Application of ultrasonic pretreatment for drying of holy basil (Ocimum sanctum L.) leaves

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Abstract. This research aimed to study the effect of ultrasound (20 kHz) on the preparation of white holy basil leaves in the hot air drying process. Five pretreatments were applied, including 30-min ultrasonic, 60-min ultrasonic, blanching, steam blanching, and 30-min ultrasonic plus blanching pretreatments. From the study on drying characteristics of hot air drying of the pretreated samples at 60°C, the shortest drying time of 30 min was obtained when sequential ultrasonic and blanching pretreatment was conducted. All pretreatments could enhance the drying characteristics as the lowest drying time of 100 min was provided by hot air drying of unpretreated sample. Significant differences in the quality values of dried holy basil leaves subjected to different pretreatment were found. Blanching pretreatment resulted in minimum shrinkage of about 66%. The maximum rehydration ratio was 3.83 and found in the sample with 30-min ultrasonic plus blanching pretreatment. Dried holy basil leaves undergoing thermal pretreatments of blanching, steam blanching, and ultrasonic plus blanching led to were inclined to be darker and greener.

1. Introduction
Ultrasonic pretreatment before drying is one of the promising techniques incorporating ultrasound into drying processes. In the past two decades, the effect of ultrasonic pretreatment on drying characteristics and properties of dried materials has been investigated. Ultrasound is known to have cavitation effect on water molecules inside material matrix. It also generates pressure variations, microstreamings, and alternative compressions and rarefaction on materials [1]. With the above effects, ultrasound can successfully accelerate drying processes and improve quality of many products such as apple [2], unripe banana [3], pineapple [4], barley grass [5], and onion [6]. On the other hand, blanching is known as a common pretreatment method before drying. It attributes to inactivation of oxidative enzyme, which results in color preservation and nutrient retention. Blanching also soften texture of materials, which leads to enhance the drying process. To date, a few studies have been conducted to use combined techniques of ultrasonic and blanching pretreatments. Thus, the study on combined ultrasonic and blanching pretreatment before drying could be useful.

Holy basil leave is an important food ingredient, especially in Thai foods. It is perishable quickly after harvesting. Drying can be one of the convenient techniques for preservation of holy basil leaves. Pretreatment of vegetables before drying has been proved to accelerate the drying process. Therefore, this work focused on investigating the effects of different pretreatment methods including ultrasonic, blanching, steam blanching, and ultrasonic plus blanching pretreatments on hot air drying characteristics of holy basil leaves and quality of the dried products.
2. Materials and Methods

2.1. Preparation of holy basil leaves
White holy basil (Ocimum sanctum L.) or Ka Pow Kaow in Thai was used in this study. To prepare the study sample, holy basil leaves were graded based on their length and width in the ranges of 5.0-5.5 cm and 2.5-3.0 cm, respectively. After grading, the leaves were washed thoroughly, drained and leaved at room temperature (25°C) prior to use.

2.2. Pretreatment experiments
In this study, a pretreatment is defined as a treatment which is applied to holy basil leaves prior to drying. It is conducted in order to make a drying process more effective. Five pretreatments of holy basil leaves were performed to compare their effects on the drying process of holy basil leaves and the quality of dried leaves including ultrasonic pretreatment for 30 min (US30), ultrasonic pretreatment for 60 min (US60), blanching pretreatment (B), steam blanching pretreatment (SB), and ultrasonic plus blanching pretreatment (US30B). Unpretreated sample was also used as a control.

In each experiment, 15 g of holy basil leaves were used. The process conditions used for each pretreatment were as follows:

2.2.1. Ultrasonic pretreatments for 30 and 60 min. Ultrasound of 20 kHz was generated in a high-power ultrasonic water bath (DT 510 H, Bandelin electronic GmbH&Co.KG, Germany). The holy basil leaves were pretreated by ultrasound for 30 min and 60 min for the US30 and US60 pretreatments, respectively.

2.2.2. Blanching pretreatment. Holy basil leaves were blanched at 97°C for 1.5 min using a temperature-controlled water bath (WB 14, Memmert GmbH+Co.KG, Germany). The amount of blanching water in the water bath was 2 L.

2.2.3. Steam blanching pretreatment. An electric steamer (VC-100665, Tefal, Groupe SEB, French) was used for steam blanching. The steam temperature was about 97±1°C. Holy basil leaves were placed in single layer on the steaming tray and allowed to be steamed for 1.5 min.

2.2.4. Ultrasonic and blanching pretreatment. Holy basil leaves were subjected to ultrasonic pretreatment for 30 min and then blanched at 97°C for 1.5 min to apply the combination effect of ultrasonic and blanching pretreatment on holy basil leaves.

After the pretreatments, the pretreated holy basil leaves were soaked in an ice water bath for 1 min and in a solution of potassium metabisulfite (2,000 ppm) for 20 min. The leaves were then drained for 5 min to remove excess water from their surface and subjected to the drying process.

2.3. Drying of holy basil leaves and determination of the drying characteristics
Hot air drying at the temperature of 60°C and air velocity of 0.47 m/s was conducted to dry either pretreated or unpretreated (control) holy basil leaves. During the process of drying, the sample was weighed at the predetermined intervals for moisture content determination. The final moisture content required for dried holy basil leaves was 0.13 g water/g dry matter.

To measure moisture content of holy basil leaves, the dry matter weight of the sample was determined by drying it in a hot air oven (UF160, Memmert GmbH+Co.KG, Germany) at 105°C for 24 h [7]. Moisture content on dry basis (g water/g dry matter) could be calculated as follows:

$$\text{Moisture content} = \frac{\text{Weight}_{\text{water}}}{\text{Weight}_{\text{dry matter}}} \quad (1)$$

Moisture ratio (MR, unitless) and drying rate (DR, g water/g dry matter min) could be converted from the moisture content data as shown in equations (2) and (3).
\[
\text{MR} = \frac{M_t - M_e}{M_i - M_e}
\]
\[
\text{DR} = \frac{M_t - M_{t+\Delta t}}{\Delta t}
\]

where \(M_i\), \(M_t\), \(M_e\), and \(M_{t+\Delta t}\) are initial, specific time, equilibrium, and \(t+\Delta t\) moisture content (g water/g dry matter), respectively; and \(t\) is drying time (min). The equilibrium moisture content of dried holy basil leaves at 60°C was zero.

2.4. Quality evaluation of dried holy basil leaves

2.4.1. Shrinkage. Shrinkage of each dried holy basil leave was determined based on its projected area as compared to the area of fresh leave. A digital planimeter (KP 90N, Placom, Koizumi Sokki Mfd. Co., Ltd., Japan) was used for measurement of the leave projected area. Twenty leaves of each treatment were randomly selected for the measurement. Shrinkage could be determined as follows:

\[
\text{Shrinkage percentage} = \left( \frac{\text{Area}_{\text{fresh sample}} - \text{Area}_{\text{dried sample}}}{\text{Area}_{\text{fresh sample}}} \right) \times 100
\]

2.4.2. Color. Color of holy basil leaf was measured using a spectrocolorimeter (ColorFlex, version 1.72, Hunter Associates Laboratory, Inc., USA). The color was reported in CIE L* (+lightness/-darkness), a* (+redness/-greenness), b* (+yellowness/-blueness) system.

2.4.3. Rehydration. Dried holy basil leaves (about 3 g) were rehydrated in 90°C hot water for 2 min, removed excess water by a filter cloth, and weighed. The rehydration ratio was calculated as follows:

\[
\text{Rehydration ratio} = \frac{\text{Weight}_{\text{rehydrated sample}} - \text{Weight}_{\text{dried sample}}}{\text{Weight}_{\text{dried sample}}}
\]

2.5. Data analysis

All experiments were triplicated. Mean and standard deviation were shown. One-way ANOVA and DMRT were used for statistical analysis of the experimental data at 95% confident level (P<0.05).

3. Results and discussions

3.1. Drying characteristics of holy basil leaves subjected to different pretreatments

Relationships between moisture content and drying time and between moisture ratio and drying time of hot air drying of holy basil leaves subjected to different pretreatments are presented in figures 1 and 2, respectively. Initial moisture contents of holy basil leaves were about 9 g water/g dry matter. Their moisture contents decreased rapidly in the first stage of drying, which is the stage of removing of free water from the materials. Figure 3 also shows the drying rate curves. It could be seen that there are two drying rate periods obtained by hot air drying of holy basil leaves, i.e. the heating up and falling rate drying periods.

From these figures, distinct characteristics of the curves were observed, indicating the distinct effect of pretreatment methods on hot air drying of holy basil leaves. Sequential 30-min ultrasonic plus blanching and blanching pretreatments were better than the other pretreatments as they caused more rapid decrease in moisture content and greater drying rate during the drying process. To meet the desirable final moisture content (also shown in table 1), hot air drying of 30-min ultrasonic plus blanching pretreated holy basil leaves required the shortest drying time of 30 min, followed by drying of blanching, steam blanching, 30-min ultrasonic, 60-min ultrasonic pretreated and control holy basil leaves. This result shows good combined effect of ultrasonic and blanching pretreatment on enhancing the drying process. It is the principle that blanching can reduce resistance of cell wall and cell membrane to water movement [8]. Ultrasound also causes sponge, i.e. the rapid series of alternative compression and expansion, and cavitation effects on the material cells [9].
Regarding to pretreatment by blanching or sonication alone, both blanching and steam blanching were more effective than ultrasonic pretreatment to improve hot air drying of holy basil leaves. The results were the same as those reported by Tao et al. [10] for drying of blanching and ultrasonic pretreated cabbages.

Comparing between ultrasonic pretreatments for 30 and 60 min, no effect of different sonication times on enhancement of the drying process was obtained. On the other hand, as compared to the control, all pretreatments could considerably improve the hot air drying process of holy basil leaves.

**Figure 1.** Relationships between moisture content and drying time of hot air drying of holy basil leaves subjected to different pretreatments (Dash line presents the level of desirable moisture content of 0.13 g water/g dry matter).

**Figure 2.** Relationships between moisture ratio and drying time of hot air drying of holy basil leaves subjected to different pretreatments.
Figure 3. Relationships between drying rate and moisture ratio of hot air drying of holy basil leaves subjected to different pretreatments.

Table 1. Drying times of hot air drying of holy basil leaves subjected to different pretreatments to meet desirable moisture content of 0.13 g water/g dry matter.

| Pretreatment | Drying time (min) |
|--------------|-------------------|
| US30         | 80                |
| US60         | 80                |
| US30B        | 30                |
| B            | 45                |
| SB           | 60                |
| Control      | 100               |

3.2. Quality of dried holy basil leaves subjected to different pretreatments

Tables 2 and 3 present quality of dried holy basil leaves in terms of shrinkage percentage, rehydration ratio, and L*, a*, and b* color values. All pretreatments resulted in a significant change in the quality parameters (P<0.05). Blanching pretreatment led to the lowest shrinkage of dried holy basil leaves. However, from the rehydration ratio result, combined ultrasonic and blanching pretreatment led to the highest rehydration ratio of dried holy basil leaves.

Thermal pretreatments including blanching, steam blanching, and ultrasonic plus blanching pretreatment resulted in significant decreases in L* and a* values. Holy basil leaves pretreated by these methods were darker and greener than the samples undergoing US pretreatment and the control.

Similar findings were also reported in the case of sequential pretreatment and drying of cabbage [10], green beans [11], and papaya [12]. Ruiz-Ojeda [11] has suggested that decrease in brightness during thermal pretreatment can be contributed by many factors such as oxidation of enzymes, vitamin C and Maillard reaction and caramelization.
Table 2. Shrinkage percentages and rehydration ratios of dried holy basil leaves subjected to different pretreatments.

| Pretreatment | Shrinkage (%) | Rehydration ratio |
|--------------|---------------|-------------------|
| US30         | 78.92±0.38a   | 2.594 ± 0.04b     |
| US60         | 76.10±0.09b   | 2.596 ± 0.11c     |
| US30B        | 74.15±0.11c   | 3.832 ± 0.07a     |
| B            | 66.25±0.28d   | 3.353 ± 0.03b     |
| SB           | 74.34±0.10c   | 2.619 ± 0.10c     |
| Control      | 76.25±0.12b   | 3.213 ± 0.26b     |

Values are given as means±standard deviations. In the same row, different superscripts indicate statistical significance ($P \leq 0.05$).

Table 3. Color properties of dried holy basil leaves subjected to different pretreatments.

| Pretreatment | L*          | a*         | b*          |
|--------------|-------------|------------|-------------|
| US30         | 34.42±0.09c | 0.68±0.02a | 14.27±0.04b |
| US60         | 35.46±0.08b | 0.64±0.04a | 14.16±0.03b |
| US30B        | 19.21±0.06c | 3.70±0.02d | 9.51±0.04c  |
| B            | 18.63±0.08f | 3.25±0.06c | 12.72±0.04c |
| SB           | 20.51±0.02d | 3.91±0.05c | 10.51±0.02d |
| Control      | 36.56±0.05a | 1.33±0.05b | 12.76±0.05c |

Values are given as means±standard deviations. In the same row, different superscripts indicate statistical significance ($P \leq 0.05$).

4. Conclusions

This study demonstrated that either ultrasonic, blanching, or steam blanching pretreatments were able to enhance the drying process of hot air drying of holy basil leaves. Blanching and ultrasonic plus blanching pretreatments contributed to greater drying rate and shorter drying time of hot air drying of holy basil leaves than no pretreatment and ultrasonic and steam blanching pretreatments alone. Blanching pretreatment was also beneficial on the quality of dried holy basil leaves. It could best preserve the shape of the dried sample. Rehydration ratio was improved by blanching and ultrasonic plus blanching pretreatments as well. However, darker and greener dried holy basil leaves were produced by these thermal pretreatments, i.e. blanching, steam blanching, and ultrasonic plus blanching pretreatments.

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