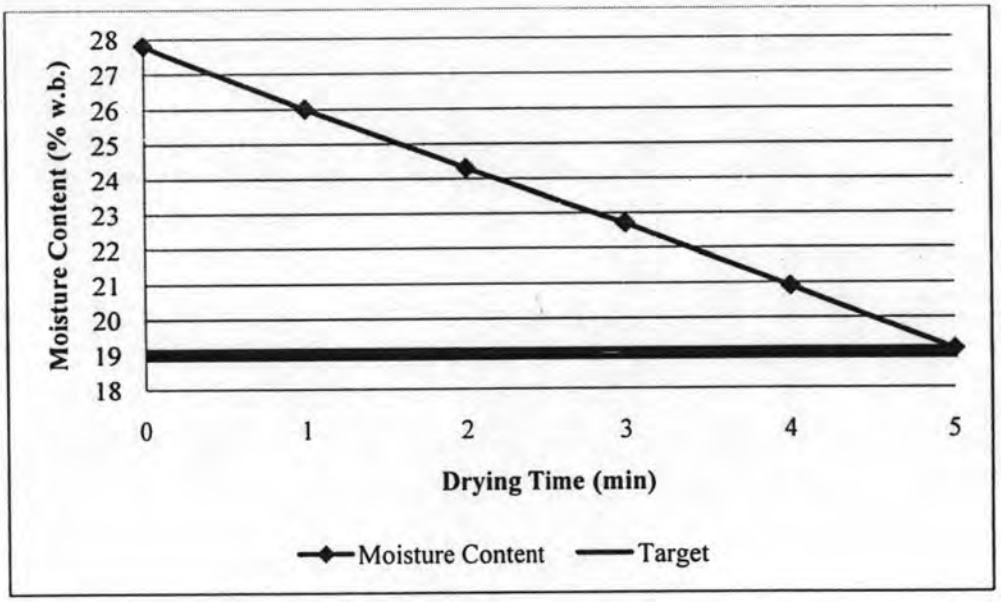

Figure 7.10 Drying result of paddy rice within high moisture content at 120°C

(2) Drying Temperature Level at 125°C

From Figure 7.11, the moisture content of paddy rice is reduced continuously with a constant drying rate. The constant drying rate of this drying temperature level is an average of 1.8% w.b./minute. However, the moisture content after drying is 19.0% w.b. equaled to the target. Moreover *MSD* is equaled to 0.009 (% w.b.)^2.

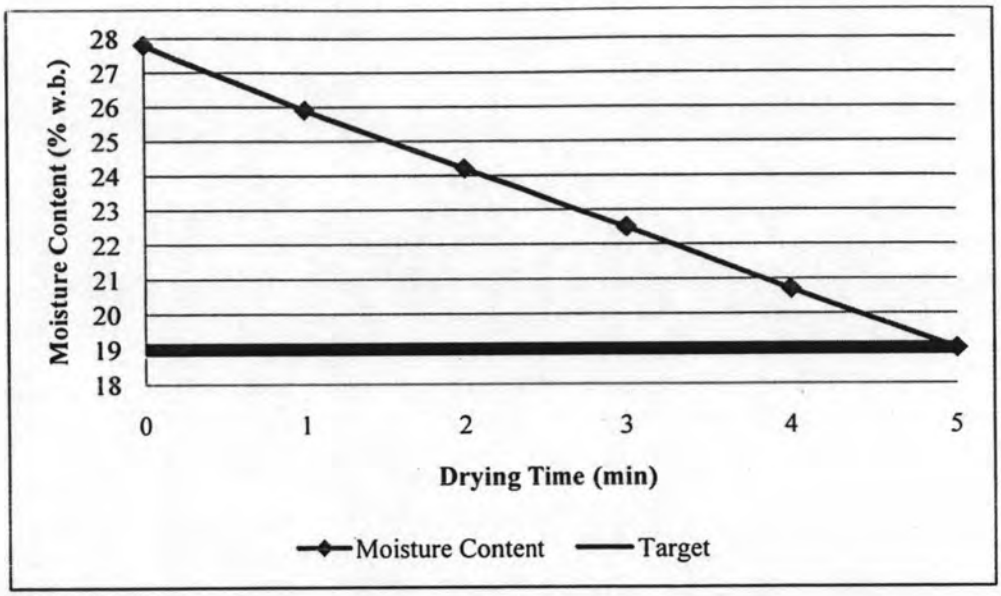

Figure 7.11 Drying result of paddy rice within high moisture content at 125°C

(3) Drying Temperature Level at 130°C

From Figure 7.12, the moisture content of paddy rice is reduced continuously with a constant drying rate. The constant drying rate of this drying temperature level is an average of 1.8% w.b./minute. However, the moisture content after drying is 18.7% w.b. It is less than 19.0% w.b. Moreover *MSD* is equaled to 0.108 (% w.b.)^2.

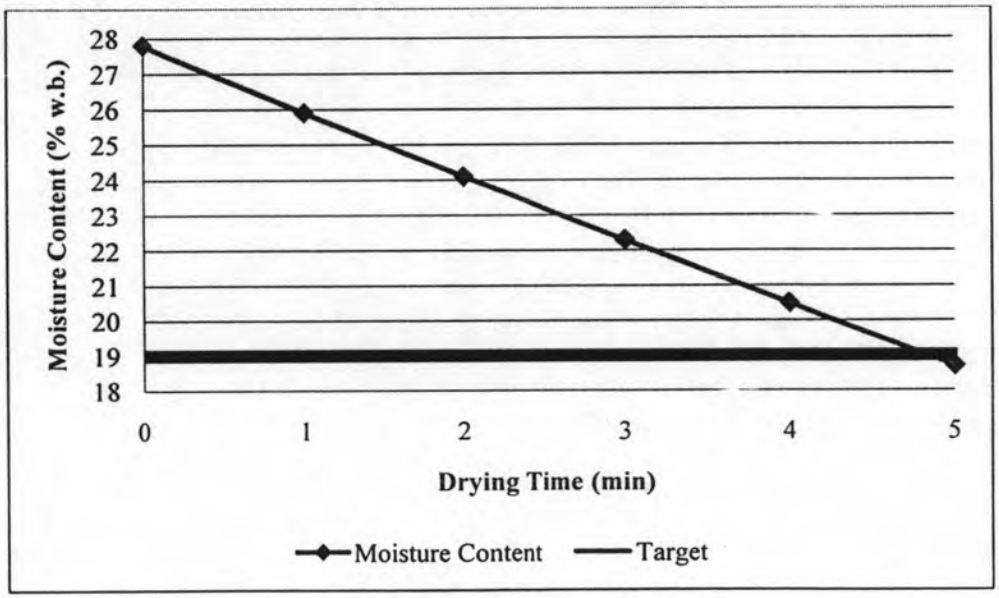

Figure 7.12 Drying result of paddy rice within high moisture content at 130°C

(4) Selecting Optimal Drying Temperature Level

Minimum *MSD* is a criterion to select the optimal drying temperature level. From all experimental results, their *MSD*s are plotted in Figure 7.13. It shows that minimum *MSD* is from drying temperature level at 125°C. Therefore, the optimal temperature level for drying paddy rice within high moisture content is at 125°C.

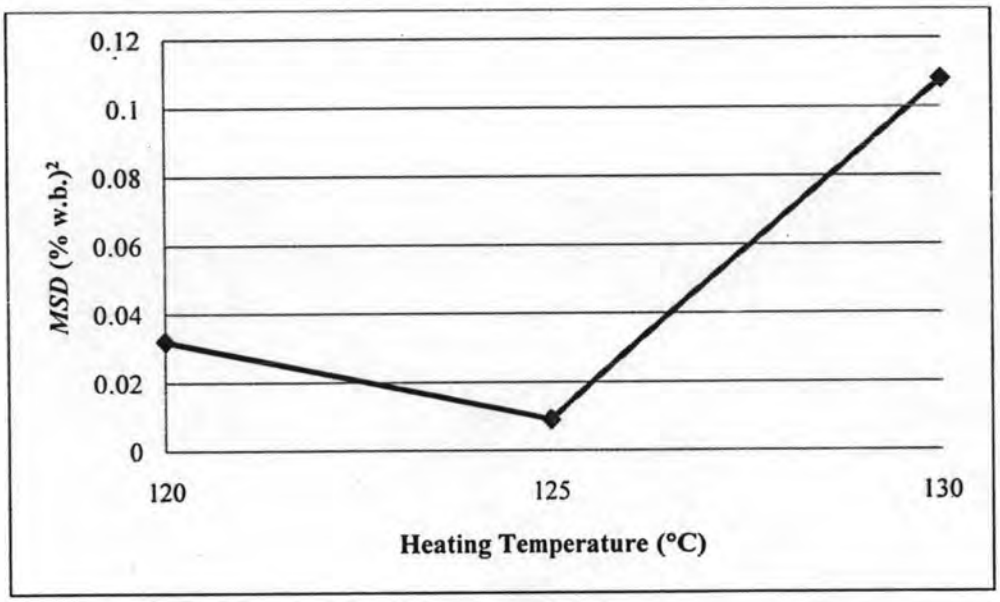

Figure 7.13 *MSD* from drying paddy rice with a constant drying rate within high moisture content

(5) Constructing Mathematical Model

After selecting the optimal drying temperature level, the mathematical model for drying paddy rice within high moisture content is constructed by Matlab program with function *polyfit*. As a result, the mathematical model is shown as Equation (7.3).

$$M(t)_1 = 27.7 - 1.75t, \qquad 0 \le t \le 5 \qquad (7.3)$$

From all drying experiments, they are summarized in Figure 7.14 which illustrates the optimal temperature levels and the mathematical models for drying paddy rice within low, medium, and high initial moisture content clusters.

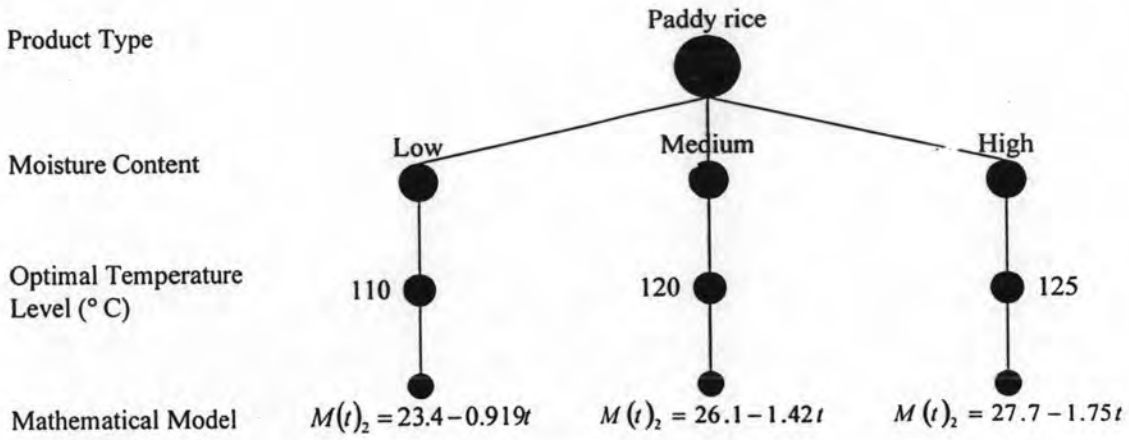

Figure 7.14 Optimal temperature levels and mathematical models for drying paddy rice with a constant drying rate

7.2 Experimental Results of Cassava Chip

In this phase, cassava chips are dried within 20 minutes by varying levels of drying temperature. The moisture content after drying is desired to 30.0% w.b. The experimental results are shown as following clustering of the raw materials.

7.2.1 Low Moisture Content

Cassava chips within low moisture content are sampled at an average initial moisture content of 52.4% w.b. They are dried with varying levels of temperature at 90, 100, and 110°C. The experimental results are explained as below.

(1) Drying Temperature Level at 90°C

From Figure 7.15, the moisture content of cassava chip is reduced continuously with a constant drying rate. The constant drying rate of this drying temperature level is an average of 1.1% w.b./minute. The moisture content after drying is 30.0% w.b. equaled to the target. Moreover *MSD* is equaled to 0.004 $(\%\ \text{w.b.})^2$.

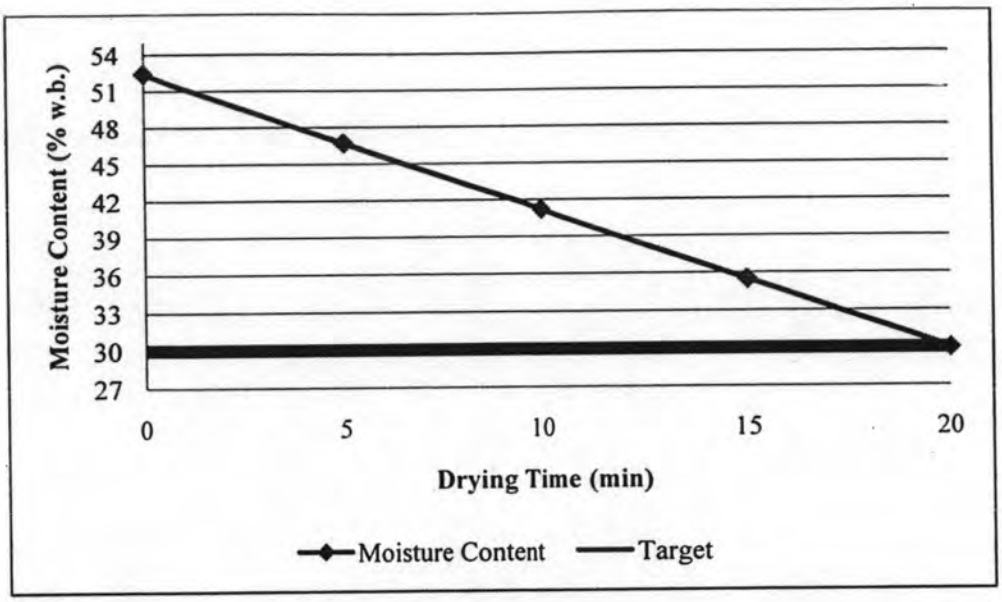

Figure 7.15 Drying result of cassava chip within low moisture content at 90°C

(2) Drying Temperature Level at 100°C

From Figure 7.16, the moisture content of cassava chip is reduced continuously with a constant drying rate. The constant drying rate of this drying temperature level is an average of 1.2% w.b./minute. However, the moisture content after drying is 28.0% w.b. It is less than 30.0% w.b. Moreover *MSD* is equaled to 4.086 (% w.b.)^2.

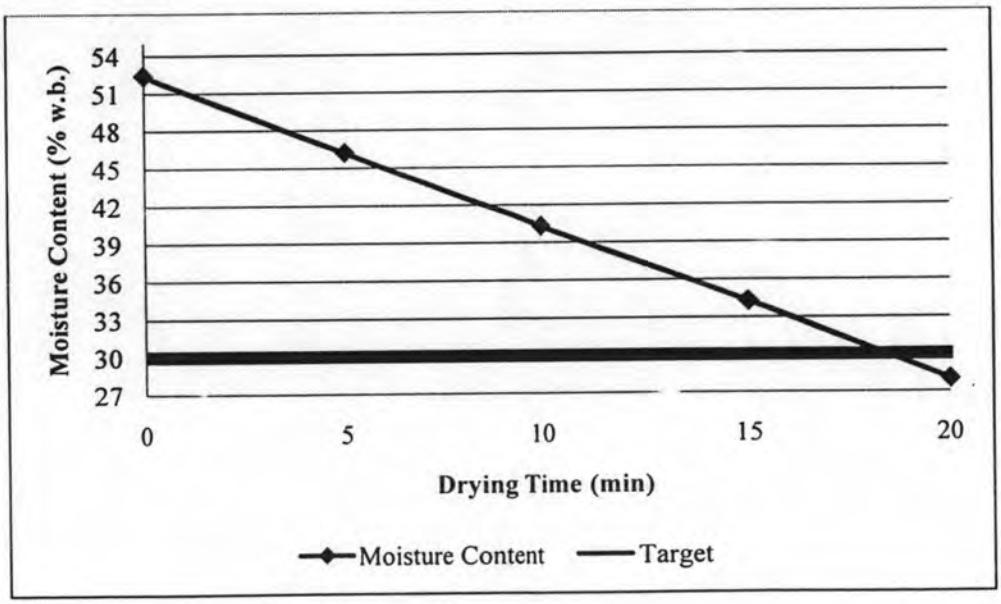

Figure 7.16 Drying result of cassava chip within low moisture content at 100°C

(3) Drying Temperature Level at 110°C

From Figure 7.17, the moisture content of cassava chip is reduced continuously with a constant drying rate. The constant drying rate of this drying temperature level is an average of 1.3% w.b./minute. However, the moisture content after drying is 26.9% w.b. It is less than 30.0% w.b. Moreover *MSD* is equaled to 9.622 (% w.b.)^2.

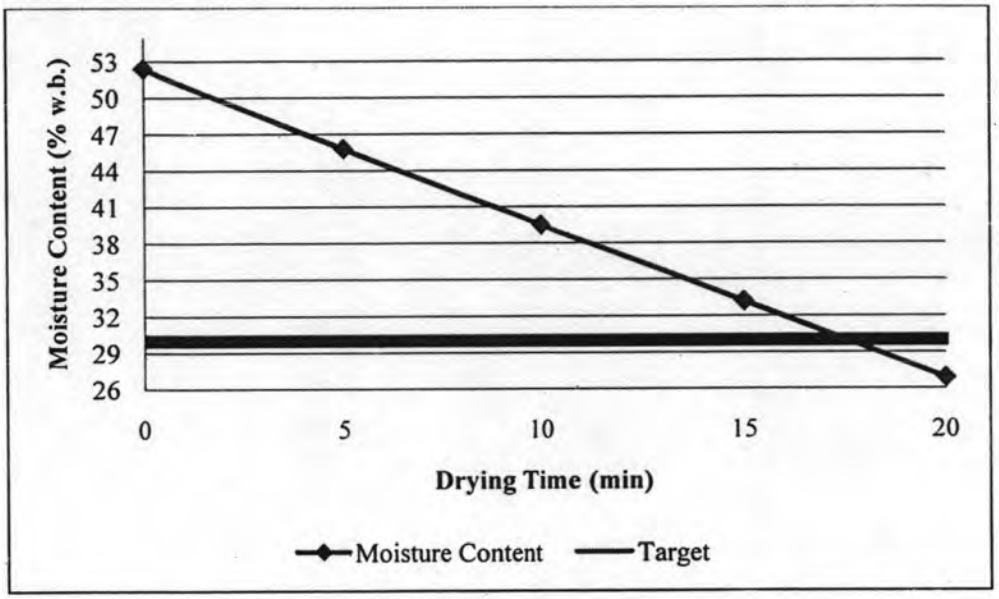

Figure 7.17 Drying result of cassava chip within low moisture content at 110°C

(4) Selecting Optimal Drying Temperature Level

Minimum *MSD* is a criterion to select the optimal drying temperature level. From all experimental results, their *MSD*s are plotted in Figure 7.18. It shows that minimum *MSD* is from drying temperature level at 90°C. Therefore, the optimal temperature level for drying cassava chip within low moisture content is at 90°C.

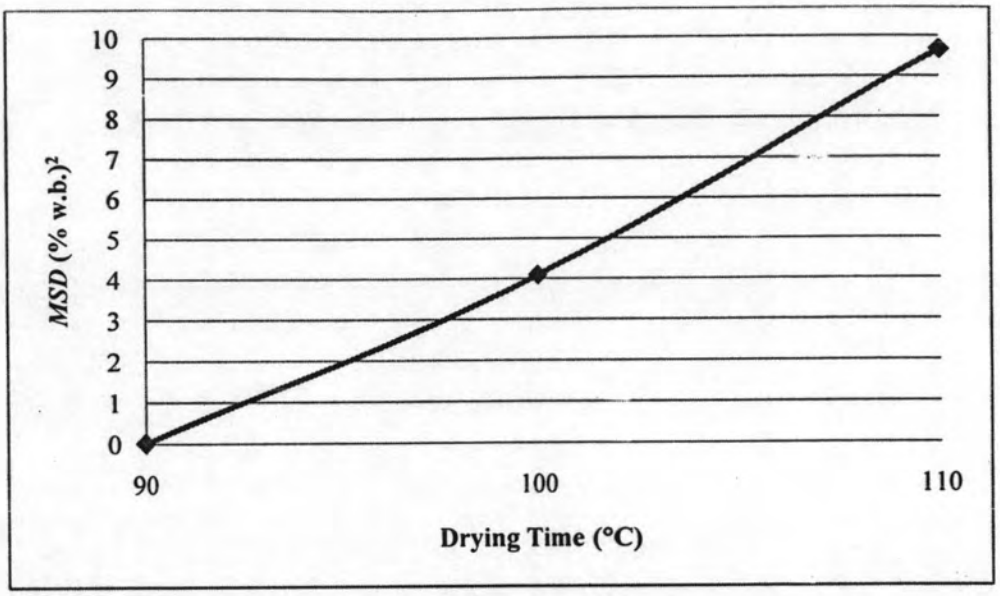

Figure 7.18 *MSD* from drying cassava chip with a constant drying rate within low moisture content

(5) Constructing Mathematical Model

After selecting the optimal drying temperature level, the mathematical model for drying cassava chip within low moisture content is constructed by Matlab program with function *polyfit*. As a result, the mathematical model is shown as Equation (7.4).

$$M(t)_1 = 52.3 - 1.12t, \qquad 0 \le t \le 20 \qquad (7.4)$$

where

$M(t)_2$ = the moisture content during a constant drying rate phase at time t

t = drying time in minutes

7.2.2 Medium Moisture Content

Cassava chips within medium moisture content are sampled at an average initial moisture content of 60.1% w.b. They are dried with varying levels of temperature at 95, 100, and 105°C. The experimental results are explained as below.

(1) Drying Temperature Level at 95°C

From Figure 7.19, the moisture content of cassava chip is reduced continuously with a constant drying rate. The constant drying rate of this drying temperature level is an average of 1.4% w.b./minute. The moisture content after drying is 32.0% w.b. It is greater than 30% w.b. as the target. Moreover *MSD* is equaled to 4.094 (% w.b.)^2.

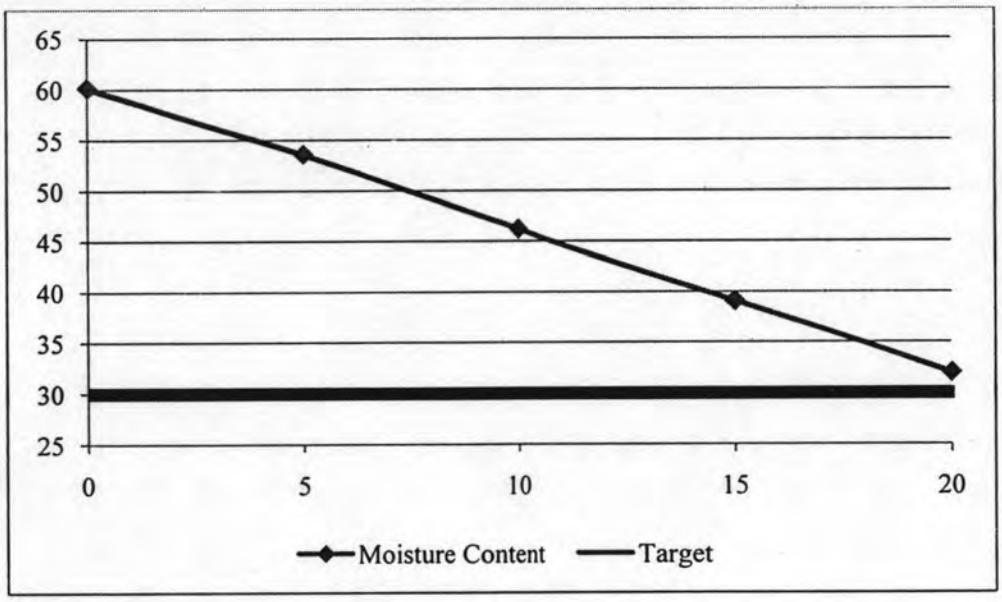

Figure 7.19 Drying result of cassava chip within medium moisture content at 95°C

(2) Drying Temperature Level at 100°C

From Figure 7.20, the moisture content of cassava chip is reduced continuously with a constant drying rate. The constant drying rate of this drying temperature level is an average of 1.5% w.b./minute. The moisture content after drying is 30.0% w.b. equaled to the target. Moreover *MSD* is equaled to 0.004 (% w.b.)^2.

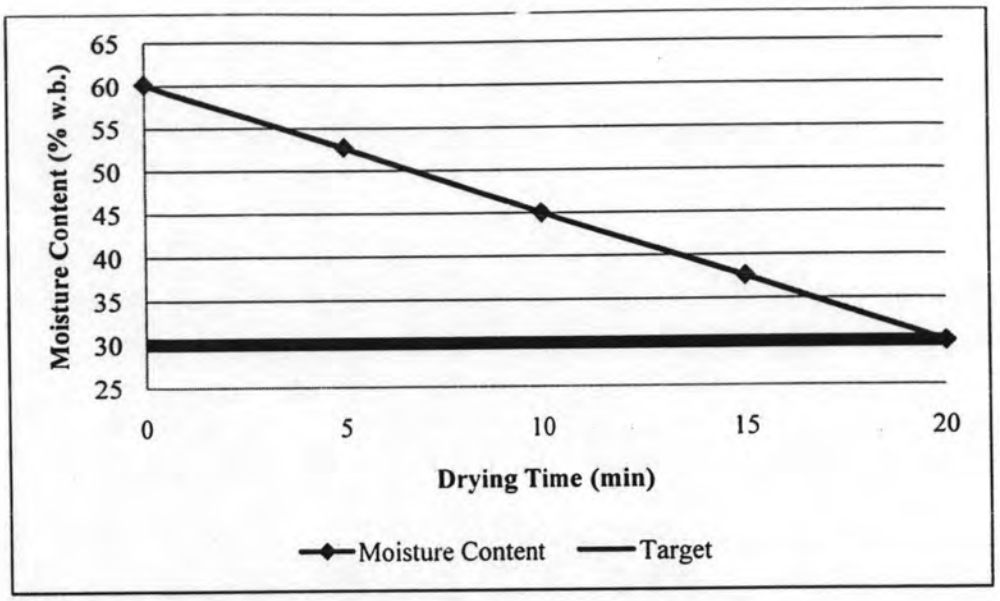

Figure 7.20 Drying result of cassava chip within medium moisture content at 100°C

(3) Drying Temperature Level at 105°C

From Figure 7.21, the moisture content of cassava chip is reduced continuously with a constant drying rate. The constant drying rate of this drying temperature level is an average of 1.6% w.b./minute. The moisture content after drying is 27.9% w.b. This is less than 30% w.b. as its target. Moreover *MSD* is equaled to 4.332 (% w.b.)^2.

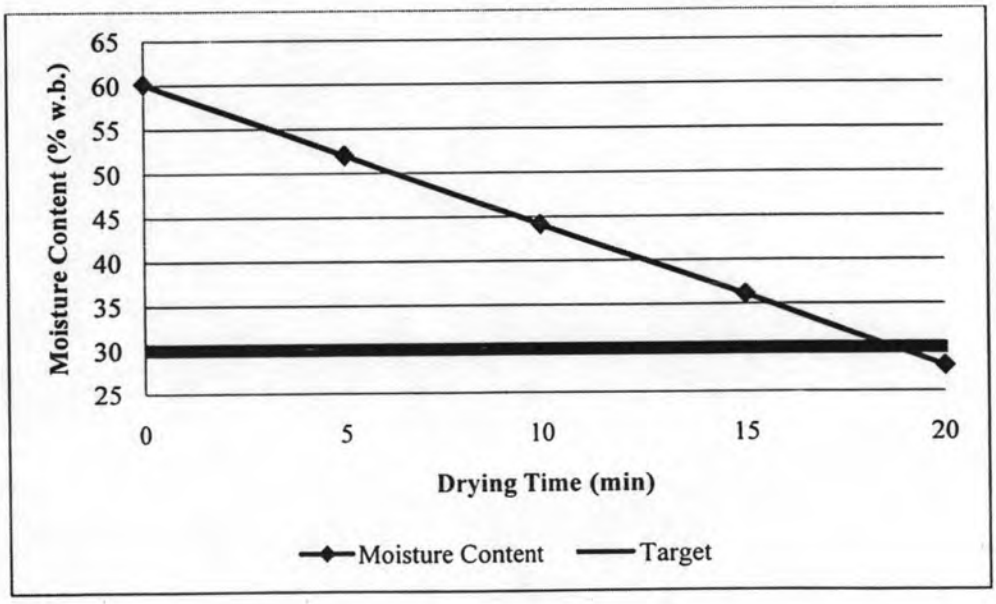

Figure 7.21 Drying result of cassava chip within medium moisture content at 105°C

(4) Selecting Optimal Drying Temperature Level

Minimum *MSD* is a criterion to select the optimal drying temperature level. From all experimental results, their *MSD*s are plotted in Figure 7.22. It shows that minimum *MSD* is from drying temperature level at 100°C. Therefore, the optimal temperature level for drying cassava chip within medium moisture content is at 100°C.

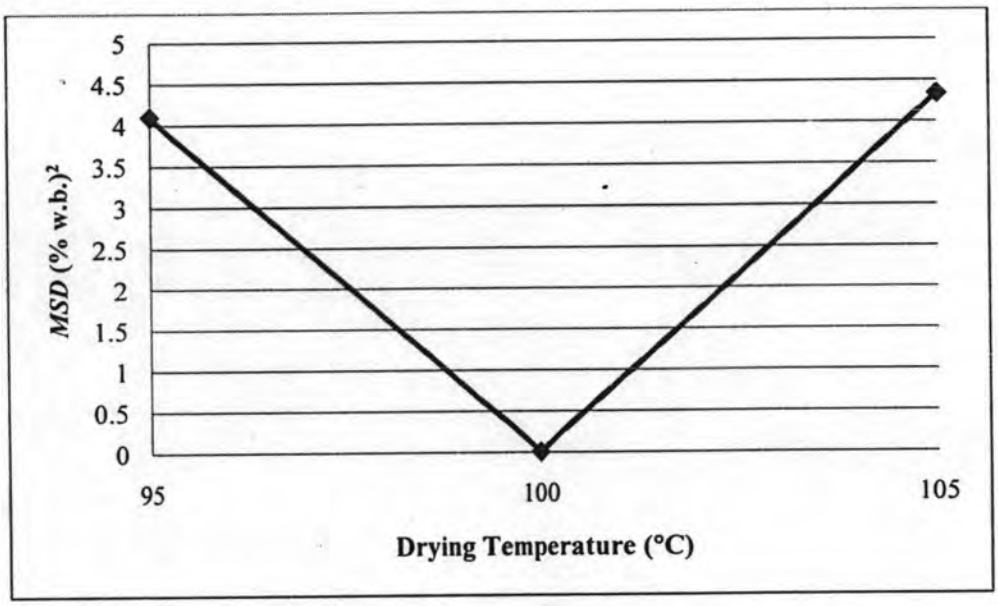

Figure 7.22 *MSD* from drying cassava chip with a constant drying rate within medium moisture content

(5) Constructing Mathematical Model

After selecting the optimal drying temperature level, the mathematical model for drying cassava chip within medium moisture content is constructed by Matlab program with function *polyfit*. As a result, the mathematical model is shown as Equation (7.5).

$$M(t)_2 = 60..2 - 1.51t, \qquad 0 \le t \le 20 \qquad (7.5)$$

7.1.3 High Moisture Content

Cassava chips within high moisture content are sampled at an average initial moisture content of 67.7% w.b. They are dried with varying levels of temperature at 105, 110, and 115°C. The experimental results are explained as below.

(1) Drying Temperature Level at 105°C

From Figure 7.23, the moisture content of cassava chip is reduced continuously with a constant drying rate. The constant drying rate of this drying temperature level is an average of 1.8% w.b./minute. The moisture content after drying is 30.8% w.b. It is very near to 30% w.b. as its target. However, *MSD* is equaled to 2.052 (% w.b.)^2.

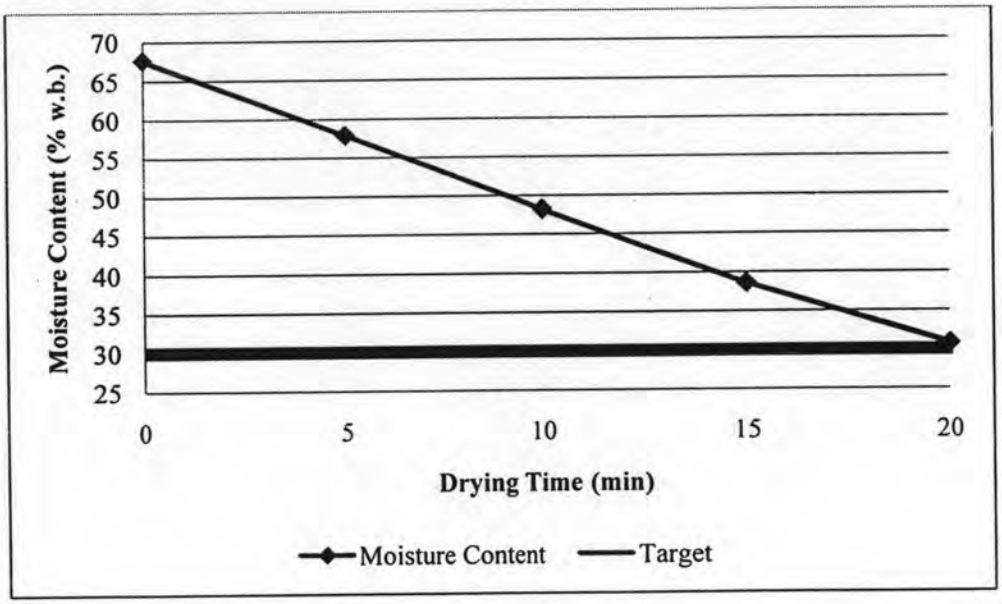

Figure 7.23 Drying result of cassava chip within high moisture content at 105°C

(2) Drying Temperature Level at 110°C

From Figure 7.24, the moisture content of cassava chip is reduced continuously with a constant drying rate. The constant drying rate of this drying temperature level is an average of 1.88% w.b./minute. The moisture content after drying is 30.0 % w.b. equaled to the target. Moreover, *MSD* is equaled to 0.012 (% w.b.)^2.

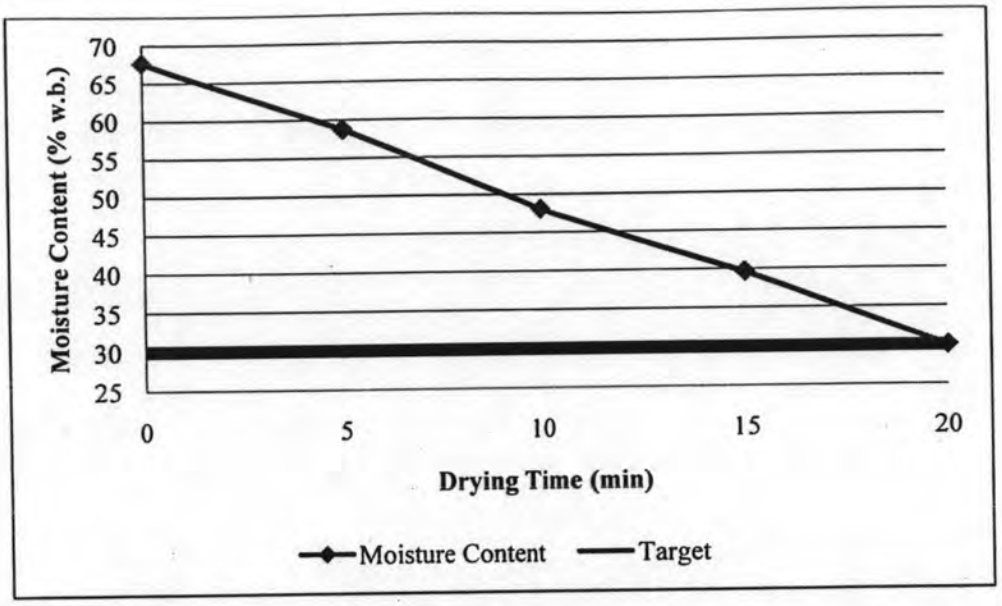

Figure 7.24 Drying result of cassava chip within high moisture content at 110°C

(3) Drying Temperature Level at 115°C

From Figure 7.25, the moisture content of cassava chip is reduced continuously with a constant drying rate. The constant drying rate of this drying temperature level is an average of 1.9% w.b./minute. The moisture content after drying is 29.0 % w.b. It is very near to 30% w.b. as its target. However, *MSD* is equaled to 1.004 (% w.b.)^2.

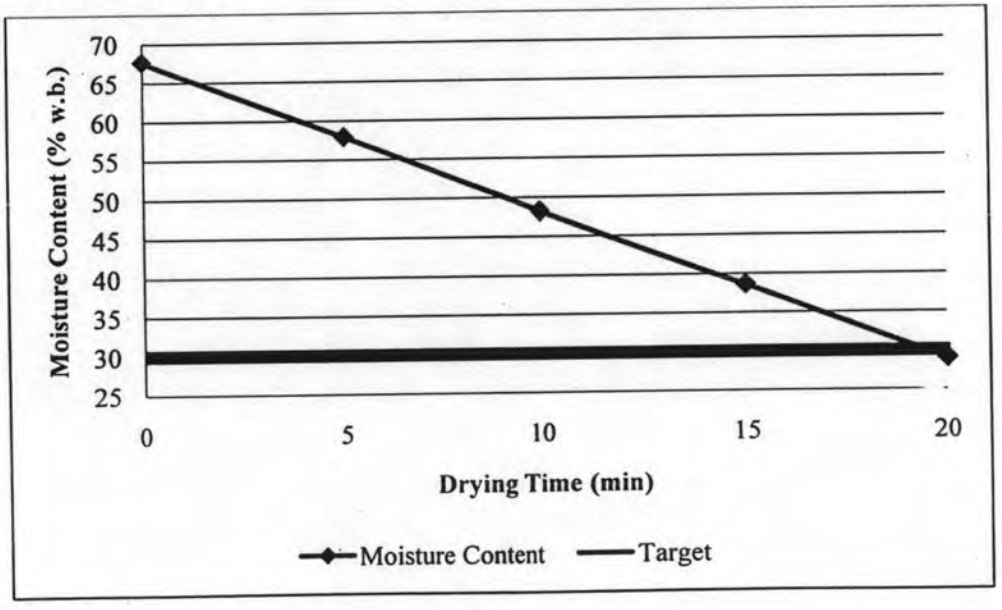

Figure 7.25 Drying result of cassava chip within high moisture content at 115°C

(4) Selecting Optimal Drying Temperature Level

Minimum *MSD* is a criterion to select the optimal drying temperature level. From all experimental results, their *MSD*s are plotted in Figure 7.26. It shows that minimum *MSD* is from drying temperature level at 110°C. Therefore, the optimal temperature level for drying cassava chip within high moisture content is at 110°C.

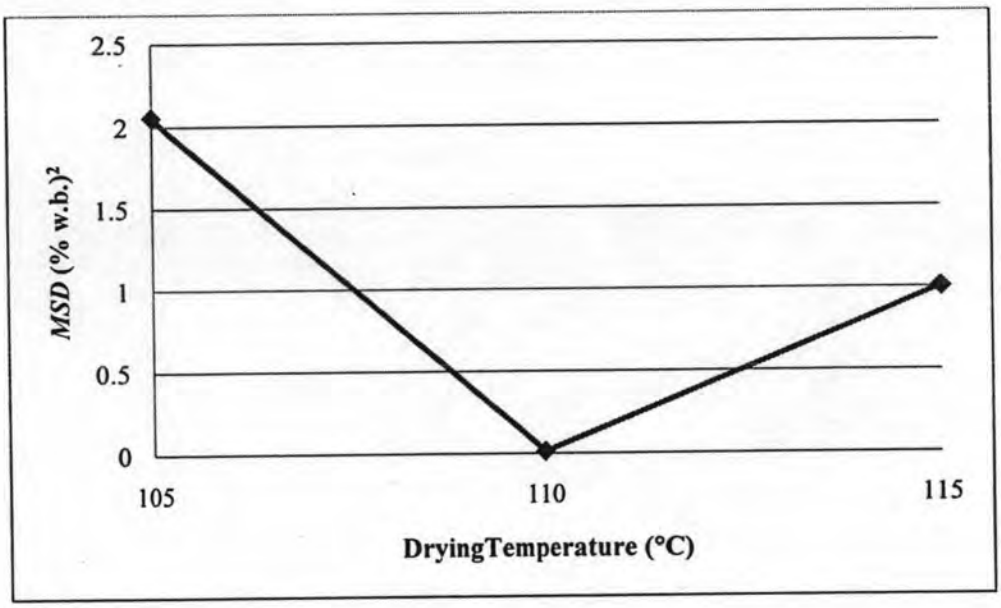

Figure 7.26 *MSD* from drying cassava chip with a constant drying rate within high moisture content

(5) Constructing Mathematical Model

After selecting the optimal drying temperature level, the mathematical model for drying cassava chip within high moisture content is constructed by Matlab program with function *polyfit*. As a result, the mathematical model is shown as Equation (7.6).

$$M(t)_1 = 67.6 - 1.88t, \qquad 0 \le t \le 20 \qquad (7.6)$$

From all drying experiments, they are summarized in Figure 7.27 which illustrates the optimal temperature levels and the mathematical models for drying cassava chip within low, medium, and high moisture content clusters.

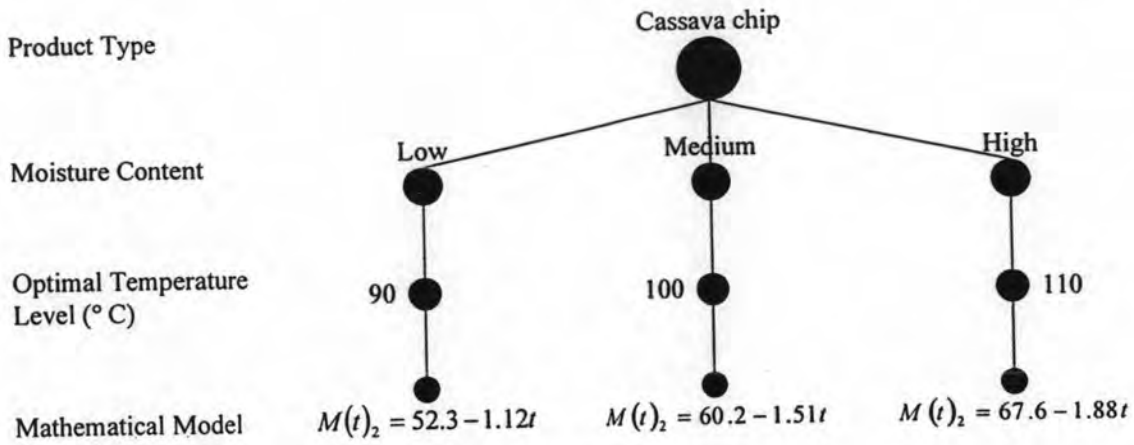

Figure 7.27 Optimal temperature levels and mathematical models for drying cassava chip with a constant drying rate

7.3 Experimental Results of Tobacco

In this phase, tobacco is dried within 10 minutes by varying levels of drying temperature. The moisture content after drying is desired to 14.0% w.b. The experimental results are shown as following clustering of the raw materials.

7.3.1 Low Moisture Content

Tobacco within low moisture content is sampled at an average initial moisture content of 17.1% w.b. It is dried with varying levels of temperature at 55, 60, and 65°C. The experimental results are explained as below.

(1) Drying Temperature Level at 55°C

From Figure 7.28, the moisture content of tobacco is reduced continuously with a constant drying rate. The constant drying rate of this drying temperature level is an average of 0.2% w.b./minute. The moisture content after drying is 14.9 % w.b. It is greater than 14.0% w.b. as its target. Moreover, *MSD* is equaled to 0.901 (% w.b.)^2.

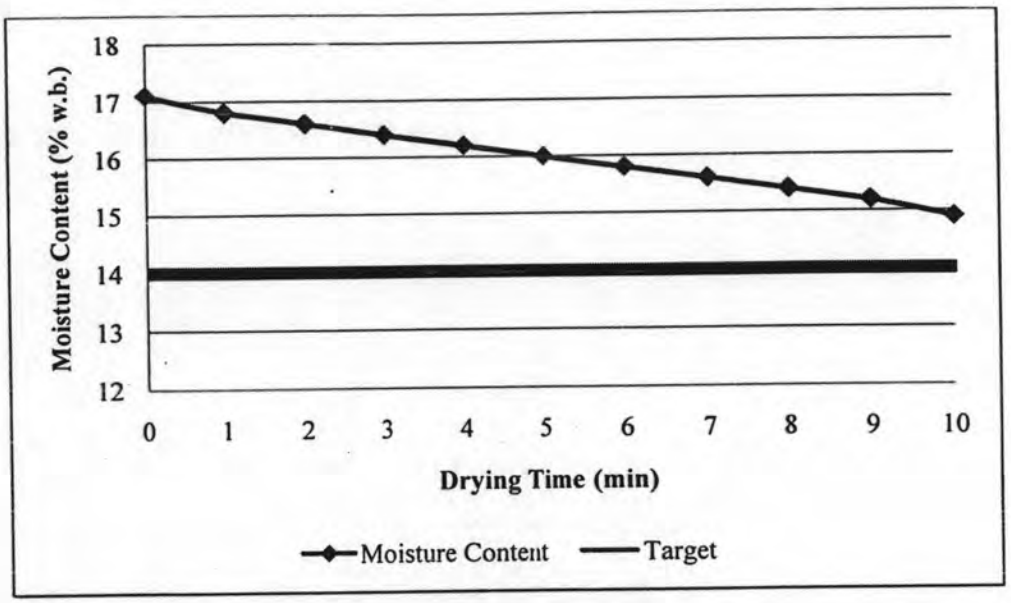

Figure 7.28 Drying result of tobacco within low moisture content at 55°C

(2) Drying Temperature Level at 60°C

From Figure 7.29, the moisture content of tobacco is reduced continuously with a constant drying rate. The constant drying rate of this drying temperature level is an average of 0.3% w.b./minute. The moisture content after drying is 14.0 % w.b. equaled to 14.0% w.b. as its target. Moreover, *MSD* is equaled to 0.013 (% w.b.)^2.

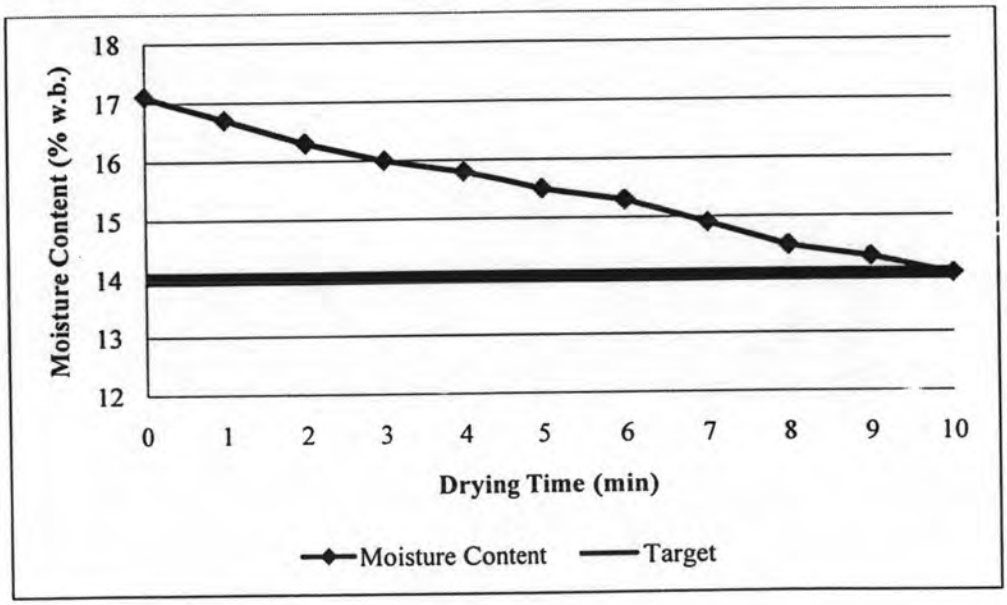

Figure 7.29 Drying result of tobacco within low moisture content at 60°C

(3) Drying Temperature Level at 65°C

From Figure 7.30, the moisture content of tobacco is reduced continuously with a constant drying rate. The constant drying rate of this drying temperature level is an average of 0.3% w.b./minute. The moisture content after drying is 13.5 % w.b. It is less than 14.0% w.b. as its target. Moreover, *MSD* is equaled to 0.257 (% w.b.)^2.

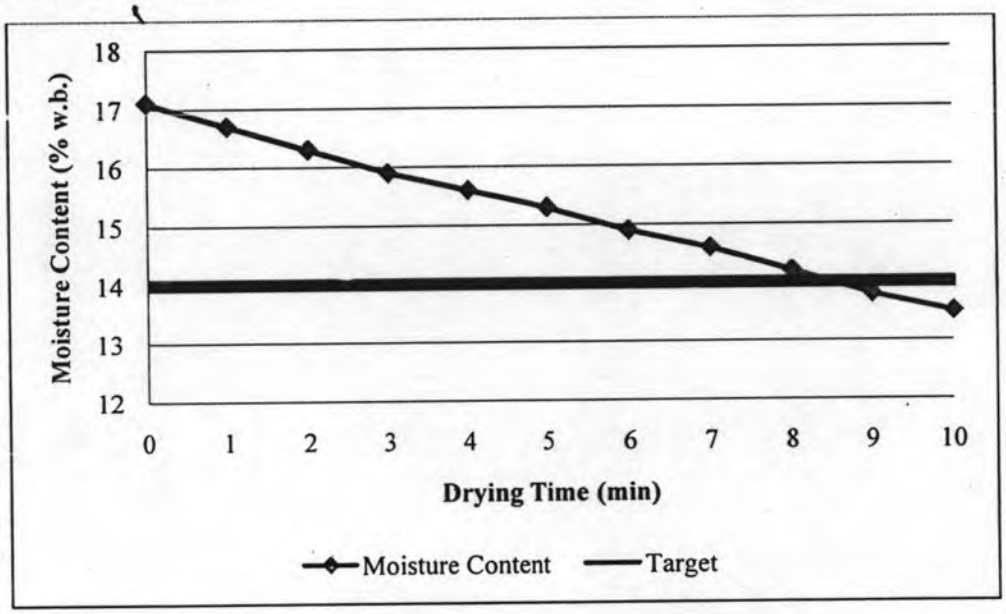

Figure 7.30 Drying result of tobacco within low moisture content at 65°C

(4) Selecting Optimal Drying Temperature Level

Minimum *MSD* is a criterion to select the optimal drying temperature level. From all experimental results, their *MSD*s are plotted in Figure 7.31. It shows that minimum *MSD* is from drying temperature level at 60°C. Therefore, the optimal temperature level for drying tobacco within low moisture content is at 60°C.

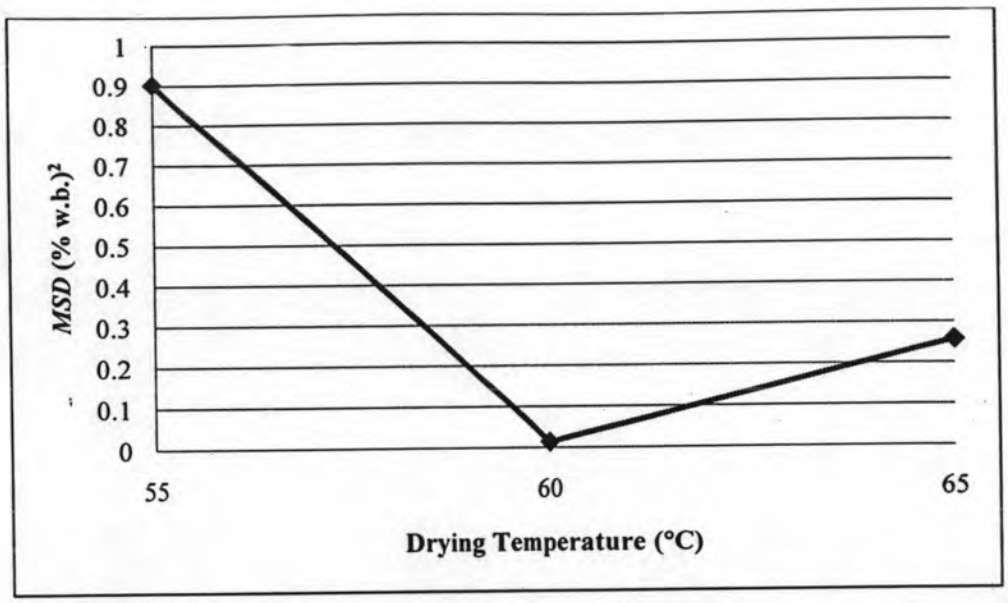

Figure 7.31 *MSD* from drying tobacco with a constant drying rate within low moisture content

(5) Constructing Mathematical Model

After selecting the optimal drying temperature level, the mathematical model for drying tobacco within low moisture content is constructed by Matlab program with function *polyfit*. As a result, the mathematical model is shown as Equation (7.7).

$$M(t)_2 = 17 - 0.302t, \qquad 0 \le t \le 10 \qquad (7.7)$$

where

$M(t)_2$ = the moisture content during drying phase at time t

t = drying time minutes

7.3.2 Medium Moisture Content

Tobacco within medium moisture content is sampled at an average initial moisture content of 18.3% w.b. It is dried with varying levels of temperature at 60, 65, and 70°C. The experimental results are explained as below.

(1) Drying Temperature Level at 60°C

From Figure 7.32, the moisture content of tobacco is reduced continuously with a constant drying rate. The constant drying rate of this drying temperature level is an average of 0.4% w.b./minute. The moisture content after drying is 14.3 % w.b. It is very near to 14.0% w.b. as its target. However, *MSD* is equaled to 0.098 (% w.b.)^2.

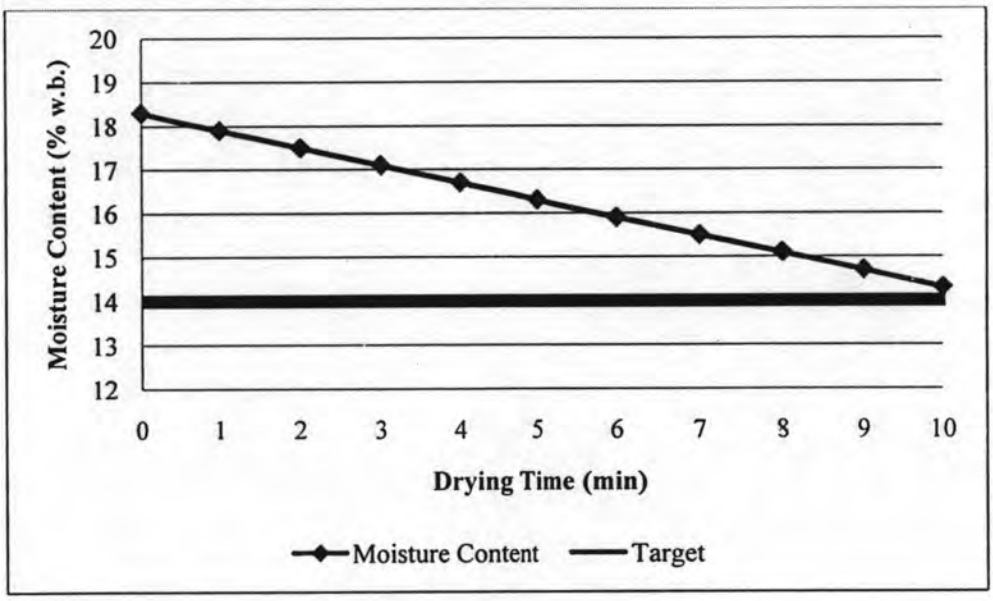

Figure 7.32 Drying result of tobacco within medium moisture content at 60°C

(2) Drying Temperature Level at 65°C

From Figure 7.33, the moisture content of tobacco is reduced continuously with a constant drying rate. The constant drying rate of this drying temperature level is an average of 0.43% w.b./minute. The moisture content after drying is 14.0 % w.b. equaled to the target. Moreover, *MSD* is equaled to 0.046 (% w.b.)^2.

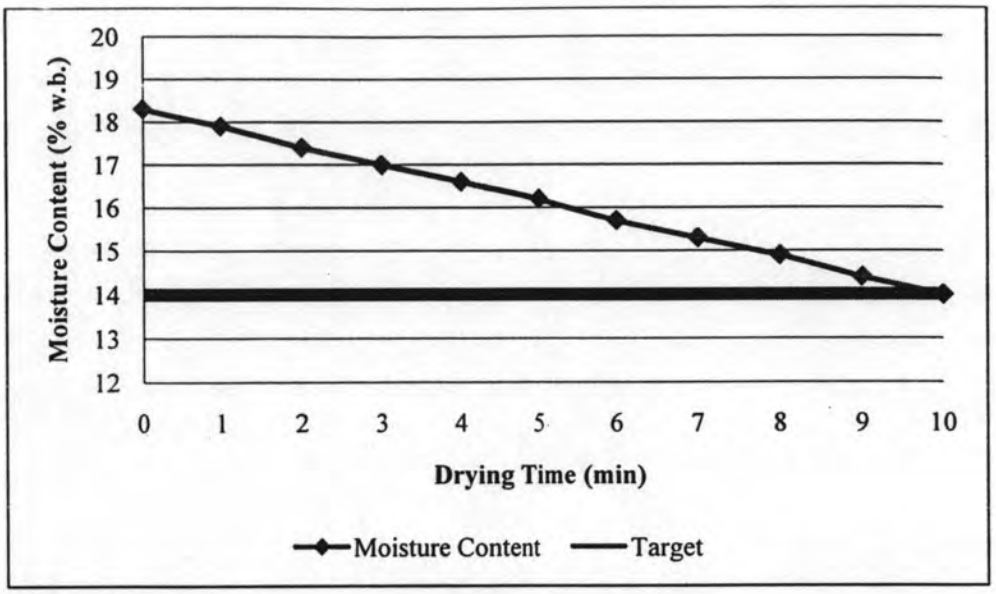

Figure 7.33 Drying result of tobacco within medium moisture content at 65°C

(3) Drying Temperature Level at 70°C

From Figure 7.34, the moisture content of tobacco is reduced continuously with a constant drying rate. The constant drying rate of this drying temperature level is an average of 0.5% w.b./minute. The moisture content after drying is 13.3 % w.b. It is less than 14.0% w.b. as its target. Moreover, *MSD* is equaled to 0.525 (% w.b.)^2.

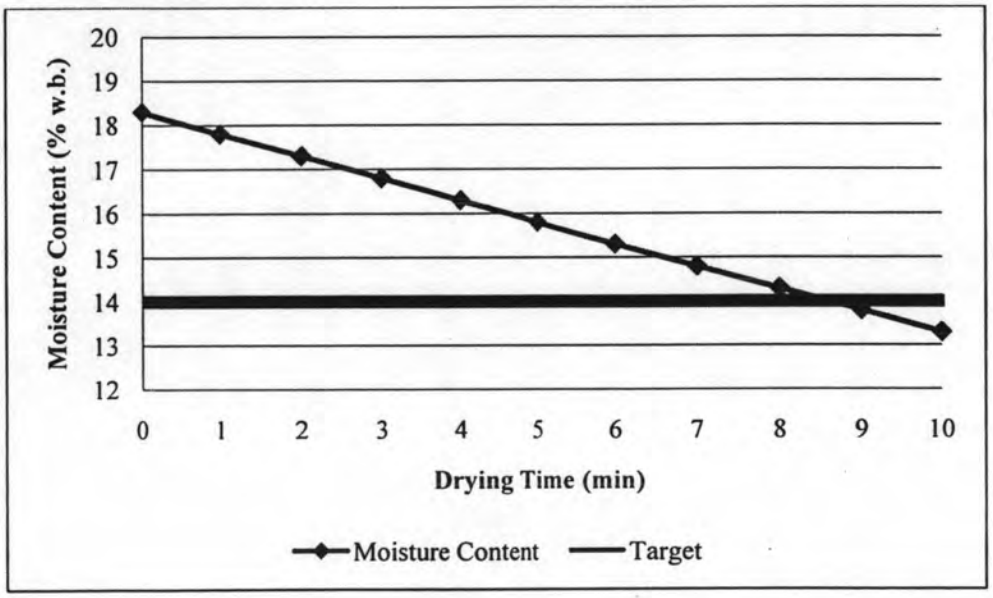

Figure 7.34 Drying result of tobacco within medium moisture content at 70°C

(4) Selecting Optimal Drying Temperature Level

Minimum *MSD* is a criterion to select the optimal drying temperature level. From all experimental results, their *MSD*s are plotted in Figure 7.35. It shows that minimum *MSD* is from drying temperature level at 65°C. Therefore, the optimal temperature level for drying tobacco within medium moisture content is at 65°C.

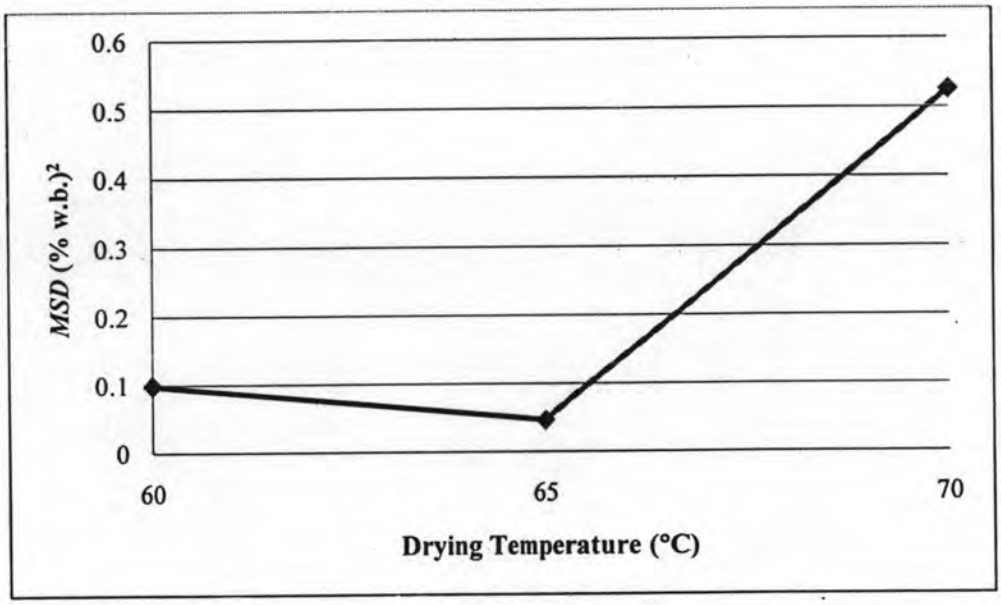

Figure 7.35 *MSD* from drying tobacco with a constant drying rate within medium moisture content

(5) Constructing Mathematical Model

After selecting the optimal drying temperature level, the mathematical model for drying tobacco within medium moisture content is constructed by Matlab program with function *polyfit*. As a result, the mathematical model is shown as Equation (7.8).

$$M(t)_2 = 18.3 - 0.43t, \qquad 0 \le t \le 10 \qquad (7.8)$$

7.3.3 High Moisture Content

Tobacco within high moisture content is sampled at an average initial moisture content of 20.0% w.b. It is dried with varying levels of temperature at 65, 70, and 75°C. The experimental results are explained as below.

(1) Drying Temperature Level at 65°C

From Figure 7.36, the moisture content of tobacco is reduced continuously with a constant drying rate. The constant drying rate of this drying temperature level is an average of 0.55% w.b./minute. The moisture content after drying is 14.5 % w.b. It is greater than 14.0% w.b. as its target. Moreover, *MSD* is equaled to 0.275 (% w.b.)^2.

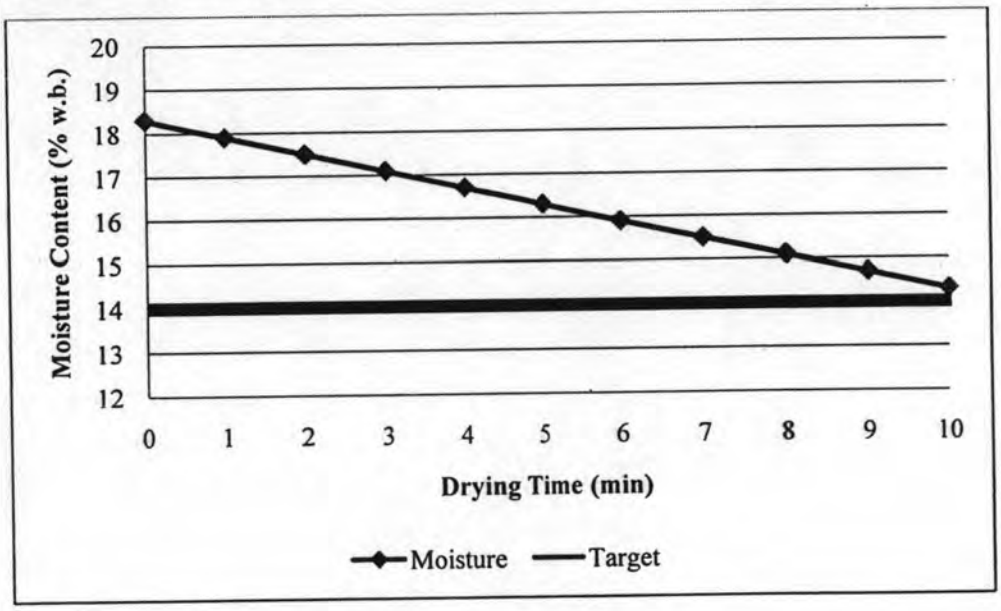

Figure 7.36 Drying result of tobacco within high moisture content at 65°C

(2) Drying Temperature Level at 70°C

From Figure 7.37, the moisture content of tobacco is reduced continuously with a constant drying rate. The constant drying rate of this drying temperature level is an average of 0.6% w.b./minute. The moisture content after drying is 14.0 equaled to the target. Moreover, *MSD* is equaled to 0.010 (% w.b.)^2.

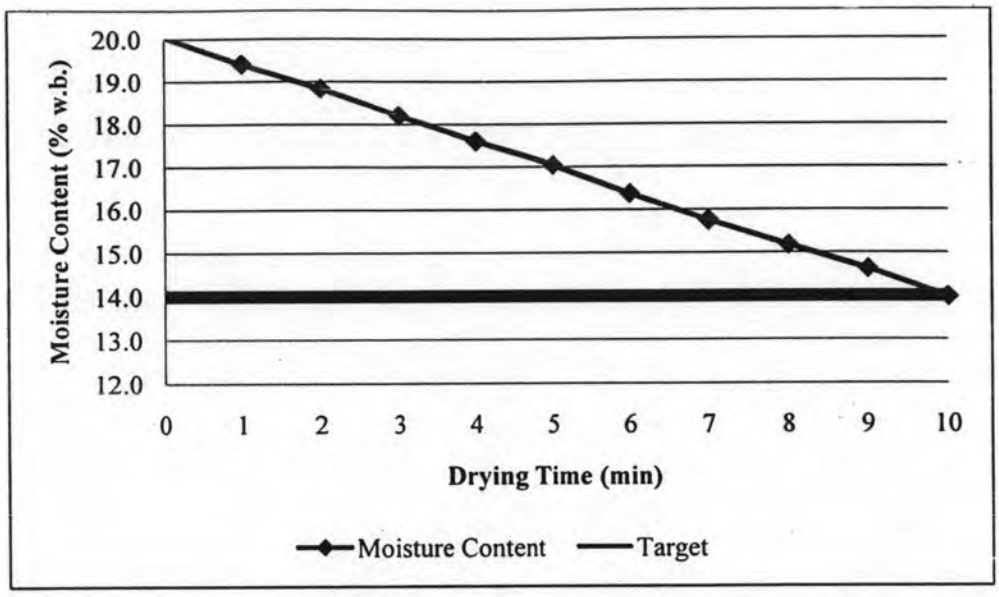

Figure 7.37 Drying result of tobacco within high moisture content at 70°C

(3) Drying Temperature Level at 75°C

From Figure 7.38, the moisture content of tobacco is reduced continuously with a constant drying rate. The constant drying rate of this drying temperature level is an average of 0.62% w.b./minute. The moisture content after drying is 13.8 % w.b. It is very near to 14.0% w.b. as its target. However, *MSD* is equaled to 0.063 (% w.b.)^2.

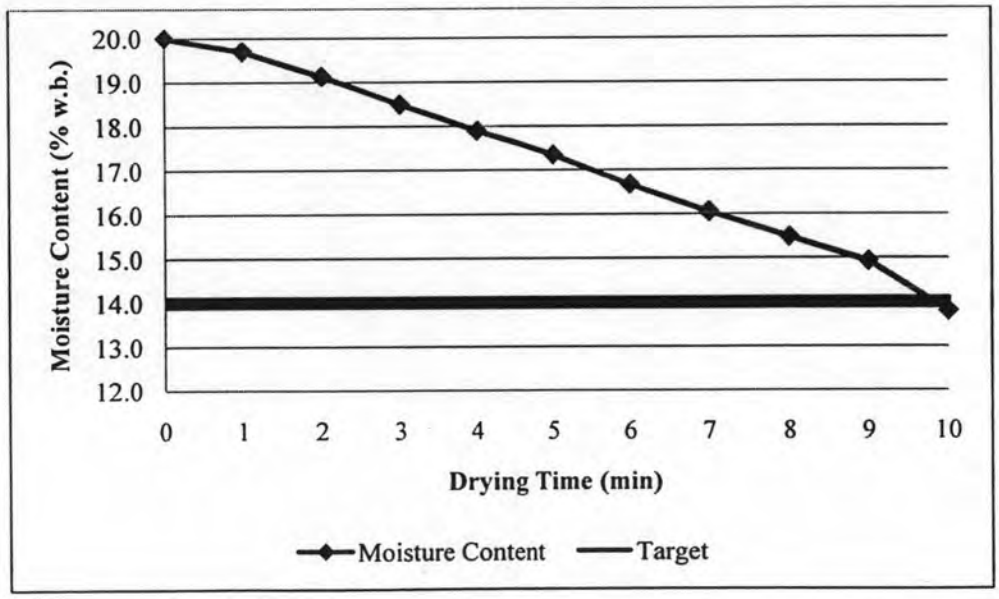

Figure 7.38 Drying result of tobacco within high moisture content at 75°C

(4) Selecting Optimal Drying Temperature Level

Minimum *MSD* is a criterion to select the optimal drying temperature level. From all experimental results, their *MSD*s are plotted in Figure 7.39. It shows that minimum *MSD* is from drying temperature level at 70°C. Therefore, the optimal temperature level for drying tobacco within high moisture content is at 70°C.

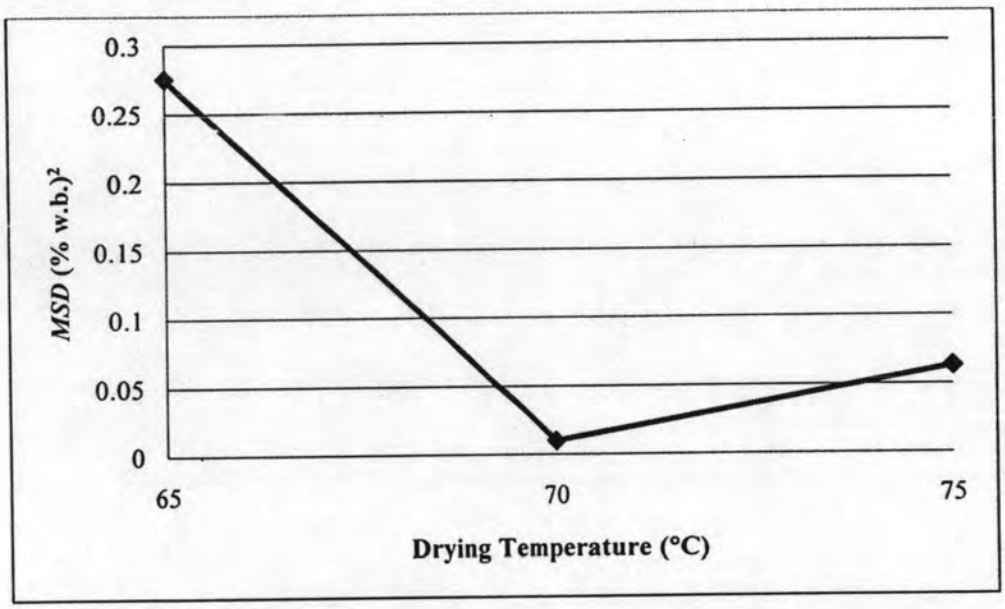

Figure 7.39 *MSD* from drying tobacco with a constant drying rate within high moisture content

(5) Constructing Mathematical Model

After selecting the optimal drying temperature level, the mathematical model for drying tobacco within high moisture content is constructed by Matlab program with function *polyfit*. As a result, the mathematical model is shown as Equation (7.9).

$$M(t)_1 = 20 - 0.604t, \qquad 0 \le t \le 10 \qquad (7.9)$$

From all drying experiments, they are summarized in Figure 7.40 which illustrates the optimal temperature levels and the mathematical models for drying tobacco within low, medium, and high moisture content clusters.

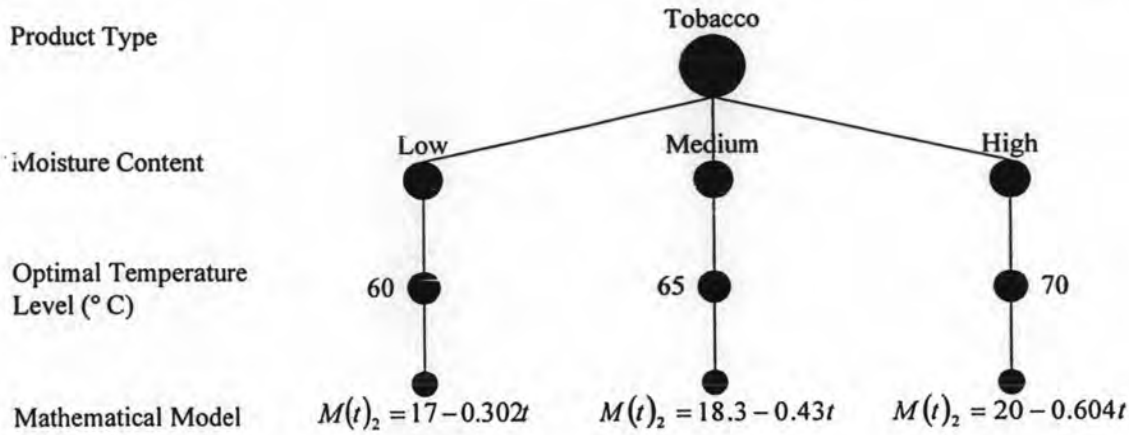

Figure 7.40 Optimal temperature levels and mathematical models for drying tobacco with a constant drying rate

7.4 Experimental Results of Longan

In this phase, longan is dried within 15 hours by varying levels of drying temperature. The experimental results are shown as following clustering of the raw materials.

7.4.1 Low Moisture Content

Longan within low moisture content is sampled at an average initial moisture content of 87.4% w.b. It is dried with varying levels of temperature at 65, 70, and 75°C. The experimental results are explained as below.

(1) Drying Temperature Level at 65°C

From Figure 7.41, the moisture content of longan is reduced continuously with a constant drying rate. The constant drying rate of this drying temperature level is an average of 0.8% w.b./hour. The moisture content after drying is 75.3 % w.b. It is greater than 73.0% w.b. as its target. Moreover, *MSD* is equaled to 5.956 (% w.b.)^2.

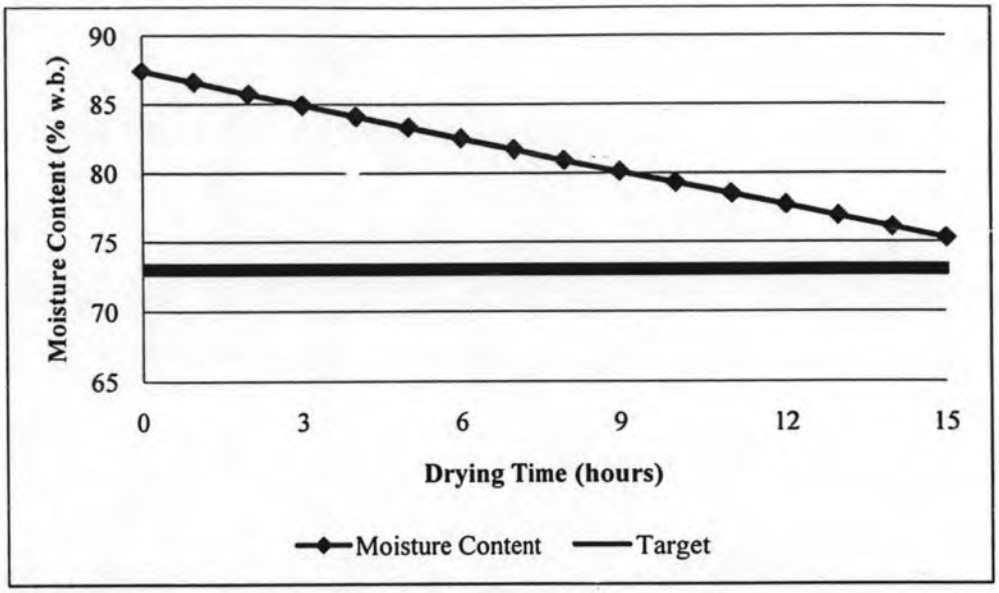

Figure 7.41 Drying result of longan within low moisture content at 65°C

(2) Drying Temperature Level at 70°C

From Figure 7.42, the moisture content of longan is reduced continuously with a constant drying rate. The constant drying rate of this drying temperature level is an average of 1.0% w.b./hour. The moisture content after drying is 73.0 % w.b. equaled to the target. Moreover, *MSD* is equaled to 0.002 (% w.b.)^2.

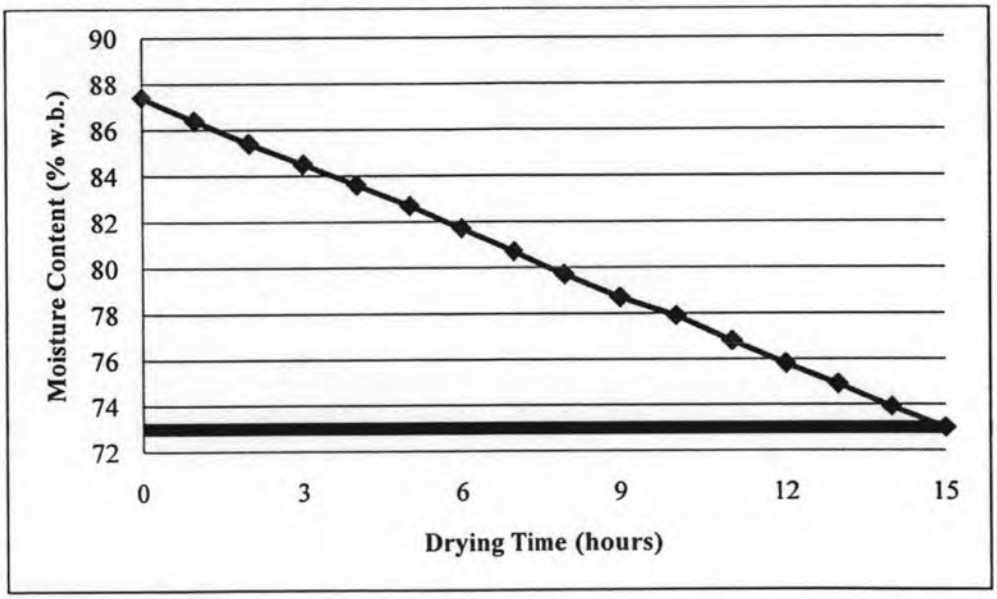

Figure 7.42 Drying result of longan within low moisture content at 70°C

(3) Drying Temperature Level at 75°C

From Figure 7.43, the moisture content of longan is reduced continuously with a constant drying rate. The constant drying rate of this drying temperature level is an average of 1.2% w.b./hour. The moisture content after drying is 70.0 % w.b. It is less than the target. Moreover, *MSD* is equaled to 8.779 (% w.b.)^2.

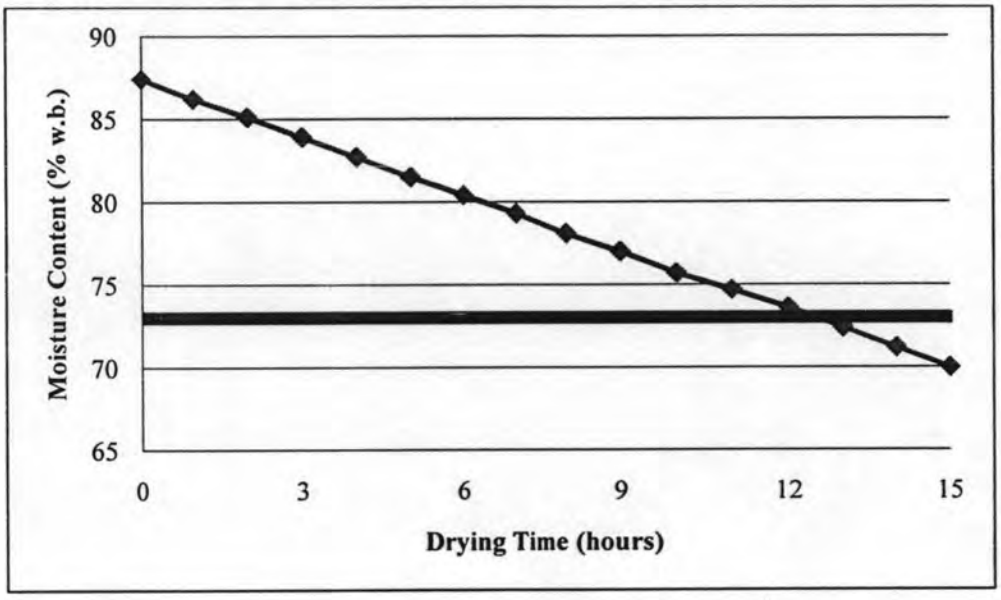

Figure 7.43 Drying result of longan within low moisture content at 75°C

(4) Selecting Optimal Drying Temperature Level

Minimum *MSD* is a criterion to select the optimal drying temperature level. From all experimental results, their *MSD*s are plotted in Figure 7.44. It shows that minimum *MSD* is from drying temperature level at 70°C is the minimum value. Therefore, the optimal temperature level for drying longan within low moisture content is at 70°C.

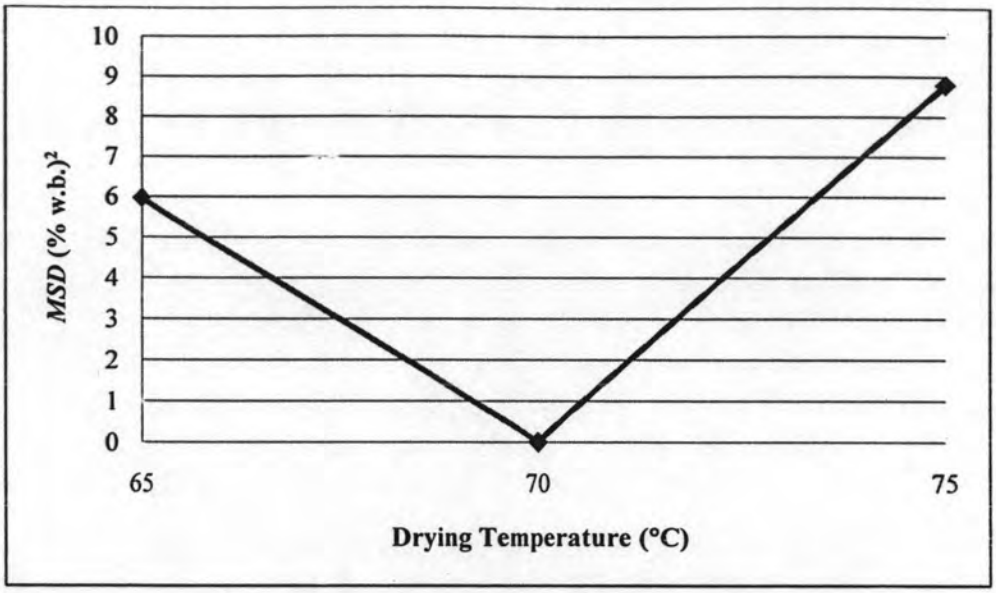

Figure 7.44 *MSD* from drying longan with a constant drying rate within low moisture content

(5) Constructing Mathematical Model

After selecting the optimal drying temperature level, the mathematical model for drying longan within low moisture content is constructed by Matlab program with function *polyfit*. As a result, the mathematical model is shown as Equation (7.10).

$$M(t)_2 = 87.4 - 0.962t, \qquad 0 \le t \le 15 \qquad (7.10)$$

where

$M(t)_2$ = the moisture content during drying phase at time t

t = drying time hours

7.4.2 Medium Moisture Content

Longan within medium moisture content is sampled at an average initial moisture content of 91.1% w.b. It is dried with varying levels of temperature at 80, 85, and 88°C. The experimental results are explained as below.

(1) Drying Temperature Level at 80°C

From Figure 7.45, the moisture content of longan is reduced continuously with a constant drying rate. The constant drying rate of this drying temperature level is an average of 1.0% w.b./hour. The moisture content after drying is 76.3% w.b. It is greater than the target. Moreover, *MSD* is equaled to 11.398 $(\%\ \text{w.b.})^2$.

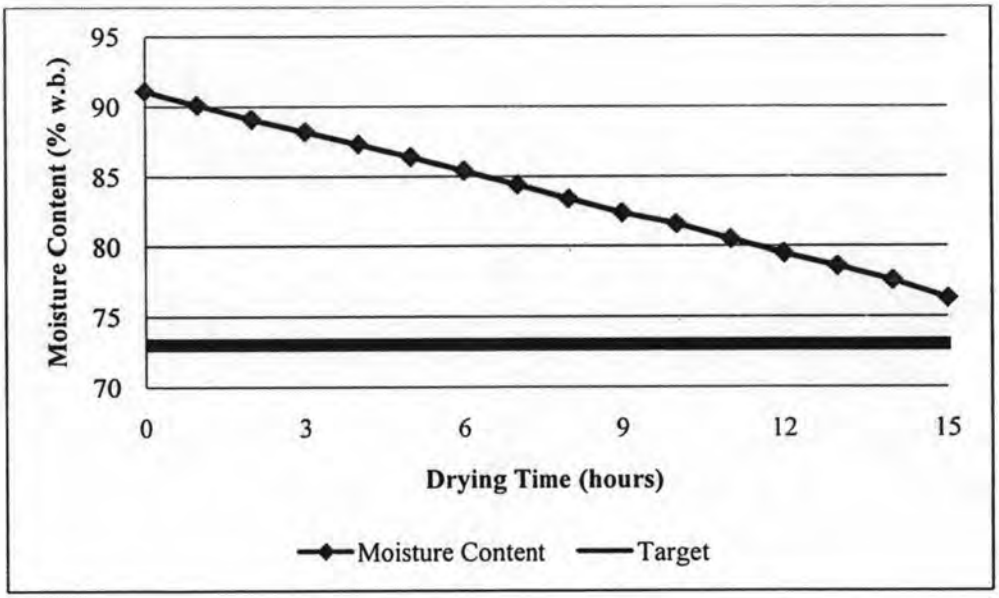

Figure 7.45 Drying result of longan within medium moisture content at 80°C

(2) Drying Temperature Level at 85°C

From Figure 7.46, the moisture content of longan is reduced continuously with a constant drying rate. The constant drying rate of this drying temperature level is an average of 1.2% w.b./hour. The moisture content after drying is 73.0% w.b. equaled to target. Moreover, *MSD* is equaled to 0.016 $(\%\ \text{w.b.})^2$.

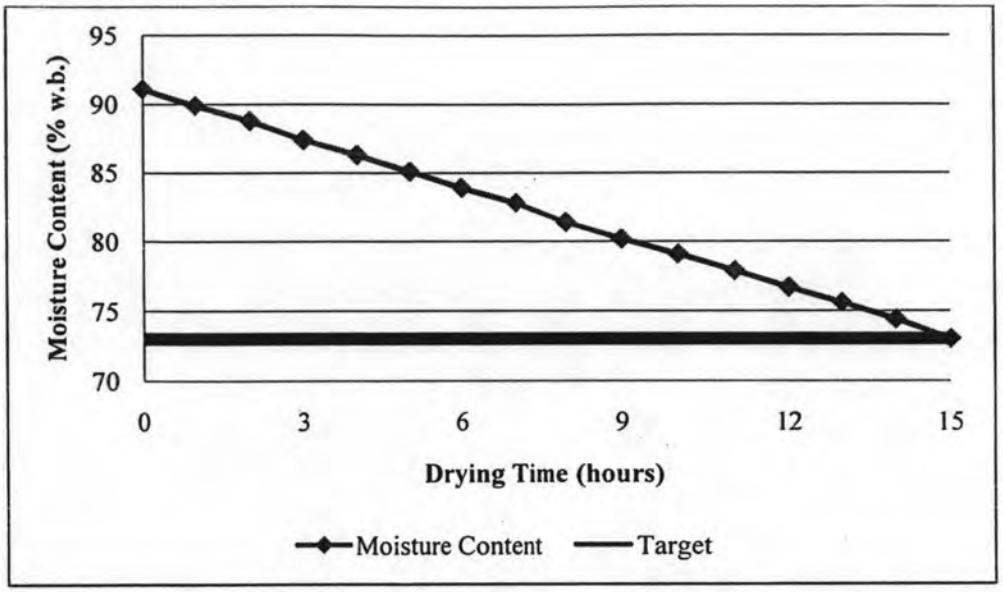

Figure 7.46 Drying result of longan within medium moisture content at 85°C

(3) Drying Temperature Level at 88°C

From Figure 7.47, the moisture content of longan is reduced continuously with a constant drying rate. The constant drying rate of this drying temperature level is an average of 1.3% w.b./hour. The moisture content after drying is 71.6% w.b. equaled to target. Moreover, *MSD* is equaled to 1.856 (% w.b.)^2.

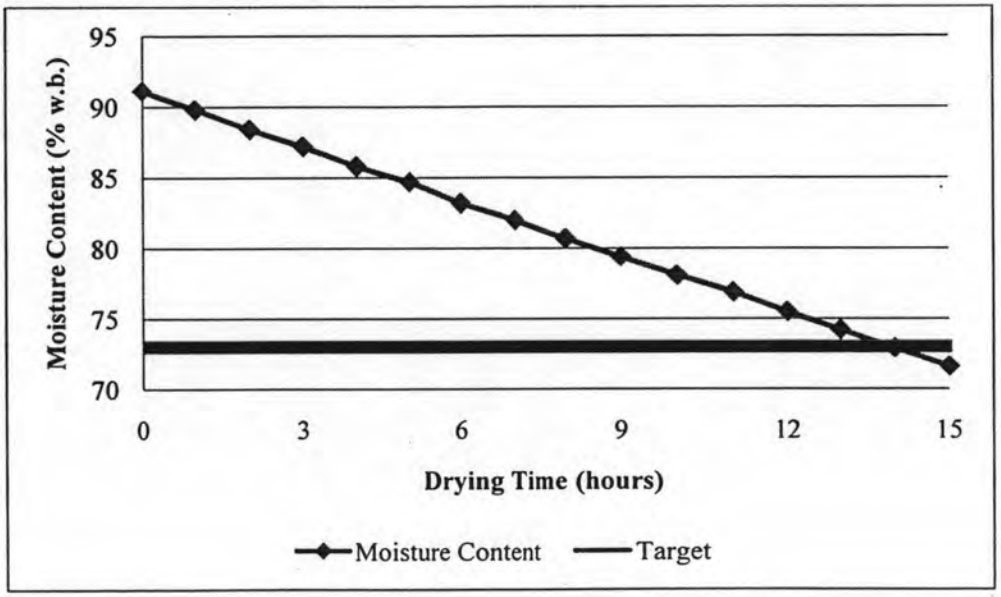

Figure 7.47 Drying result of longan within medium moisture content at 88°C

(4) Selecting Optimal Drying Temperature Level

Minimum *MSD* is a criterion to select the optimal drying temperature level. From all experimental results, their *MSD*s are plotted in Figure 7.48. It shows that minimum *MSD* is from drying temperature level at 85°. Therefore, the optimal temperature level for drying longan within medium moisture content is at 85°C.

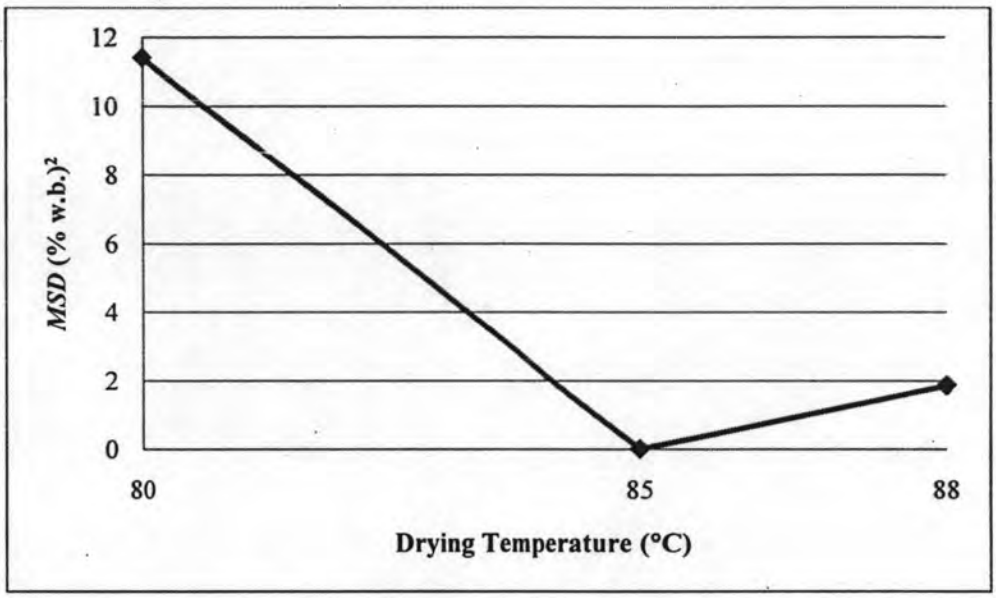

Figure 7.48 *MSD* from drying longan with a constant drying rate within medium moisture content

(5) Constructing Mathematical Model

After selecting the optimal drying temperature level, the mathematical model for drying longan within medium moisture content is constructed by Matlab program with function *polyfit*. As a result, the mathematical model is shown as Equation (7.11).

$$M(t)_2 = 91.1 - 1.2t, \qquad 0 \le t \le 15 \qquad (7.11)$$

7.4.3 High Moisture Content

Longan within high moisture content is sampled at an average initial moisture content of 94.3% w.b. It is dried with varying levels of temperature at 85, 88, and 90°C. The experimental results are explained as below.

(1) Drying Temperature Level at 85°C

From Figure 7.49, the moisture content of longan is reduced continuously with a constant drying rate. The constant drying rate of this drying temperature level is an average of 1.3% w.b./hour. The moisture content after drying is 74.5% w.b. It is greater than 73.0% w.b. as its target. Moreover, *MSD* is equaled to 2.196 (% w.b.)^2.

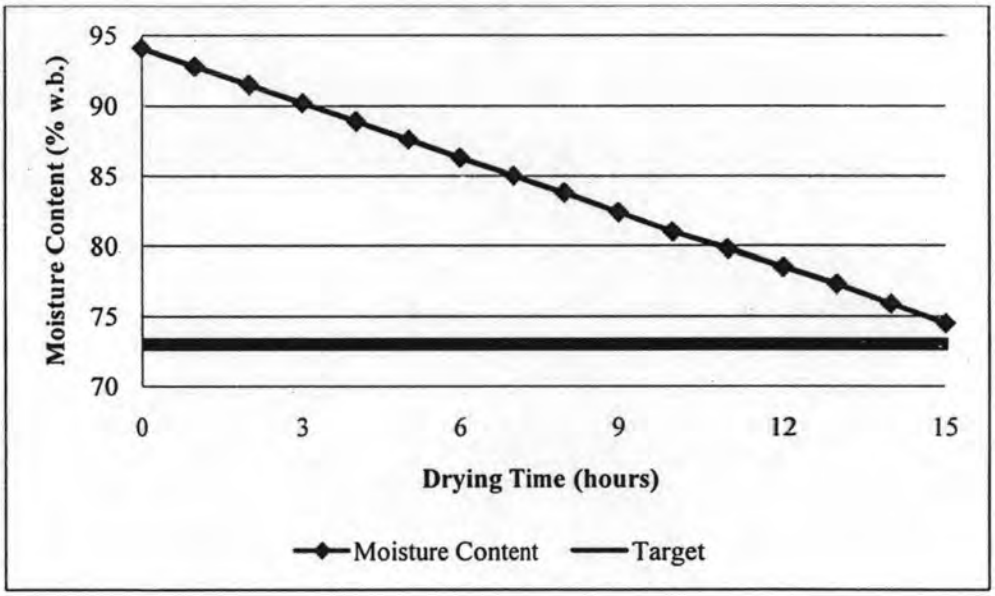

Figure 7.49 Drying result of longan within high moisture content at 85°C

(2) Drying Temperature Level at 88°C

From Figure 7.50, the moisture content of longan is reduced continuously with a constant drying rate. The constant drying rate of this drying temperature level is an average of 1.4% w.b./hour. The moisture content after drying is 73.1% w.b. It is very near to 73.0% w.b. as its target. Moreover, *MSD* is equaled to 0.014 (% w.b.)^2.

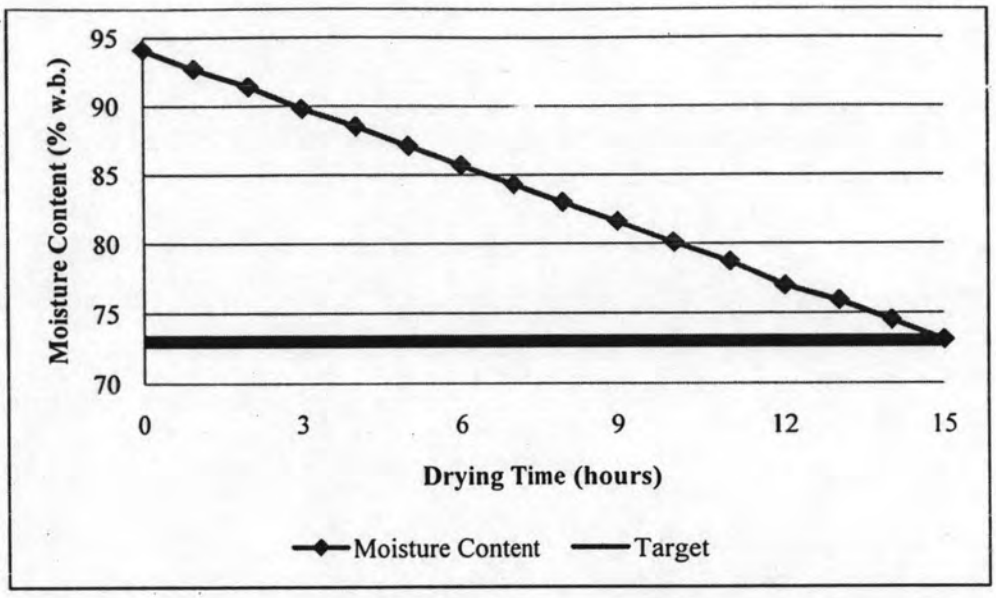

Figure 7.50 Drying result of longan within high moisture content at 88°C

(3) Drying Temperature Level at 90°C

From Figure 7.51, the moisture content of longan is reduced continuously with a constant drying rate. The constant drying rate of this drying temperature level is an average of 1.5% w.b./hour. The moisture content after drying is 71.6% w.b. It is less than 73.0% w.b. as its target. Moreover, *MSD* is equaled to 1.910 (% w.b.)^2.

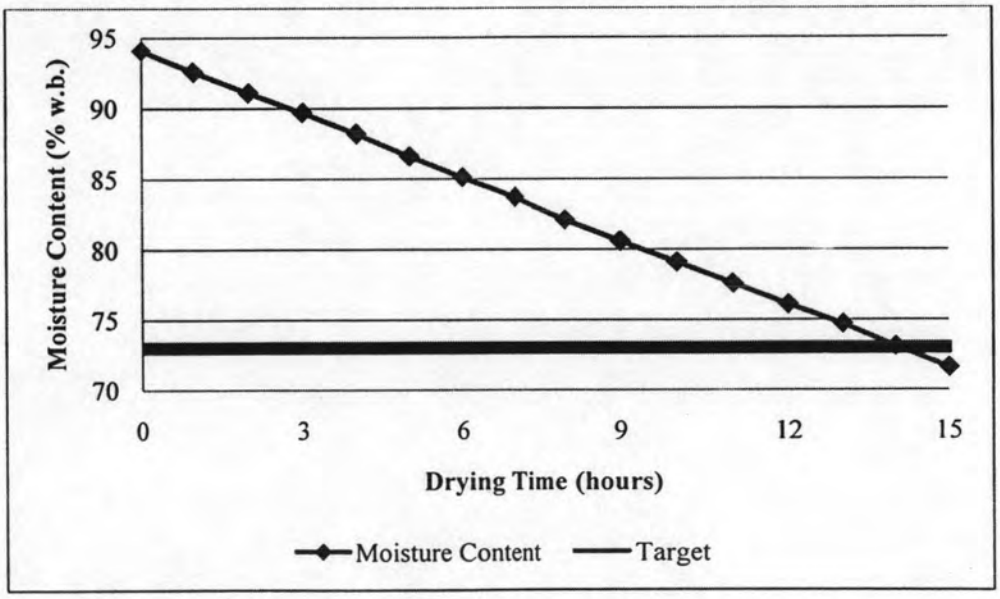

Figure 7.51 Drying result of longan within high moisture content at 90°C

(4) Selecting Optimal Drying Temperature Level

Minimum *MSD* is a criterion to select the optimal drying temperature level. From all experimental results, their *MSD*s are plotted in Figure 7.52. It shows that minimum *MSD* is from drying temperature level at 88°. Therefore, the optimal temperature level for drying longan within high moisture content is at 88°C.

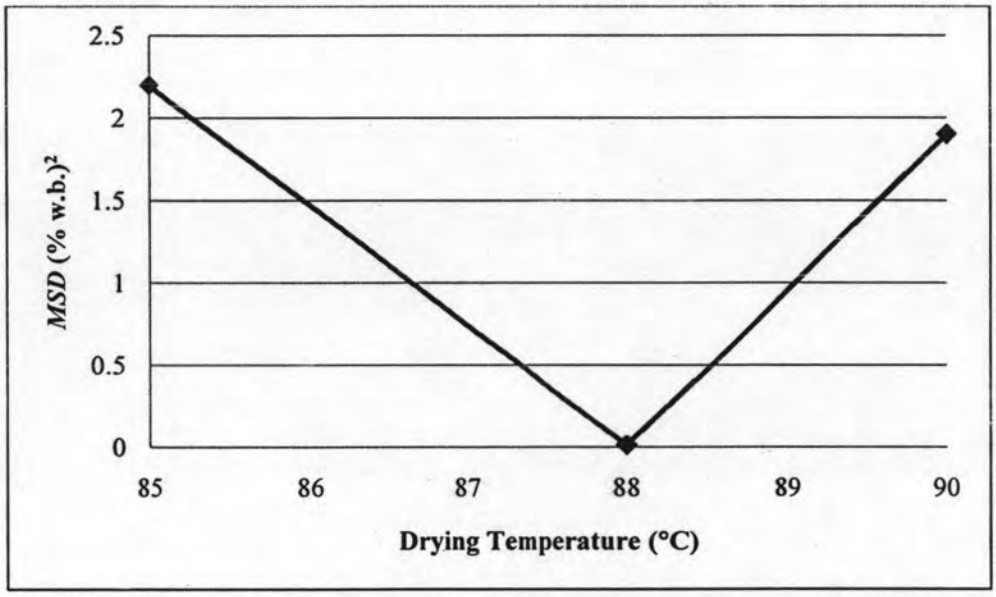

Figure 7.52 *MSD* from drying longan with a constant drying rate within high moisture content

(5) Constructing Mathematical Model

After selecting the optimal drying temperature level, the mathematical model for drying longan within high moisture content is constructed by Matlab program with function *polyfit*. As a result, the mathematical model is shown as Equation (7.12).

$$M(t)_1 = 94.1 - 1.39t, \qquad 0 \le t \le 15 \qquad (7.12)$$

From all drying experiments, they are summarized in Figure 7.53 which illustrates the optimal temperature levels and the mathematical models for drying longan within low, medium, and high moisture content clusters.

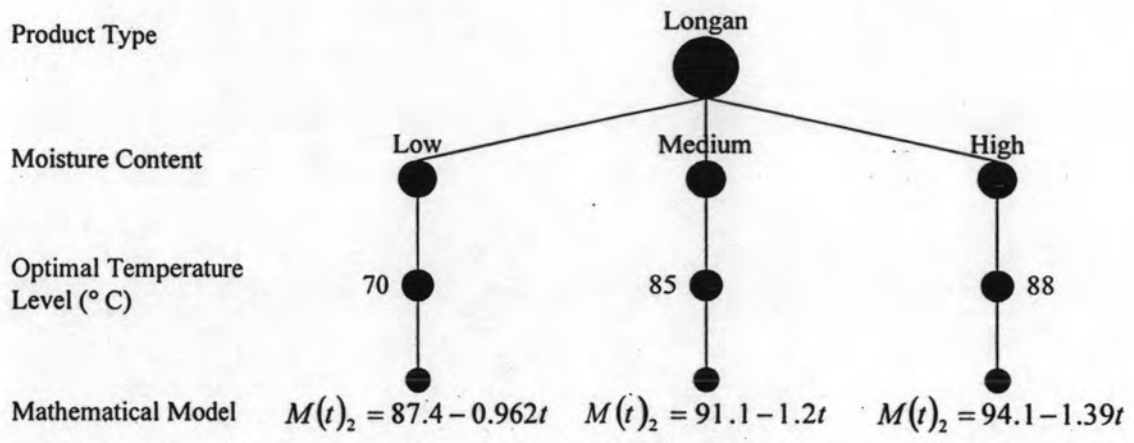

Figure 7.53 Optimal temperature levels and mathematical models for drying longan with a constant drying rate

7.5 Conclusion

The aims of this chapter are to find the optimal temperature level for drying the heated raw materials within each cluster and to construct the mathematical models in order to represent the behavior of the moisture content during drying period time with a constant drying rate. Experiments are conducted by varying levels of drying temperature. The drying temperature level which can minimize *MSD* is selected to be the optimal drying temperature level of the raw materials within their clusters. After selecting the optimal drying temperature level, the mathematical models are constructed by Matlab with function *polyfit*. All mathematical models are in uniform distribution. However, all experimental results of this chapter can be summarized in Table 7.1.

Table 7.1 Summary results of drying process within a constant drying rate phase

Product	Drying Time	Moisture Content	Optimal Temperature Level (°C)	Mathematical model
Paddy rice	5 minutes	Low	110	$M(t)_2 = 23.4 - 0.919t$
		Medium	120	$M(t)_2 = 26.1 - 1.42t$
		High	125	$M(t)_2 = 27.7 - 1.75t$
Cassava chip	20 minutes	Low	90	$M(t)_2 = 52.3 - 1.12t$
		Medium	100	$M(t)_2 = 60.2 - 1.51t$
		High	110	$M(t)_2 = 67.6 - 1.88t$
Tobacco	10 minutes	Low	60	$M(t)_2 = 17.0 - 0.302t$
		Medium	65	$M(t)_2 = 18.3 - 0.43t$
		High	70	$M(t)_2 = 20.0 - 0.604t$
Longan	15 hours	Low	70	$M(t)_2 = 87.4 - 0.962t$
		Medium	85	$M(t)_2 = 91.1 - 1.2t$
		High	88	$M(t)_2 = 94.1 - 1.39t$