Drying Characteristics of Lime (Citrus aurantifolia [Christm.] Swingle) at Different Temperatures

Shanika Dedunu Kumari[1], H.M.S.P.Bandaranayake[2]

[1]Department of Agricultural and Plantation Engineering, The Open University of Sri Lanka, Nawala, Sri Lanka
[2]Kurunegala Regional Centre, The Open University of Sri Lanka, Kurunegala, Sri Lanka

Abstract— *Drying rate of lime was determined experimentally as a function of drying temperature. Single layer drying data obtained at four different temperatures (45, 60, 70 and 100ºC) were fitted to the logarithmic drying model. The drying process was conducted until the moisture content reaching up to 8% d.b. at different drying temperatures. According the results, the rate of drying changed with the drying temperature. Drying time for reaching 8 % d.b. moisture contents of lime were 27, 38, 371 and 825 hours at drying temperatures of 100, 70, 60 and 45°C respectively. Drying lime at observed temperatures can be considered as drying in a falling rate period and the equilibrium moisture content varied with the drying temperature of lime.*

Keywords— Drying, Equilibrium Moisture Content, Logarithmic Drying Model, Moisture Content, Temperature.

I. INTRODUCTION

Limes (Citrus aurantifolia [Christm.] Swingle) are the fruit of tropical citrus tree closely related to lemons [3]. Lime juice resembles lemon juice and it contains 8% of citric acid [5]. The fruits are almost always picked when unripe (green), and are usually consumed before they reach the ripe state (yellow) [7]. It is smaller, seedier, has a higher acidity and a stronger aroma [4].

The normally used plant parts of lime are juice and fruit skin (pericarp). Juice is always used as drink and for culinary purposes. Citrus fruits are generally not stored as long as apples, thus common or refrigerated storage are more economical and widely used [6].

Controlled atmospheric storage has modest benefits for citrus fruit storage but is not recommended due to the limited interest and high cost Limes can be preserved as dehydrated slices, cordials, salted lime and black lime.

Dehydration of fruits is commonly done in different parts of the world to improve the keeping quality and to preserve the fruit for consumption during off seasons.

In the gulf region where fresh Lime fruits are not available, dehydrated whole lime is used as an excellent thirst quencher.

Dehydrated whole lime is called black lime. Whole fruit or powder of black lime is used as a spice. Black lime is a unique product, consumed mainly in the Middle East [2]. However, no reports are available on systematic drying conditions of lime fruit, [1].

At present there are no well set international standards for dehydrated lime. But, based on the gulf demand, moisture content less than 10% and regarding the color black is preferred in Saudi Arabia where as brown for the other gulf countries. When the fruit is broken it must gives the characteristic lime flavor and when dipped in water there should not be any bitterness [8].

So far dehydration characteristics of whole lime fruit have not been studied of black lime. Therefore, in this study the drying characteristics of whole lime were studied in detail.

II. MATERIALS AND METHODOLOGY

Drying characteristics of lime was studied at different drying air temperatures. Effect of drying temperature on the drying time is important in developing commercial scale lime dryers. Range of temperature for the study was 45°C to 100°C. The normal fruit and vegetable drying temperature is 60°C and the lower drying temperatures than 60°C can be used for in-bin drying. The higher temperature of 100°C was selected as the lime is presently dried at higher temperatures than 60°C.

2.1 Materials

This study was conducted during the Maha season, October 2008 to February 2009. Lime (Citrus aurantifolia) is widely used in black lime preparation. Lime fruits which are visually similar in size and maturity (greenish yellow) were procured from Hadabima Super Market (Gannoruwa, SL) and stored in the cold storage at 5°C until use. Initial moisture contents of samples were determined by air-oven method. Before the start of each drying experiment, fruit samples were removed from the

refrigerator and left in a plastic bag in the laboratory for 8 hours to equilibrate to the room temperature.

2.2 Drying characteristics

Single layer drying characteristics of lime were studied using a convectional dryer at temperatures of 45, 60, 70 and 100°C. Fig. 1 shows the schematic diagram of the air recirculating dryer unit.

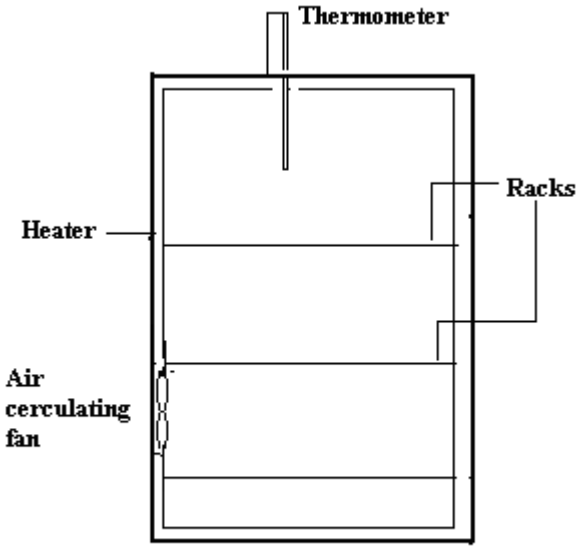

Fig. 1: Schematic diagram of the drying chamber

Dryer was preheated to the required temperature and samples of thirty fruits were placed on trays inside the dryer. Weights of the samples were recorded at predetermined time intervals until the equilibrium (weight change is less than 0.01g for 4 hours). Moisture content of the samples during the course of drying was calculated using the final moisture content and the weight data.

Drying data were fitted to the logarithmic drying model (1) using the method of least-squares and the draying coefficients (k) were calculated for different drying conditions.

$$k = \frac{1}{t} - \ln\left[\frac{(M - Me)}{(Mi - Me)}\right] \qquad (1)$$

Where,

M = moisture content (decimal d.b.)

Me = equilibrium moisture content (decimal d.b.) corresponding to the drying air

Mi = initial moisture content (decimal d.b.)

k = drying coefficient (h–1)

2.3 Moisture content measurement

Moisture content of lime was determined by air oven method (100±2ºC in 24 hours). The whole sample of lime was dried in an air oven at 100±2ºC for 24 hours to determine the dry matter content of lime. Moisture content (dry basis) was calculated (2).

$$MC_{db} = \left[\frac{(FW - DW)}{(DW)}\right] \qquad (2)$$

Where;

MCdb = Moisture content, decimal d. b.,

FW = Fresh weight, g,

DW = Dry weight, g.

III. RESULTS AND DISCUSSION

Drying data were analyzed and the effects of temperature on quality parameters were presented. Single layer drying data were fitted to the logarithmic drying model and goodness of fit was expressed as the standard error of the estimate. These data are important in selecting the required drying procedure in getting the final quality of dehydrated lime based on the demand.

3.1 Drying characteristics of lime at different temperatures

Average moisture contents of lime, calculated based on weight loss and the moisture content after drying at selected drying temperatures (100, 70, 60 and 45°C) are shown in fig. 2. The rate of drying changes with the drying temperature and it takes 27 hours to reduce the moisture content up to 8% d.b. at 1000C drying. At 450C, it takes 825 hours to bring down the moisture to 8% d.b. At 60 and 700C it takes 371 and 38 hours respectively to reach 8% d.b. moisture content.

Fig. 3 shows the observed (dotted line) and the simulated moisture contents (solid line) of lime dried at 100°C.

Time taken by drying lime to reach 8% d.b. moisture content at different drying temperatures was presented from Table 1.

Table 2 lists the drying constant calculated based on the equation 2.9, initial and final moisture and the standard error of the estimate. According to the results logarithmic drying model fitted well (SE 0.11 to 0.5 decimal d.b.) with the observed data within the temperature range studied (45 to 100°C).

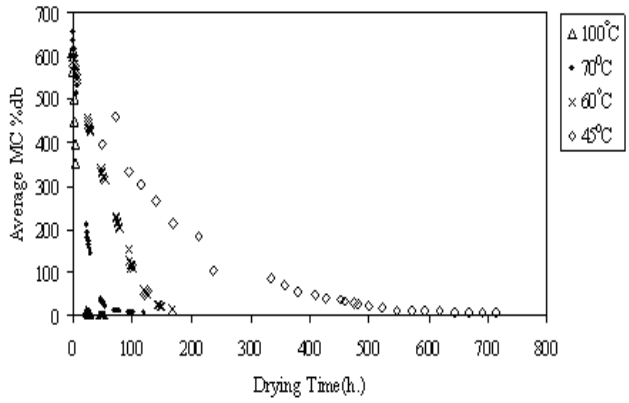

Fig. 2: Change in moisture content of lime with time at different drying temperatures

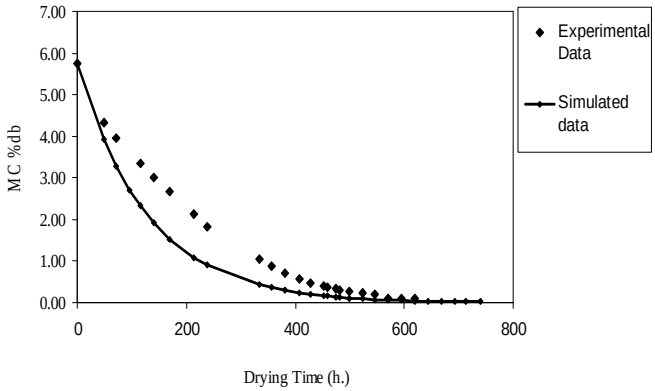

Fig. 3: Observed and the simulated moisture contents of lime dried at 100°C

Table 1. Time taken by drying lime to reach 8% d.b. moisture content at different drying temperatures.

Drying condition Temperature(°C)	Time taken to reach 8% d.b. Moisture content (h.)
100	27
70	38
60	371
45	825

Table 2: Drying Coefficient 'k' and the logarithmic drying model with drying air conditions

Temperature (°C)	100	70	60	45
Average % RH (Room)	60.45	37.5	52.91	56.48
Drying constant (k) 1/h	0.1608	0.114	0.0124	0.0078
Equilibrium Moisture Content (Me) Decimal d.b.	0	0	0.029	0.08
Original Moisture Content (Mo) Decimal d.b.	6.09	6.12	6.09	6.28
Standard error (S.E, Decimal d.b.)	0.33368	0.152	0.05886	0.50009

According to the results, drying time decreased with increasing drying temperature. The drying constant "k" of the logarithmic drying model increased with increasing drying temperature. Drying lime at all temperatures were considered as in the falling rate period. The equilibrium moisture content was decreased with increasing drying temperature. Equilibrium moisture contents were close to zero above 70°C of drying temperature.

IV. CONCLUSIONS

Drying lime at selected temperatures can be considered as drying in a falling rate period. The equilibrium moisture content varies with the drying temperature and the higher the drying temperature lower the equilibrium moisture content.

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