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## Hot air drying of coconut residue: shelf life, drying characteristics, and product quality

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# Hot air drying of coconut residue: shelf life, drying characteristics, and product quality

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**Abstract.** The longest and the shortest shelf lives of coconut residue based on microbial analysis were more than 140 and less than 3 days when varied the moisture content from 0.03 to 0.25 g water/g dry matter, respectively. Drying characteristics and quality of coconut residue were determined at various drying temperatures (50-80°C) and layer thicknesses (5-10 mm). These drying factors significantly affected drying time, whiteness and oil content of coconut residue. The highest temperature and the smallest thickness resulted in the shortest drying time (70 min). As compared to fresh sample, drying for less than 200 min gave whiter coconut residue and all dried samples had higher oil content.

## 1. Introduction

In the process of coconut milk extraction, the major by-product is coconut solid residue which is still rich in nutrients [1]. Because of its high moisture and nutritional contents, the coconut residue is rapidly degraded and hence poses a tremendous disposal problem to the processors of coconut milk. Drying of fresh coconut residue containing 50-55% moisture must be carried out as quickly as possible to prevent microbial deterioration. In addition to the purpose of safe storage of coconut residue, process improvement in coconut residue drying is needed to enhance its drying characteristics and improve the quality of the dried product in order that the dried product can be more value-added and used as the high-fibre food ingredient.

Currently, study on drying characteristics of coconut residue simultaneously with the shelf life of the dried coconut residue as influenced by its moisture content are still lacking. Therefore, in this study, attempts have been made to investigate the effect of moisture content of coconut residue on its shelf life. This study also aimed to determine drying characteristics of thin-layer drying of coconut residue at different layer thicknesses and drying temperatures. The effects of layer thickness and drying temperature on the quality of dried coconut residue were investigated as well.

## 2. Materials and methods

### 2.1. Coconut residue

Coconut residue obtained after the coconut milk extraction was provided by Ampol Food Processing Ltd., Thailand. It was stored at 4±0.5°C and maintained at room temperature (25°C) before use. To determine its initial moisture content, sixty samples of 5 g each were dried by hot air drying at 105±2°C



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(500/108I, Memmert GmbH + Co.KG, Germany) for 24 h [2]. Its moisture content was 1.56 g water/g dry matter. Its particle diameter was also determined to be 850  $\mu\text{m}$  by sieve analysis [3]. The coconut residue of this study can be defined as extra-fine desiccated coconut [4].

## 2.2. Evaluation of shelf life of coconut residue with various moisture content

Coconut residue with five moisture content levels (0.03, 0.10, 0.15, 0.20, and 0.25 g water/g dry matter) was prepared by drying in a hot air oven (500/108I, Memmert GmbH + Co.KG, Germany). They (30 g each) were packed in 0.13×0.15 m<sup>2</sup> polypropylene woven bags and kept at 35°C and 60-75%RH (imitated warehouse temperature) for 20 weeks. During storage, samples were taken out every three days for the first 60 days and every two days after Day 60 for the determination of the total plate count and yeast and mold count. The spread plate technique was used for microorganism counts. Shelf life was determined and expressed as the number of days after which the microbial and yeast and mold growths appeared to exceed the current Codex standard for desiccated coconut (PNS/BAFPS 25:2007). According to the standard, the maximum total plate count and yeast and mold count are allowed at 5,000 and 100 CFU/g, respectively [5].

## 2.3. Drying experiments

A rectangular tunnel-tray dryer developed by the Drying and Dehydration Technology Research Unit, Faculty of Engineering and Agro-Industry, Maejo University was used in this study. Four levels of drying temperature (50, 60, 70, and 80°C) and three levels of layer thickness of the coconut residue (5, 10, and 15 mm) were studied. The coconut residue weighing between 85 and 120 g was spread over the sample tray to the predetermined thicknesses. The desirable final moisture content for safe storage of coconut residue as a result of section 2.2 was 0.03 g water/g dry matter. The air velocity used was 0.4 m/s as measured by an anemometer (AM-4201, Lutron Electronic Enterprise Co., Ltd., Taiwan). During the drying process, the temperature and weight loss of the coconut residue were continuously recorded at 1-min intervals using a computer software data logger.

## 2.4. Calculations of moisture content and moisture ratio

The moisture content was reported on the dry basis in the unit of g water/g dry matter (equation (1)). The data was then converted into moisture ratio (equation (2)).

$$\text{Moisture content (g water/g dry matter)} = \frac{\text{Weight of water in the sample}}{\text{Weight of dry matter of the sample}} \quad (1)$$

$$\text{MR} = \frac{M_t - M_e}{M_i - M_e} \quad (2)$$

where  $M_i$ ,  $M_t$ , and  $M_e$  are moisture content at initial, specific time, and equilibrium, respectively.

## 2.5. Evaluation of the quality of dried coconut residue

Quality of dried coconut residue product with the moisture content of 0.03 g water/g dry matter were evaluated in terms of whiteness and oil content and compared to the quality of fresh coconut residue as a control.

**2.5.1. Whiteness.** The Hunter spectrophotometer (ColorFlex, version 1.72, Hunter Associates Laboratory, Inc., USA) was used to measure color of dried coconut residue in CIE L\*a\*b\* system. L\*, a\*, and b\* stand for lightness, redness (+)/greenness (-), and yellowness (+)/blueness (-), respectively. The whiteness was calculated according to equation (3).

$$\text{Whiteness (\%)} = 100 - ((100 - L^*)^2 + a^{*2} + b^{*2})^{1/2} \quad (3)$$

**2.5.2. Oil content.** Coconut residue (3 g) was added to the extract solution of petroleum ether (50 ml) in extraction cups. The mixture was extracted in the Soxtec system (HT1043, Foss Tecator AB, Sweden). The extraction cups were allowed to boil for 15-20 min and rinse for 30-45 min. The cups

were then dried in a hot air oven at 100°C for 30 min [6]. The oil content was calculated according to equation (4).

$$\text{Oil content (g oil/g dry matter)} = \frac{w_3 - w_2}{w_1} \quad (4)$$

where  $w_1$ ,  $w_2$ , and  $w_3$  were weights (g) of the dry matter sample, extraction cup, and extraction cup with oil after the extraction process, respectively.

### 2.6. Data analysis

The experiments were triplicated. The one-way ANOVA and Duncan's multiple range test were applied for statistical analysis at 95% confident level.

## 3. Results and discussion

### 3.1. Effect of moisture content of coconut residue on its shelf life

As shown in table 1, the higher the moisture content of dried coconut residue was, the shorter their shelf life became. As recommended by the Philippine National Standard for Desiccated Coconut [5], the total plate count must not exceed 5,000 CFU/g and the yeast and mold count must not exceed 100 CFU/g. It is obvious that the yeast and mold count were more indicative than the total plate count in the aspect of shelf life evaluation of dried coconut residue as the former was found to exceed the limit before the latter in almost every samples. The sample of 0.25 g water/g dry matter was spoiled the fastest on day 3 whereas the sample of 0.03 g water/g dry matter could be safely kept for more than 140 days. These results are in good agreement as compared to the Codex standard that the moisture content of fine and extra fine desiccated coconut should not be higher than 3%.

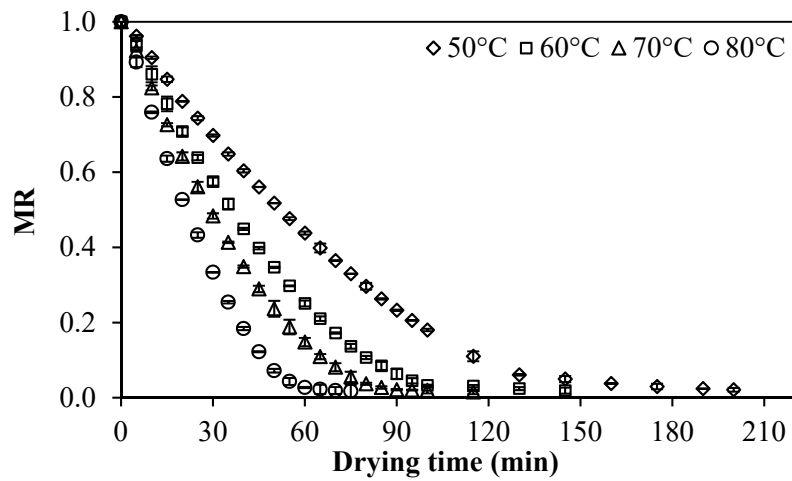
**Table 1.** Shelf life expression of coconut residue with different moisture contents according to the Codex standard of total plate count and yeast and mold count.

Moisture content (g water/g dry matter)	Microbial analysis (CFU/g)		Shelf life (day)
	Total plate count	Yeast and mold count	
0.03	NF	NF	>140
0.10	NF	300 (day 77)	< 77
0.15	NF	450 (day 63)	< 63
0.20	NF	450 (day 18)	< 18
0.25	38,700 (day 3)	2,250 (day 3)	< 3

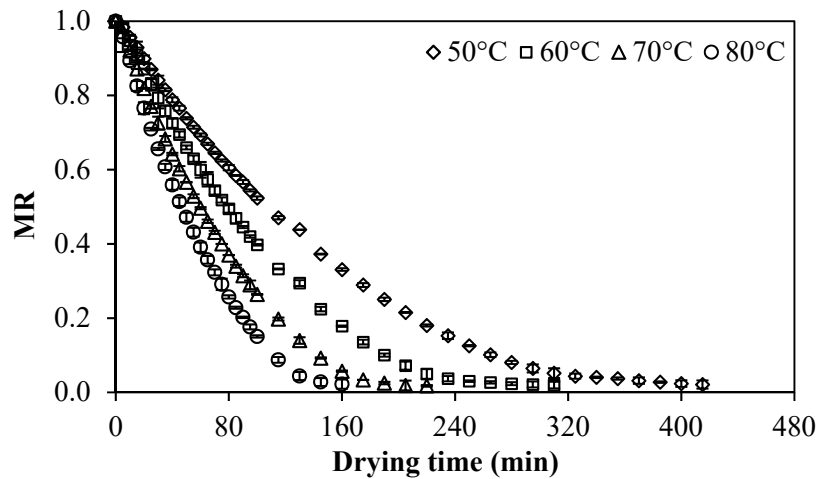
NF = not found at the end of shelf life.

### 3.2. Drying characteristics of coconut residue

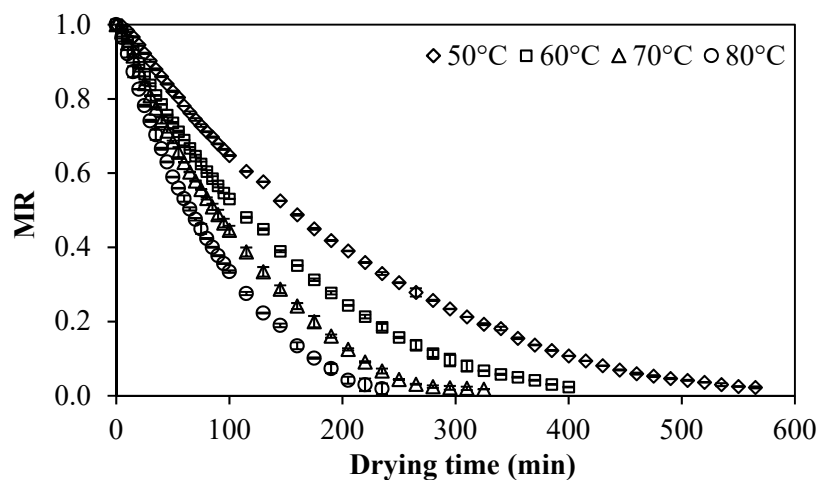
Drying curves of coconut residue subjected to hot air drying at 50, 60, 70, and 80°C are shown in figures 1-3 for the layer thicknesses of 5, 10, and 15 mm, respectively. Drying times of hot air drying of coconut residue from 1.56 g water/g dry matter to 0.03 g water/g dry matter are also listed in table 2. As expected, the drying time depended on drying temperature and layer thickness. Drying time decreased as increased drying temperature and decreased layer thickness. The shortest drying time of 70 min was achieved by drying at the highest temperature of 80°C and the thinnest thickness of 5 mm. On the other hand, the longest drying time of 565 min was obtained by drying at the lowest temperature of 50°C and the thickest thickness of 15 mm. It should be noted that the layer thickness had more considerable effect on drying time than the drying temperature as much more difference between drying times at varied layer thicknesses was observed at the same drying temperature.



**Figure 1.** Drying curves of coconut residue with the layer thickness of 5 mm at different drying temperatures.



**Figure 2.** Drying curves of coconut residue with the layer thickness of 10 mm at different drying temperatures.



**Figure 3.** Drying curves of coconut residue with the layer thickness of 15 mm at different drying temperatures.

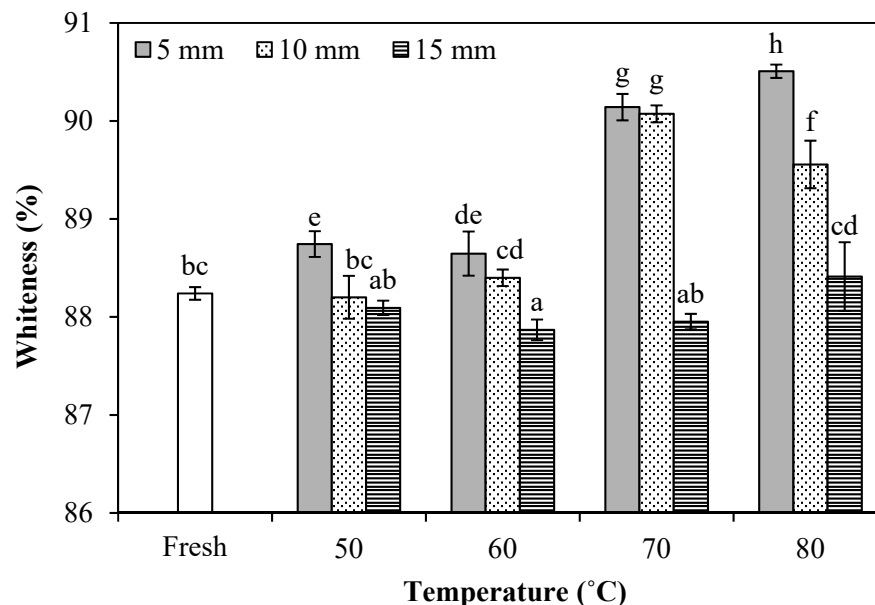
**Table 2.** Drying times (min) of coconut residue drying at different drying temperatures and layer thicknesses to the desirable moisture content of 0.03 g water/g dry matter.

Layer thickness (mm)	Drying temperature (°C)			
	50	60	70	80
5	200	145	100	70
10	415	310	220	160
15	565	400	310	235

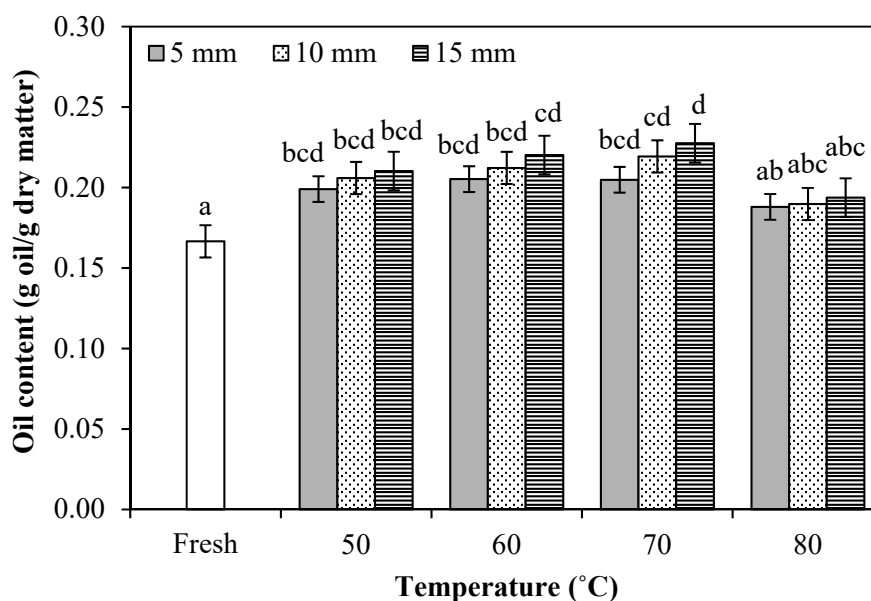
### 3.3. Effects of temperature and layer thickness on quality of dried coconut residue

**3.3.1. Whiteness.** Whiteness of dried coconut residue undergoing different drying conditions was from  $87.87 \pm 0.11\%$  to  $90.51 \pm 0.07\%$ . As shown in figure 4, significant difference in whiteness values of the dried coconut residue was obtained. Although there is no clear trend of the whiteness change with the change in drying temperature, higher layer thickness of coconut residue resulted in higher whiteness loss. Regarding to the drying time, the whiteness of dried coconut could be affected by this parameter as well. In short, the lower the layer thickness was, and hence the shorter the drying time spent, the whiter the dried coconut residue was. Surprisingly, the samples with the drying time lower than 200 min were whiter than the fresh coconut residue. The darker fresh sample as compared to the dried samples was visible and could be due to its high moisture content.

**3.3.2. Oil content.** Oil contents of dried and fresh coconut residue samples are presented in figure 5. The fresh sample had the lowest oil content of  $0.167 \pm 0.008$  g oil/g dry matter. An increase in oil content of coconut residue after drying was also reported by Raghavarao et al. [7]. When moisture lost to the surrounding air stream during drying, residual oil is trapped inside the empty space between the fiber matrixes of the coconut residue.



**Figure 4.** Whiteness of coconut residue subjected to different drying temperatures and layer thicknesses.



**Figure 5.** Oil contents of coconut residue subjected to different drying temperatures and layer thicknesses.

#### 4. Conclusions

For long shelf life for more than 140 days, coconut residue should have the moisture content not higher than 0.03 g water/g dry matter. For thin-layer drying of coconut residue, the drying time, depending on the drying temperature and layer thickness, was in the range of 70-565 min. The greater the drying temperature and the thinner the layer thickness were, the shorter the drying time was. Decrease in layer thickness had more crucial effect on drying time than increase in drying temperature. As compared to fresh coconut residue, dried coconut residue with the drying time lower than 200 min was whiter (88.40-90.51%) and all dried coconut residue had higher oil content (0.188-0.228 g oil/g dry matter).

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