CHAPTER IX

VALIDATION OF QUALITY VARIATION MANAGEMENT IN DRYING PROCESS

After the raw materials and the drying process with three phases are already studied in previous chapters, validation of quality variation management in the drying process is required in this chapter as Figure 9.1. The validation can be used to ensure that all results of this dissertation can be used in the real drying process in order to improve the quality of the dried products by minimizing the dried product quality variation.

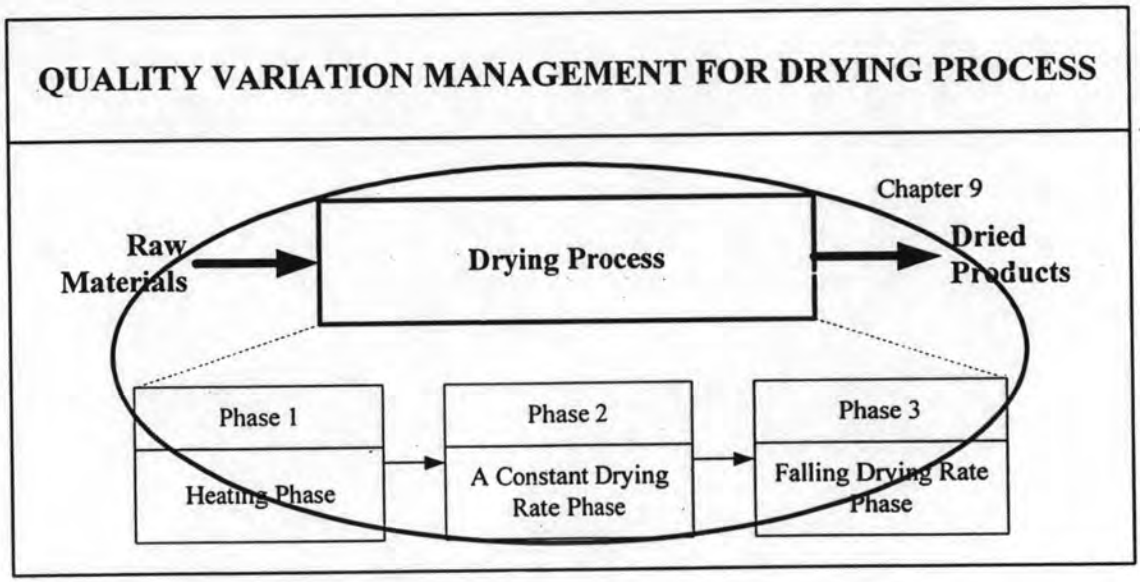

Figure 9.1 Scope of validation of quality variation management in drying process

The outline of this chapter is organized into five sections. In Section 9.1 to 9.4, experimental results of paddy rice, cassava chip, tobacco, and longan are explained and discussed respectively. For each product type, the results of the validation are shown as following the cluster of the raw material (low, medium, and high moisture content). After all results of the validation are shown, they are concluded and summarized into the last section as Section 9.5.

9.1 Experimental Results of Paddy Rice

The samples of paddy rice are organized into three clusters as low, medium, and high moisture content. The criteria for organizing the sample of paddy rice are: low moisture content is in a range of 22.1-25.3% w.b.; medium moisture content is in a range of 25.5-27.0% w.b.; and high moisture content is in a range of 27.1-29.0% w.b. Experimental results are shown as below.

9.1.1 Low Moisture Content

From the heating mathematical model of paddy rice within low moisture content, the initial moisture content is at 23.4% w.b. Therefore, the sample is selected with the initial moisture content at 23.4% w.b. in order to compare the difference between the mathematical models and the real drying process. In this dissertation, the upper bound of the difference of the moisture contents between from the mathematical model and from the real drying process is desired at an average of 5.0%.

The result of the comparison is illustrated as Figure 9.2. The moisture content after drying from the mathematical models is at 14.1% w.b., while the moisture content after drying from the real drying process is at 13.8% w.b. It is different from the mathematical models as 0.3% w.b. Moreover, the difference of the moisture contents between from the mathematical models and from the real drying process is an average of 0.83%. This difference is less than the upper bound. Thus, the mathematical models of all drying phase for drying paddy rice can be used.

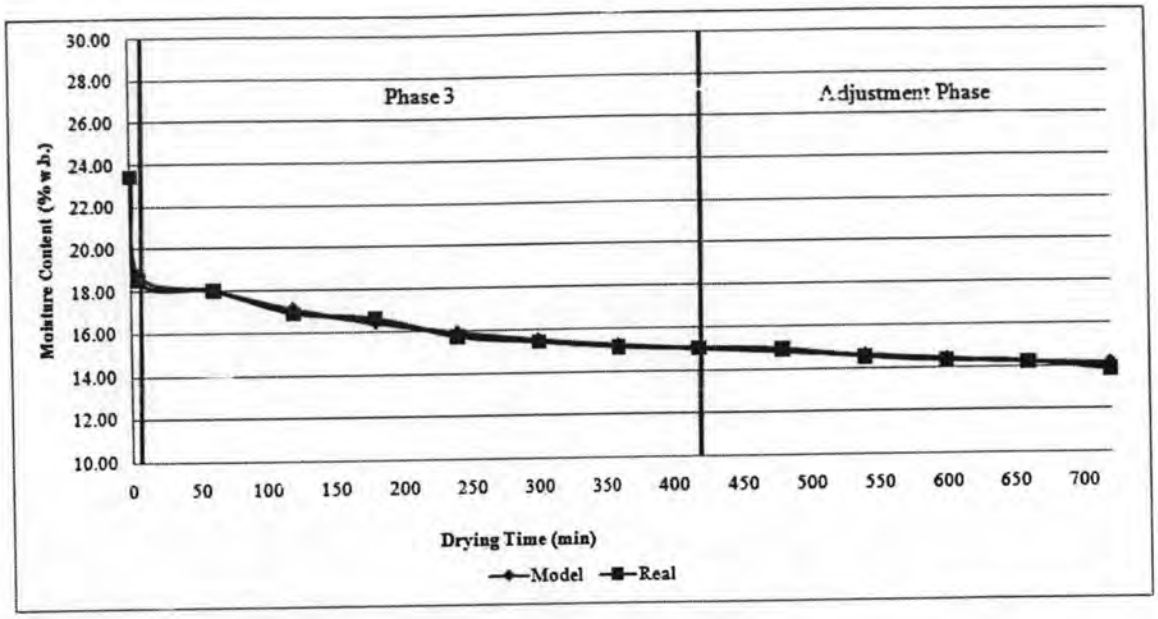

Figure 9.2 Comparison of the moisture contents between from the mathematical model and the real drying process of paddy rice within low moisture content

9.1.2 Medium Moisture Content

From the heating mathematical model of paddy rice within medium moisture content, the initial moisture content is at 26.1% w.b. Therefore, the sample is selected with the initial moisture content at 26.1% w.b. in order to compare the difference between the mathematical models and the real drying process. In this dissertation, the upper bound of the difference of the moisture contents between from the mathematical model and from the real drying process is desired at an average of 5.0%.

The result of the comparison is illustrated as Figure 9.3. The moisture content after drying from the mathematical models is at 14.1% w.b., while the moisture content after drying from the real drying process is at 14.0% w.b. It is different from the mathematical models as 0.1% w.b. Moreover, the difference of the moisture contents between from the mathematical models and from the real drying process is an average of 1.30%. This difference is less than the upper bound. Thus, the mathematical models of all drying phase for drying paddy rice can be used.

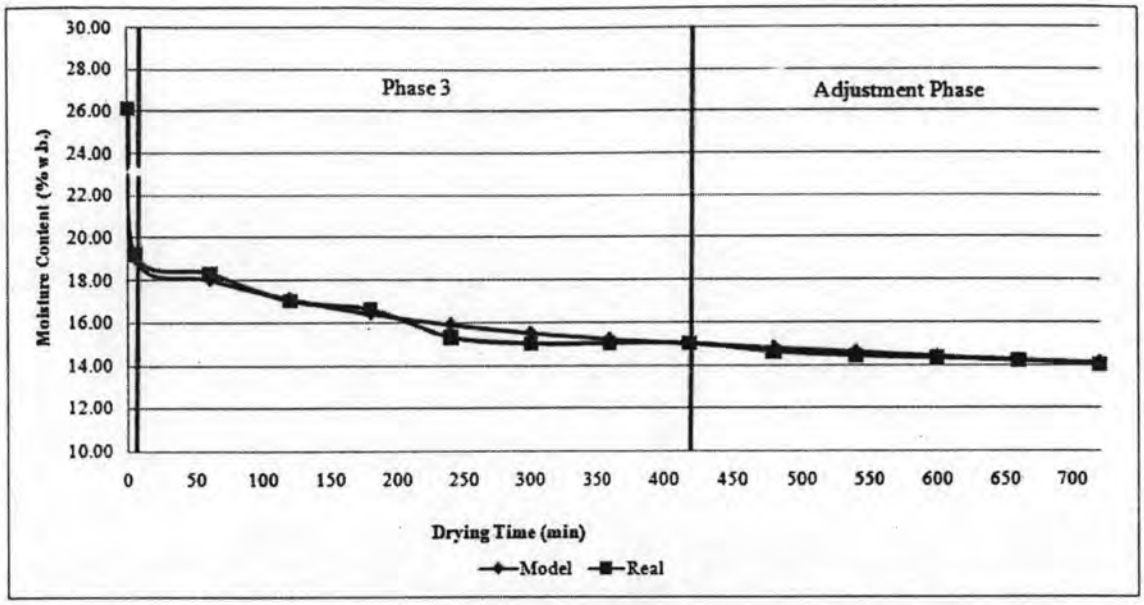

Figure 9.3 Comparison of the moisture contents between from the mathematical model and the real drying process of paddy rice within medium moisture content

9.1.3 High Moisture Content

From the heating mathematical model of paddy rice within high moisture content, the initial moisture content is at 27.7% w.b. Therefore, the sample is selected with the initial moisture content at 27.7% w.b. in order to compare the difference between the mathematical models and the real drying process. In this dissertation, the upper bound of the difference of the moisture contents between from the mathematical model and from the real drying process is desired at an average of 5.0%.

The result of the comparison is illustrated as Figure 9.4. The moisture content after drying from the mathematical models is at 14.1% w.b., while the moisture content after drying from the real drying process is at 13.8% w.b. It is different from the mathematical models as 0.3% w.b. Moreover, the difference of the moisture contents between from the mathematical models and from the real drying process is an average of 1.83%. This difference is less than the upper bound. Thus, the mathematical models of all drying phase for drying paddy rice can be used.

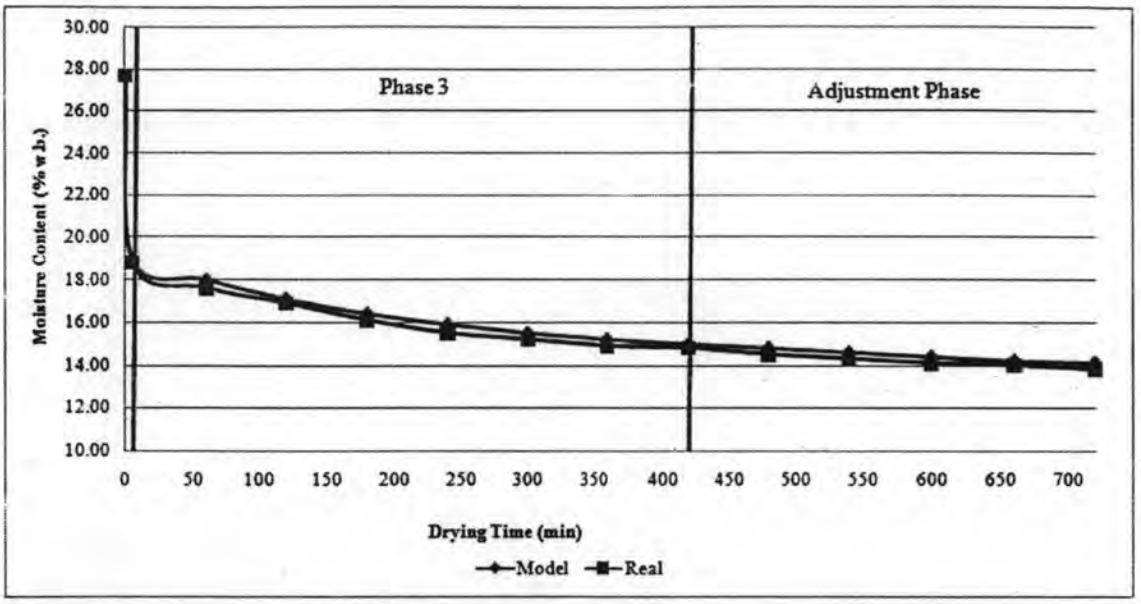

Figure 9.4 Comparison of the moisture contents between from the mathematical model and the real drying process of paddy rice within high moisture content

With all drying temperature levels and mathematical models, the dried product quality variation of paddy rice can be reduced from 3.655 (% w.b.)^2 to 0.030 (% w.b.)^2.

9.2 Experimental Results of Cassava Chip

The samples of cassava chip are organized into three clusters as low, medium, and high moisture content. The criteria for organizing the sample of cassava chip are: low moisture content is in a range of 40.2-55.5% w.b.; medium moisture content is in a range of 55.6-62.4% w.b.; and high moisture content is in a range of 62.5-73.4% w.b. Experimental results are shown as below.

9.2.1 Low Moisture Content

From the heating mathematical model of cassava chip within low moisture content, the initial moisture content is at 52.3% w.b. Therefore, the sample is selected with the initial moisture content at 52.3% w.b. in order to compare the difference between the mathematical models and the real drying process. In this

dissertation, the upper bound of the difference of the moisture contents between from the mathematical model and from the real drying process is desired at an average of 5.0%.

The result of the comparison is illustrated as Figure 9.5. The moisture content after drying from the mathematical models is at 13.9% w.b., while the moisture content after drying from the real drying process is at 13.5% w.b. It is different from the mathematical models as 0.4% w.b. Moreover, the difference of the moisture contents between from the mathematical models and from the real drying process is an average of 1.93%. This difference is less than the upper bound. Thus, the mathematical models of all drying phase for drying cassava chip can be used.

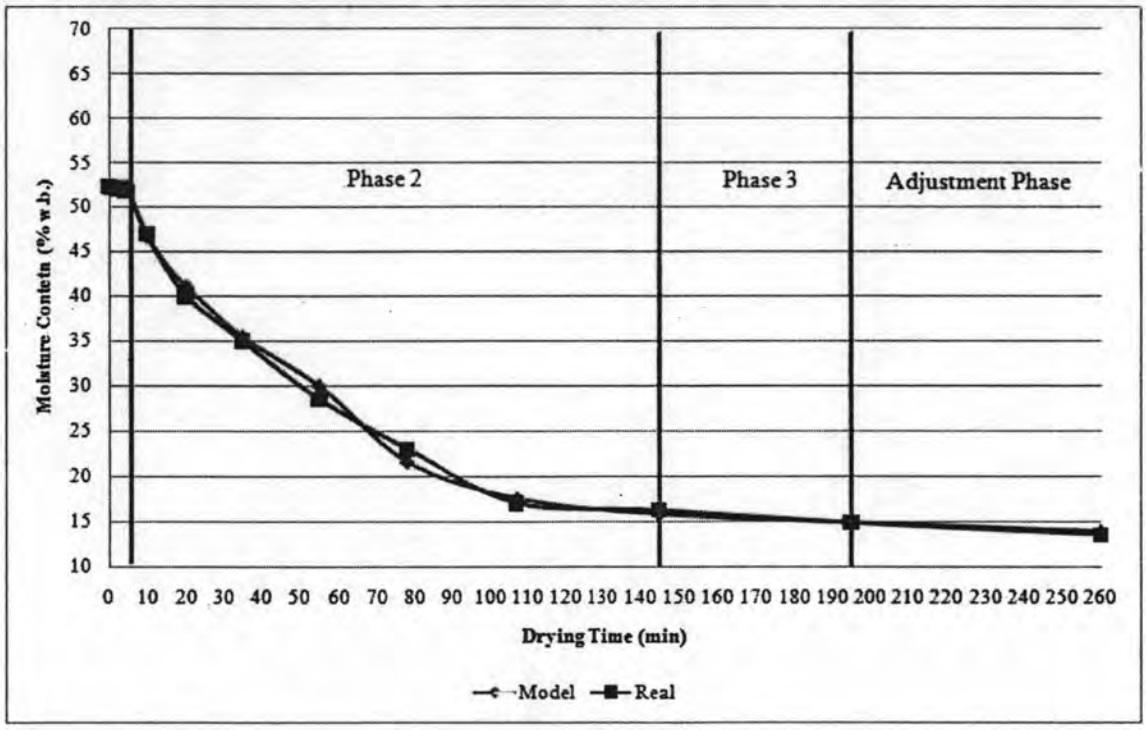

Figure 9.5 Comparison of the moisture contents between from the mathematical model and the real drying process of cassava chip within low moisture content

9.2.2 Medium Moisture Content

From the heating mathematical model of cassava chip within medium moisture content, the initial moisture content is at 60.2% w.b. Therefore, the sample is selected with the initial moisture content at 60.2% w.b. in order to compare the

difference between the mathematical models and the real drying process. In this dissertation, the upper bound of the difference of the moisture contents between from the mathematical model and from the real drying process is desired at an average of 5.0%.

The result of the comparison is illustrated as Figure 9.6. The moisture content after drying from the mathematical models is at 13.9% w.b., while the moisture content after drying from the real drying process is at 13.5% w.b. It is different from the mathematical models as 0.4% w.b. Moreover, the difference of the moisture contents between from the mathematical models and from the real drying process is an average of 3.17%. This difference is less than the upper bound. Thus, the mathematical models of all drying phase for drying cassava chip can be used.

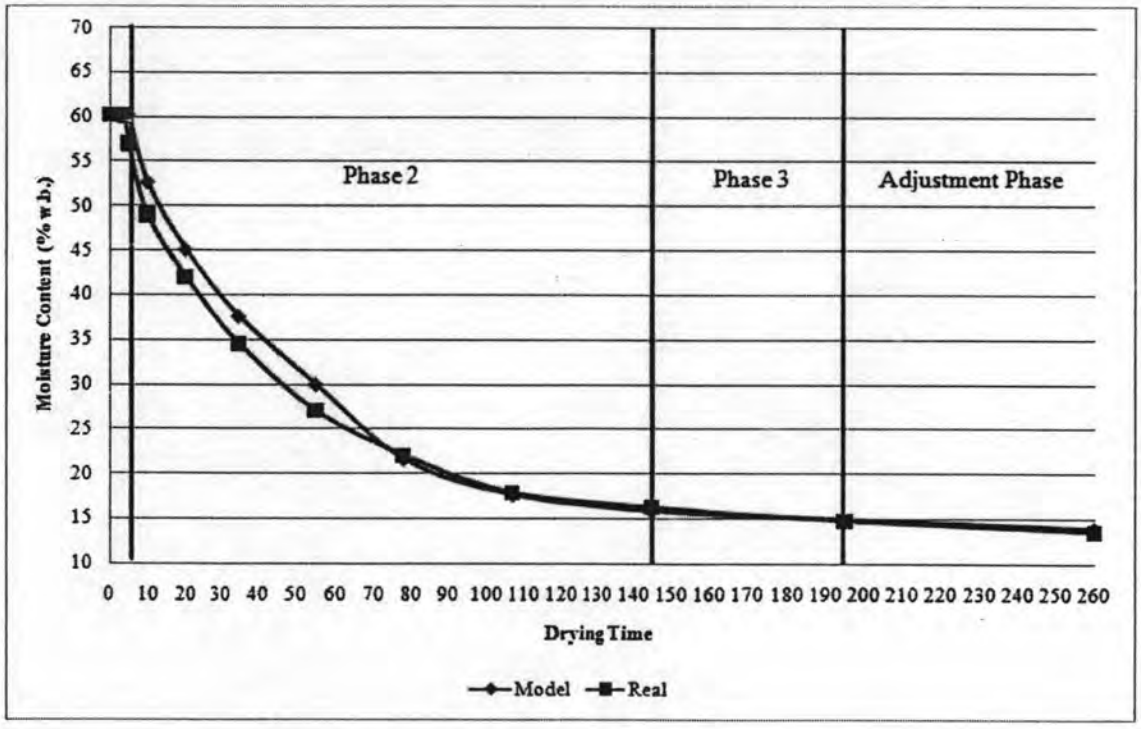

Figure 9.6 Comparison of the moisture contents between from the mathematical model and the real drying process of cassava chip within medium moisture content

9.2.3 High Moisture Content

From the heating mathematical model of cassava chip within high moisture content, the initial moisture content is at 67.7% w.b. Therefore, the sample is

selected with the initial moisture content at 67.7% w.b. in order to compare the difference between the mathematical models and the real drying process. In this dissertation, the upper bound of the difference of the moisture contents between from the mathematical model and from the real drying process is desired at an average of 5.0%.

The result of the comparison is illustrated as Figure 9.7. The moisture content after drying from the mathematical models is at 13.9% w.b., while the moisture content after drying from the real drying process is at 14.1% w.b. It is different from the mathematical models as 0.2% w.b. Moreover, the difference of the moisture contents between from the mathematical models and from the real drying process is an average of 1.97%. This difference is less than the upper bound. Thus, the mathematical models of all drying phase for drying cassava chip can be used.

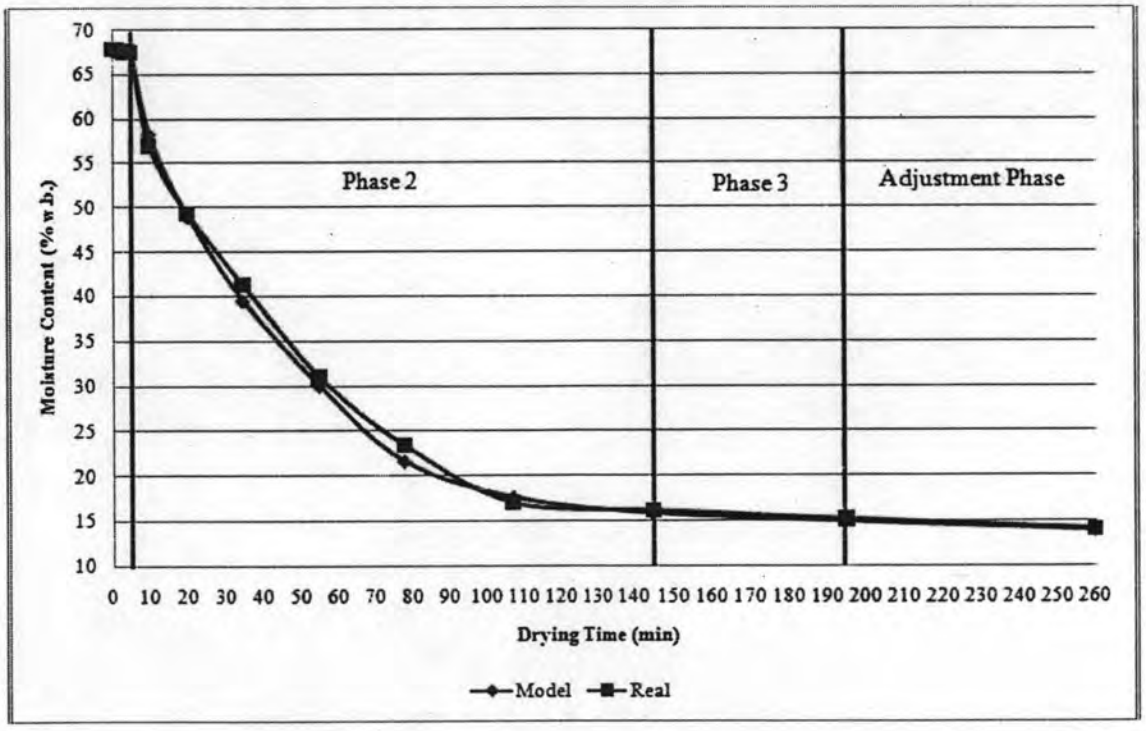

Figure 9.7 Comparison of the moisture contents between from the mathematical model and the real drying process of cassava chip within high moisture content

With all drying temperature levels and mathematical models, the dried product quality variation of cassava chip can be reduced from 7.619 (% w.b.)^2 to 0.170 (% w.b.)^2.

9.3 Experimental Results of Tobacco

The samples of tobacco are organized into three clusters as low, medium, and high moisture content. The criteria for organizing the sample of tobacco are: low moisture content is in a range of 15.0-17.6% w.b.; medium moisture content is in a range of 17.7-19.4% w.b.; and high moisture content is in a range of 19.5-22.4% w.b. Experimental results are shown as below.

9.3.1 Low Moisture Content

From the heating mathematical model of tobacco within low moisture content, the initial moisture content is at 17.0% w.b. Therefore, the sample is selected with the initial moisture content at 17.0% w.b. in order to compare the difference between the mathematical models and the real drying process. In this dissertation, the upper bound of the difference of the moisture contents between from the mathematical model and from the real drying process is desired at an average of 5.0%.

The result of the comparison is illustrated as Figure 9.8. The moisture content after drying from the mathematical models is at 12.5% w.b., while the moisture content after drying from the real drying process is at 12.2% w.b. It is different from the mathematical models as 0.3% w.b. Moreover, the difference of the moisture contents between from the mathematical models and from the real drying process is an average of 2.37%. This difference is less than the upper bound. Thus, the mathematical models of all drying phase for drying tobacco can be used.

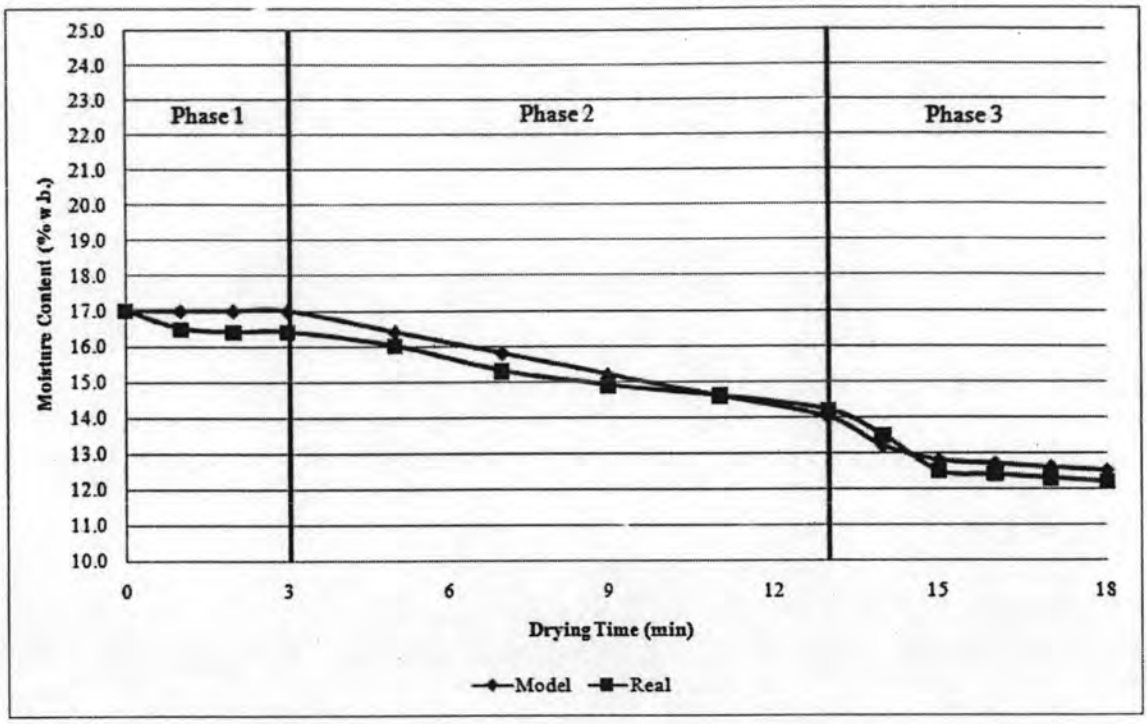

Figure 9.8 Comparison of the moisture contents between from the mathematical model and the real drying process of tobacco within low moisture content

9.3.2 Medium Moisture Content

From the heating mathematical model of tobacco within medium moisture content, the initial moisture content is at 18.3% w.b. Therefore, the sample is selected with the initial moisture content at 18.3% w.b. in order to compare the difference between the mathematical models and the real drying process. In this dissertation, the upper bound of the difference of the moisture contents between from the mathematical model and from the real drying process is desired at an average of 5.0%.

The result of the comparison is illustrated as Figure 9.9. The moisture content after drying from the mathematical models is at 12.5% w.b., while the moisture content after drying from the real drying process is at 12.2% w.b. It is different from the mathematical models as 0.3% w.b. Moreover, the difference of the moisture contents between from the mathematical models and from the real drying

process is an average of 1.74%. This difference is less than the upper bound. Thus, the mathematical models of all drying phase for drying tobacco can be used.

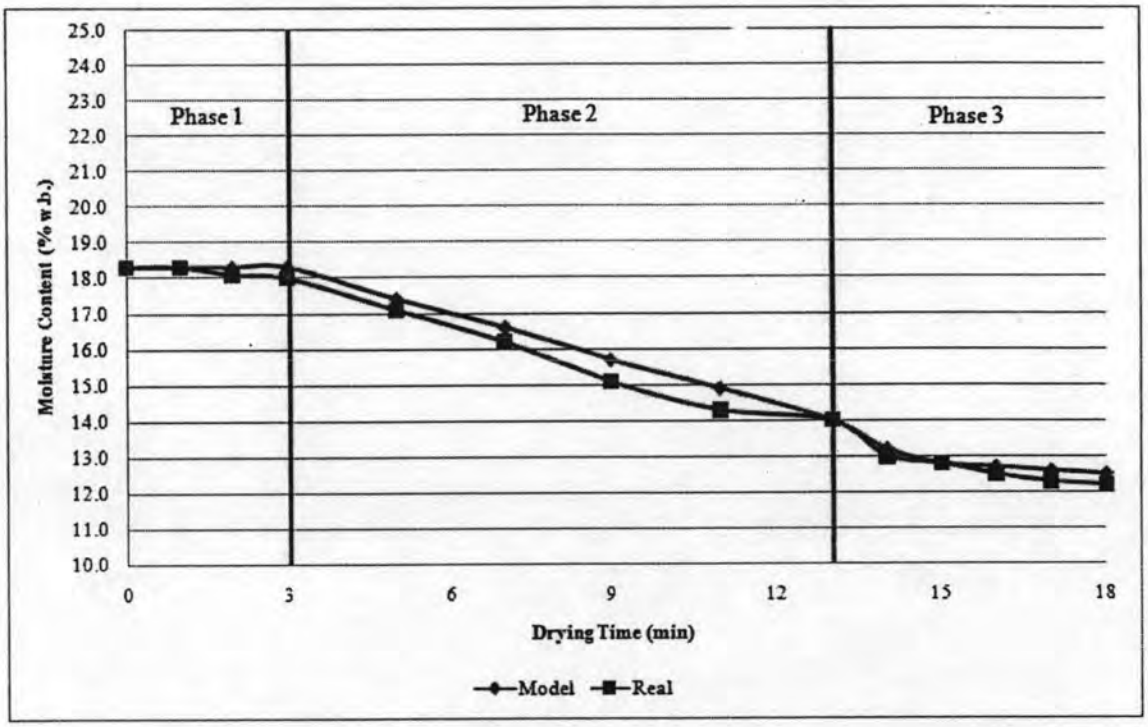

Figure 9.9 Comparison of the moisture contents between from the mathematical model and the real drying process of tobacco within medium moisture content

9.3.3 High Moisture Content

From the heating mathematical model of tobacco within high moisture content, the initial moisture content is at 20.0% w.b. Therefore, the sample is selected with the initial moisture content at 20.0% w.b. in order to compare the difference between the mathematical models and the real drying process. In this dissertation, the upper bound of the difference of the moisture contents between from the mathematical model and from the real drying process is desired at an average of 5.0%.

The result of the comparison is illustrated as Figure 9.10. The moisture content after drying from the mathematical models is at 12.5% w.b., while the moisture content after drying from the real drying process is at 12.3% w.b. It is different from the mathematical models as 0.2% w.b. Moreover, the difference of the moisture contents between from the mathematical models and from the real drying

process is an average of 1.91%. This difference is less than the upper bound. Thus, the mathematical models of all drying phase for drying tobacco can be used.

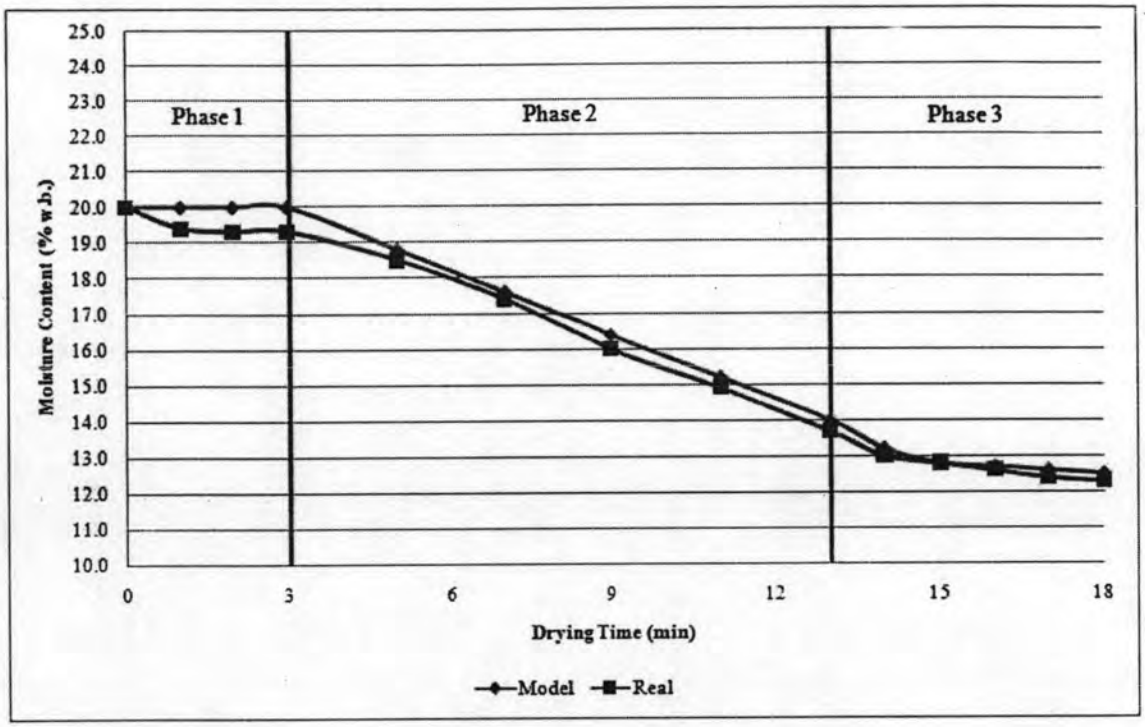

Figure 9.10 Comparison of the moisture contents between from the mathematical model and the real drying process of tobacco within high moisture content

With all drying temperature levels and mathematical models, the dried product quality variation of tobacco can be reduced from 2.902 (% w.b.)^2 to 0.070 (% w.b.)^2.

9.4 Experimental Results of Longan

The samples of longan are organized into three clusters as low, medium, and high moisture content. The criteria for organizing the sample of longan are: low moisture content is in a range of 84.6-89.5% w.b.; medium moisture content is in a range of 89.6-93.0% w.b.; and high moisture content is in a range of 93.1-97.0% w.b. Experimental results are shown as below.

9.4.1 Low Moisture Content

From the heating mathematical model of longan within low moisture content, the initial moisture content is at 87.4% w.b. Therefore, the sample is selected with the initial moisture content at 87.4% w.b. in order to compare the difference between the mathematical models and the real drying process. In this dissertation, the upper bound of the difference of the moisture contents between from the mathematical model and from the real drying process is desired at an average of 5.0%.

The result of the comparison is illustrated as Figure 9.11. The moisture content after drying from the mathematical models is at 18.0% w.b., while the moisture content after drying from the real drying process is at 17.8% w.b. It is different from the mathematical models as 0.2% w.b. Moreover, the difference of the moisture contents between from the mathematical models and from the real drying process is an average of 1.71%. This difference is less than the upper bound. Thus, the mathematical models of all drying phase for drying longan can be used.

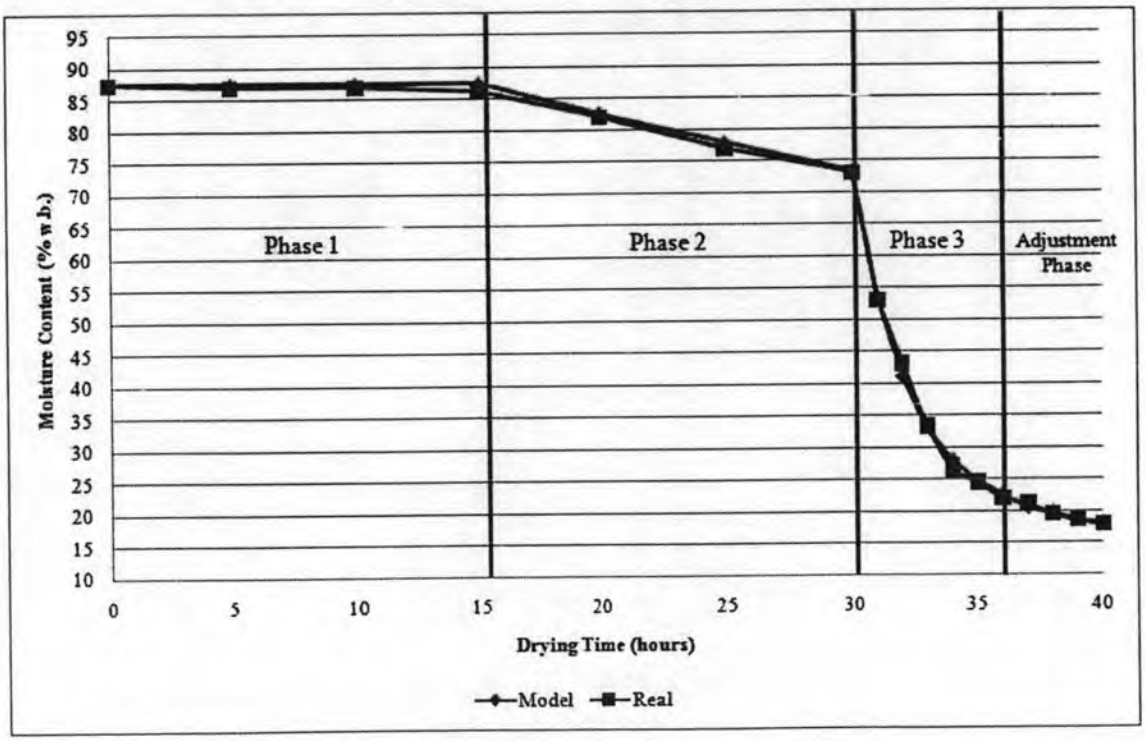

Figure 9.11 Comparison of the moisture contents between from the mathematical model and the real drying process of longan within low moisture content

9.4.2 Medium Moisture Content

From the heating mathematical model of longan within medium moisture content, the initial moisture content is at 91.1% w.b. Therefore, the sample is selected with the initial moisture content at 91.1% w.b. in order to compare the difference between the mathematical models and the real drying process. In this dissertation, the upper bound of the difference of the moisture contents between from the mathematical model and from the real drying process is desired at an average of 5.0%.

The result of the comparison is illustrated as Figure 9.12. The moisture content after drying from the mathematical models is at 18.0% w.b., while the moisture content after drying from the real drying process is at 17.9% w.b. It is different from the mathematical models as 0.1% w.b. Moreover, the difference of the moisture contents between from the mathematical models and from the real drying process is an average of 1.75%. This difference is less than the upper bound. Thus, the mathematical models of all drying phase for drying longan can be used.

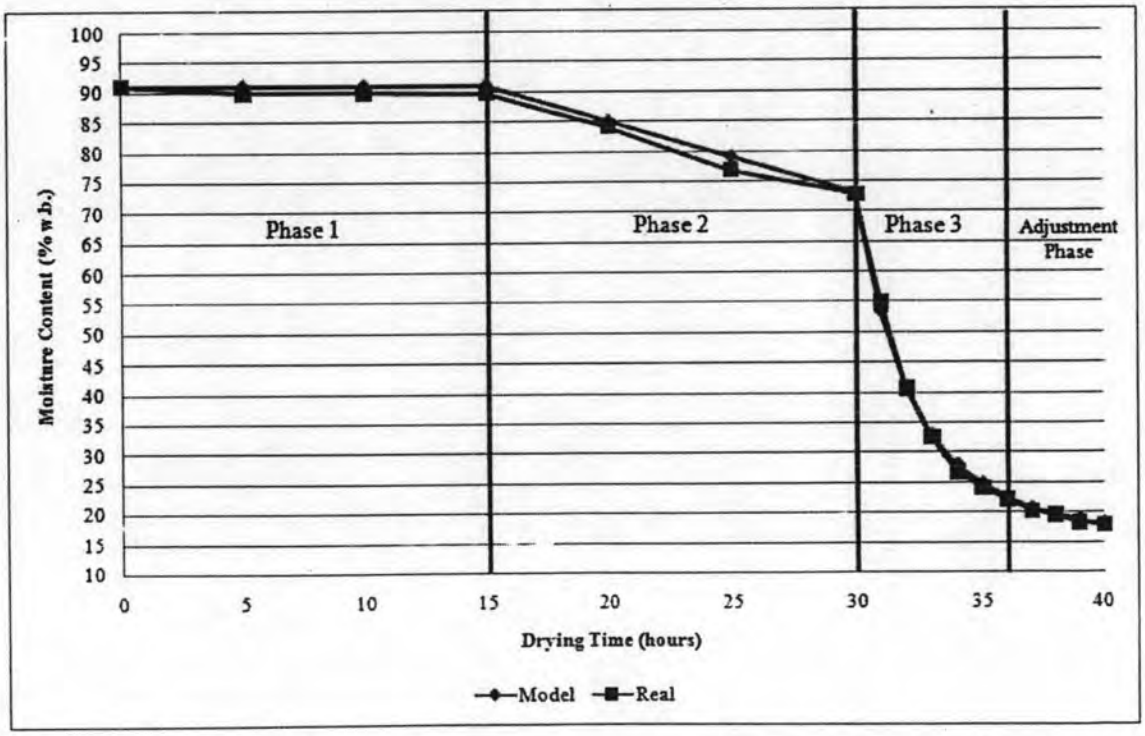

Figure 9.12 Comparison of the moisture contents between from the mathematical model and the real drying process of longan within medium moisture content

9.4.3 High Moisture Content

From the heating mathematical model of longan within high moisture content, the initial moisture content is at 93.6% w.b. Therefore, the sample is selected with the initial moisture content at 93.6% w.b. in order to compare the difference between the mathematical models and the real drying process. In this dissertation, the upper bound of the difference of the moisture contents between from the mathematical model and from the real drying process is desired at an average of 5.0%.

The result of the comparison is illustrated as Figure 9.13. The moisture content after drying from the mathematical models is at 18.0% w.b., while the moisture content after drying from the real drying process is at 18.0% w.b. It is not different from the mathematical models. Moreover, the difference of the moisture contents between from the mathematical models and from the real drying process is an average of 1.82%. This difference is less than the upper bound. Thus, the mathematical models of all drying phase for drying longan can be used.

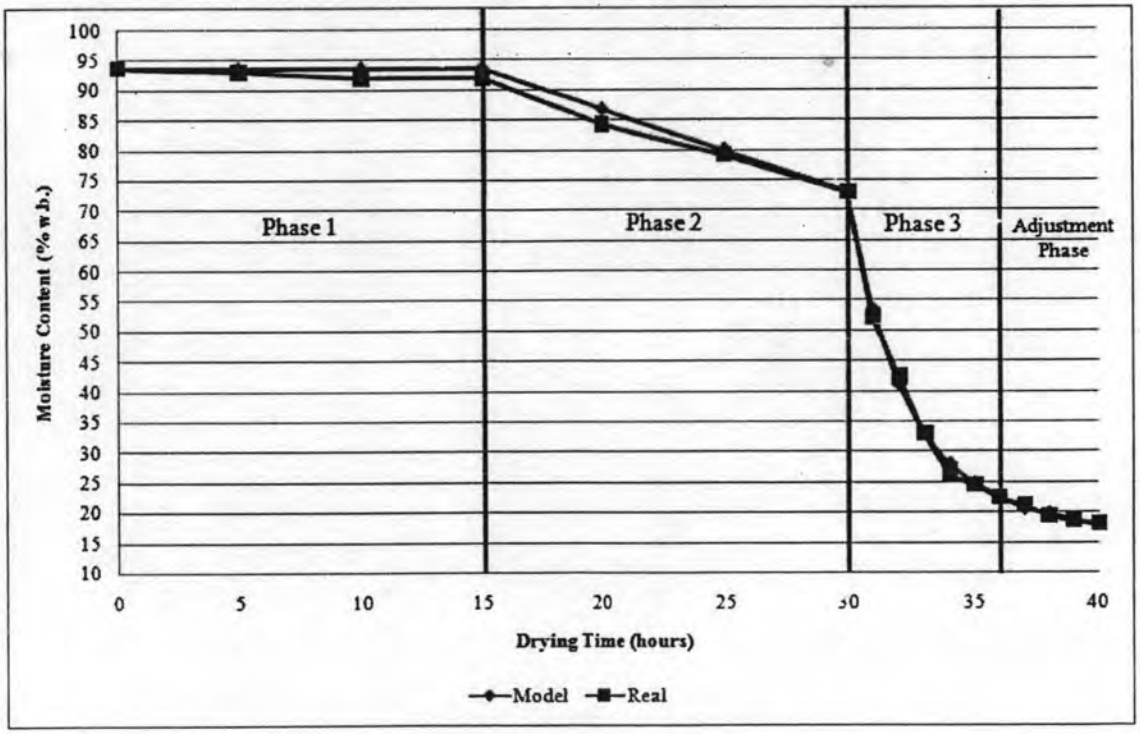

Figure 9.13 Comparison of the moisture contents between from the mathematical model and the real drying process of longan within high moisture content

With all drying temperature levels and mathematical models, the dried product quality variation of longan can be reduced from 10.758 (% w b.)^2 to 0.020 (% w.b.)^2.

9.5 Conclusion

From the results of the validation, all drying mathematical models which are constructed from this dissertation can be used to the real drying process in Thai agro-industry. The results of the validation are summarized in Table 9.1. Moreover, Table 9.2 illustrates the reduction of the dried product quality variation.

Table 9.1 Summary of the results of the validation

Product	Range of moisture content	Output moisture content (%w.b.)		Average of difference (%)
		Mathematical models	Real process	
Paddy rice	Low	14.1	13.8	0.83
	Medium	14.1	14.0	1.30
	High	14.1	13.8	1.83
Cassava chip	Low	13.9	13.5	1.93
	Medium	13.9	13.5	3.17
	High	13.9	14.1	1.97
Tobacco	Low	12.5	12.2	2.37
	Medium	12.5	12.2	1.74
	High	12.5	12.3	1.91
Longan	Low	18.0	17.8	1.71
	Medium	18.0	17.9	1.75
	High	18.0	18.0	1.82

Table 9.2 Summary of the reduction of the dried product quality variation

Product	*MSD* (% w.b.)^2	
	Conventional Method	**This Dissertation**
Paddy rice	3.655	0.030
Cassava chip	7.691	0.170
Tobacco	2.902	0.070
Longan	10.758	0.020