KKU Engineering Journal

https://www.tci-thaijo.org/index.php/kkuenj/index

Whiteness index prediction of para rubber sheet during hot air drying

Chaiwat Rattanamechaiskul*[1)], Nittaya Junka[2)], Jakkrit Potichalung[1)], Thawatchai Wingwon[1)], Wattana Boontum[1)] and Naruebodee Srisang[1)]

[1)]Department of Engineering, King Mongkut's Institute of Technology Ladkrabang,
Prince of Chumphon Campus, Chumphon 86160, Thailand.
[2)]Division of Crop Production Technology, Faculty of Science and Technology,
Nakhon Pathom Rajabhat University, Nakhon Pathom 73000, Thailand.

Received April 2016
Accepted June 2016

Abstract

This research's objective was to study the color change by analyzing whiteness index (WI) of unsmoked sheet (USS) during hot air drying at different temperatures compared with reference USS dried by sun drying. Result data then was used to develop the equation to predict the WI change by response surface methodology (RSM). The times to dry the raw para rubber sheet (RPRS) at initial moisture content of 25.0±2.0 % dry basis (d.b.) with hot air temperature of 50, 60 and 70˚C to final moisture content of 3.0±1.0 % d.b. were 68, 44 and 16 hr, respectively. At the final moisture content, WI values of the dried USS were 48.8, 50.1 and 54.5, respectively, whereas that value of reference USS was 43.3. Consequently, the brown color of dried USS by hot air was not darker than the reference USS and regarded good quality color. In addition between the first and second degree models of WI prediction, it was found the second degree model was better with a mean of coefficient of determination (R^2) of 0.9424.

Keywords: Para rubber sheet, Whiteness index, Hot air drying, Response Surface

1. Introduction

Para rubber prior delivery for distribution must be passed the initial process beginning from collecting latex from rubber tree plantation followed by dirt and impurity filtration, coagulation and sheeting. High-moisture content RPRS then should be dried to USS to avoid mold problem during storage and shipment. At the present, the general methods to dry RPRS were sun or hot air drying. Although advantage of sun drying had no energy cost, under daily different weather conditions particularly in the South of Thailand resulted in the longer drying time used for demoisture process to 14 days, leading to frequent mold problem [1]. For hot air drying, despite of its time shorter than sun drying due to constant temperature control advantage, physical effects such as air bubble, dark color from burn, irregular USS color etc. might occur from the unsuitable drying condition selected [2]. Other researches on RPRS were the mathematical model developments and designs drying chamber which significantly considered to air flow characteristics and drying kinetics only [3-4]. At present no researches on drying process effects to USS physical change in the quantitative color have been available.

In this research's objective was to study the color change which was a significant USS physical characteristic using WI as indicator. Result data then used to develop the equation to predict change of WI value during drying by RSM. The research would be benefit of USS production to enable the product quality on the required standard.

2. Materials and methods

2.1 RPRS drying

The RPRS used in this research was from Agriculture, Food and Energy Center, King Mongkut's Institute of Technology Ladkrabang, Prince of Chumphon Campus, Chumphon, Thailand with a 1:3 proportional reduced size from the Rubber Research Institute standard size to 12.5x30x0.3cm (WxLxT) and initial moisture content of 25.0±2.0 % d.b. The RPRS sample was dried by the 60x70x100cm (WxLxH) hot air oven in Figure 1 at the drying temperatures of 50, 60 and 70°C and air velocity of 0.7 m/s until the final moisture content reduced to 3.0±1.0 % d.b. For the reference USS sample, it was the good quality USS dried by sun drying for 14 day.

2.2 Whiteness index analysis

Color of the para rubber sheet samples dried by hot air at different temperatures and time periods was measured with colorimeter (Minolta, model CR400, Tokyo, Japan). The parameters expressed by L^*, a^* *and* b^* and then WI value could be calculated by Equation 1 [5].

*Corresponding author. Tel.: +66 7750 6410
Email address: rat.chaiwat@gmail.com
doi: 10.14456/kkuenj.2016.122

$$WI = 100 - \left[\left(100 - L^*\right)^2 + \left(a^*\right)^2 + \left(b^*\right)^2 \right]^{0.5} \quad (1)$$

2.3 Response surface model

RSM is a mathematical technique developed to form the response of interest (*y*) and input or independent variables (*x*) relationship. For the equation to predict change of WI value during hot drying, drying temperature (*T*) and drying time (*t*) would be the independent variables as functions in the Equation 2.

$$WI = f(T,t) \quad (2)$$

Change of WI was expressed by the first and second degree models in their general forms in Equations 3 and 4 [6].

$$y = \beta_0 + \sum_{i=1}^{k} \beta_i x_i + \varepsilon \quad (3)$$

$$y = \beta_0 + \sum_{i=1}^{k} \beta_i x_i + \sum_{i=1}^{k} \beta_{ii} x_i^2 + \sum\sum_{i<j} \beta_{ij} x_i x_j + \varepsilon \quad (4)$$

where β_0 is a constant ; β_i , β_{ii} and β_{ij} are the linear, quadratic and interaction coefficients, respectively; k is number of independent variables and ε is a random experimental error assumed to have a zero mean. Substituting parameter values to Equations 3 and 4, the both WI prediction models could be written as the following Equations 5 and 6.

$$WI = \beta_0 + \beta_1 T + \beta_2 t \quad (5)$$

$$WI = \beta_0 + \beta_1 T + \beta_2 t + \beta_3 T^2 + \beta_4 t^2 + \beta_5 Tt \quad (6)$$

3. Results and discussion

3.1 Drying kinetics

Figure 2 shows evolution of the RPRS moisture content during hot air dryings at temperatures of 50°, 60° and 70°C which were found in the first 6 hr that the sample moisture content was still high evaporation from sample surface to drying air at all drying temperatures. Afterward as the drying time increased, the evaporation rate would directly relate with the drying temperature level. For reducing moisture content of RPRS to desire level, the required drying time at temperature of 70°C was 16 hr whereas that of value at temperatures of 50°C and 60°C was longer at 68 and 44 hr.

3.2 Change of WI during drying

Figure 3 shows WI change of sample during hot air drying at temperature of 50, 60 and 70°C. The initial WI value was in the range of 86.7-87.4. When the drying process was started, the trend of WI decreased as the drying time increased. In addition as drying process continued more than 6 hr, the increasing of drying temperature would have direct effect to decrease of WI value, particularly at temperature of 70°C. At 3.0% d.b. final moisture content, the WI values of dried USS by hot air drying at temperature of 50, 60 and 70°C were 48.8, 50.1 and 54.5, respectively, while that of value of reference USS was 43.3. Figure 4 illustrates color quality at final moisture content of reference and dried USS. It revealed that dried USS had brown color and not darker than reference USS, corresponding to WI result.

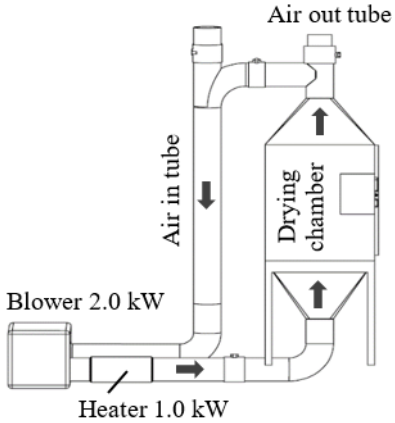

Figure 1 Hot air dryer

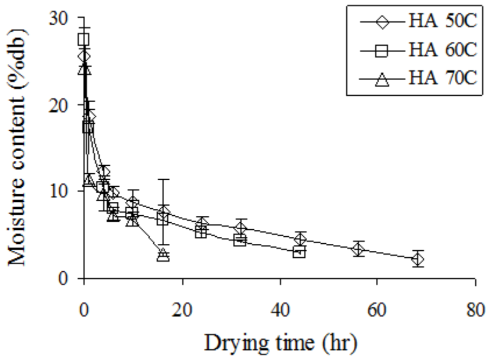

Figure 2 Moisture content evolution (HA = hot air)

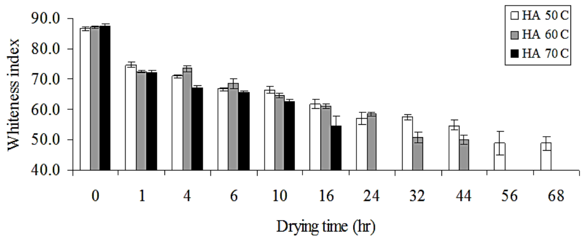

Figure 3 WI Change during drying by hot air

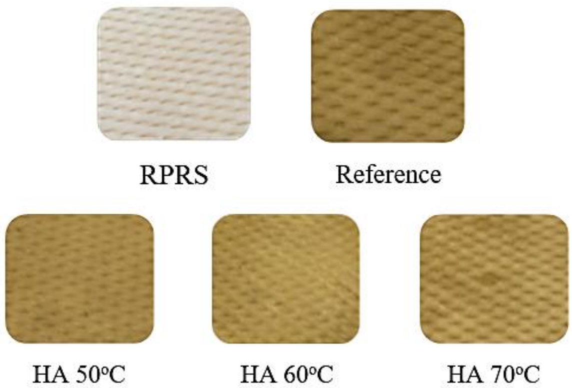

Figure 4 RPRS, reference and dried USS at final moisture content

Table 1 Coefficient values of first and second degree models

Degree of model	Coefficients					
	β_0	β_1	β_2	β_3	β_4	β_5
First	142.3383	-0.2070	-0.5257	-	-	-
Second	-2459.0846	15.3272	3.3850	-0.0231	0.0102	-0.0138

3.3 Prediction of WI

Figure 5a and 5b show WI 3-D surface plots by the Equations 5 and 6, first and second-degree models, which β coefficient values calculated by the least-squares method as shown in the Table 1. As found from the figures at the first stage of drying process, responses of both degree models showed the decreased trend of WI as the drying time increased. When the drying time proceeded, however, only the response of second degree model showed effect of drying temperature on decrease of WI value, relating with the experimental result. For comparing WI between experimental and predicted value, the second degree model revealed the better fit with the experimental result, confirming by higher in mean of R^2 (Figures 6a and 6b).

4. Conclusions

In the range of scope study, the drying time affected decrease of WI value, particularly in the first 6 hr of drying process. When the process was more continued, drying temperature was important factor to decrease of WI; WI value decreased with increasing the drying temperature. At the final moisture content, the dried USS had good color quality in required standard. For prediction of WI value during hot air drying, the result by proposed second degree model was satisfactory fit with the experimental result.

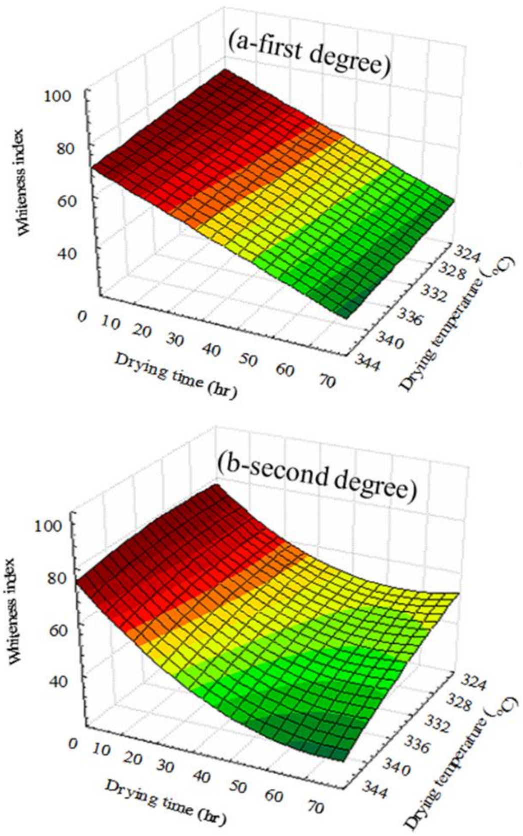

Figure 5 WI Surface plot by first (a) and second (b) degree models

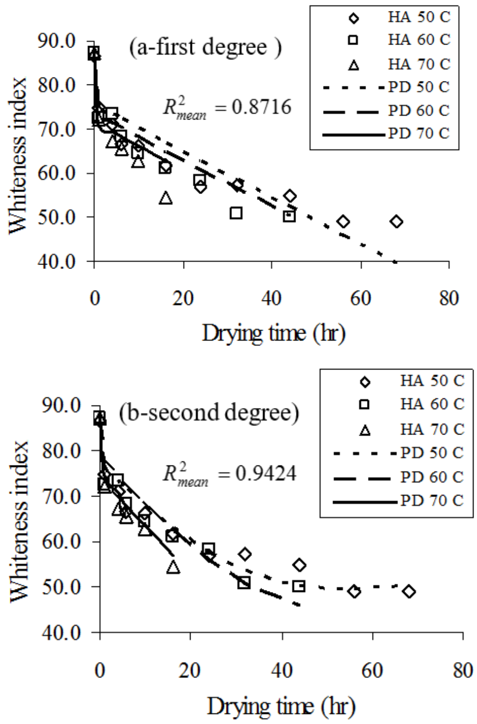

Figure 6 Comparison of experimental and predicted WI value (PD = prediction)

5. Acknowledgements

The authors thanks to Agriculture, Food and Energy Center, King Mongkut’s Institute of Technology Ladkrabang, Prince of Chumphon Campus, Chumphon, Thailand for RPRS sample and also thanks to King Mongkut’s Institute of Technology Ladkrabang Research Fund for financial support.

6. References

[1] Seephueak P, Petcharat V, Phongpaichit S. Fungi associated with leaf litter of para rubber (*Hevea brasiliensis*). Mycology 2010;1(4):213-227.

[2] Suchonpanit W, Tirawanichakul Y, Tirawanichakul S. Experimental study of the effects of different drying methods on the kinetics and quality of air dried sheet (ADS) rubber. IEEE Colloquium on Humanities, Science and Engineering Research (CHUSER 2011); 2011 Dec 5-6, Penang, Malaysia. New Jersey: IEEE; 2011. p. 202-207.

[3] Naon B, Berthomieu G, Benet JC, Saix C. Improvement of industrial drying of natural rubber through analysis of heat and mass transfers. Drying Technology 1995;13(8-9):1807-1824.

[4] Tanwanichkul B, Thepa S, Rordprapat W. Thermal modeling of the forced convection Sandwich Greenhouse drying system for rubber sheets. Energy Conversion and Management 2013;74: 511-523.

[5] Jaiboon P, Prachayawarakorn S, Devahastin S, Soponronnarit S. Effects of fluidized bed drying temperature and tempering time on quality of waxy rice. Journal of Food Engineering 2009;95:517-524.

[6] Myers RH, Montgomery DC. Response Surface Methodology: Process and Product Optimization Using Designed Experiments. 3rd ed. USA: John Wiley & Sons Inc.; 2009.