

Research Article

Effect of pre-treatments on drying characteristics and colour of dried lettuce leaves

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Abstract

Most drying processes usually bring about some degradation of the final product. As a result, pre-treatments are sometimes required to preserve the product quality. The objective of this study was to investigate the effect of pre-treatments on drying characteristics and colour of dried lettuce (*Lactuca sativa* L.) leaves. The pre-treatments of lettuce included blanching at 95°C for 1 min in 3 different solutions comprising water, 1% (w/v) calcium chloride (CaCl₂) and 1%(w/v) sodium bicarbonate (NaHCO₃). Untreated samples served as the control. Drying of all samples was performed in a hot air oven at 70°C for 3 hrs. All dried lettuce leaves studied were evaluated for drying characteristics, colour and rehydration capacity. It was found that final moisture content of all samples was similar (14.7 ± 4.91%db). Pre-treatments did not improve the drying rate of lettuce leaves, but did influence the colour of the final product. Drying of fresh leaves resulted in undesirable colour changes from green to olive-brown, while the colour of samples pre-treated by blanching in various solutions maintained their green colour. ΔE-value of pre-treated lettuce leaves was not significantly different from that of control (p > 0.05), except that of the sample treated by blanching with NaHCO₃ (p ≤ 0.05). According to hue angle, it was found that the colour of pre-treated dried lettuce leaves was greener than untreated dried lettuce leaves. The effect of blanching with CaCl₂ on rehydration capacity of dried lettuce leaves was not significant, while dried lettuce leaves treated by NaHCO₃ blanching gave the lowest rehydration capacity (p ≤ 0.05).

Keywords: *Lactuca sativa*, calcium chloride, sodium bicarbonate, hot air oven, blanching, Thailand

Introduction

Lettuce (*Lactuca sativa* L.) is a leafy vegetable which is difficult to process because of its high mechanical and physiological fragility. They are perishable and must be either consumed rapidly or preserved by various methods such as freezing or cold storage.

Drying of vegetables and fruit is one of the oldest procedures for food preservation known to man. It is the most important process for preserving food, because it decreases considerably the water activity of the material, reduces microbiological activity and minimizes physical and chemical changes during its storage. Drying also brings about substantial reduction in mass and volume, minimizing packaging, storage and transportation costs [1]. Browning of dried vegetables is a phenomenon known as chlorophyll degradation because the thermal processing of green vegetables results in a pheophytinization reaction caused by the replacement of magnesium ions by hydrogen and the consequent formation of brown pheophytins. Improvement of dried food quality can be achieved by applying various pre-treatments before the drying process. Blanching is one such common method.

Blanching is one of the most widely used pre-treatments in the drying of vegetables because of the resultant inactivation of enzymes, changes in tissue structure and shorter drying time [2, 3]. Calcium chloride (CaCl_2) blanching also helps prevent or reduce browning. It has been reported that calcium may be acting in some manner to block the amino group, whereby the latter is restrained from entering into the browning reaction. It is also believed that calcium is capable of forming chelating compounds with organic substances having an alpha amino carboxylic acid structure [4], while addition of alkalizing agents in blanching solution raises the pH and therefore, retains the green colour of vegetables because chlorophyll is stable in base condition. The investigation of the drying behaviour and colour of different agricultural products has recently been carried out by several investigators, for example, olive leaves [5], mint leaves [6], leek [7], tomato [2, 4] and coriander leaves [8]. However, there appears to be no such reports on drying of lettuce leaves which may be used as an ingredient in further developing rice seasoning powder, known as Furikake. Therefore, the objective of this study was to investigate the effect of pre-treatments on drying characteristics, colour and rehydration capacity of dried lettuce leaves.

Materials and Methods

Materials

Fresh lettuces (*Lactuca sativa* L.) were purchased from a local market in Nakhon Pathom, Thailand.

Methods

Sample preparation and treatments

Lettuces were washed with water to remove dirt and soil. Stems were removed by cutting with a knife. Lettuce leaves were then blanched at $95 \pm 1^\circ\text{C}$ for 1 min in 3 different solutions (20:1 solution/leaves) comprising water, 1% (w/v) calcium chloride (CaCl_2), and 1% (w/v) sodium bicarbonate (NaHCO_3). The blanched samples were cooled under ambient conditions prior to spreading on a tray and drying in a hot air oven. Untreated samples served as the control.

Drying procedure

Lettuce leaves were dried in a hot air oven at 70°C for 3 hrs. The dryer was started before drying experiments to achieve steady-state conditions for the desired temperature.

Moisture content determination

Samples were withdrawn at 0.5 hourly intervals to determine the moisture content at different drying times. Moisture content was measured by the gravimetric method at 105°C up to constant weight (24 hrs) [5], and reported on dry basis (g moisture/g dry matter).

Drying characterization

The moisture ratio (MR) and drying rate were calculated using the following equations:

$$MR = \frac{M - M_e}{M_0 - M_e} \dots\dots\dots(1)$$

$$\text{Drying rate} = \frac{M_t - M_{t+dt}}{dt} \dots\dots\dots(2)$$

where M , M_0 , M_e , M_t and M_{t+dt} are moisture content, initial moisture content, moisture content in equilibrium with the drying air, moisture content at t and moisture content at $t+dt$ (g water/g dry matter), respectively, and t is drying time (min).

Colour measurements

The colour of the fresh and dried (blanched and unblanched) leaves was determined by image processing (light source is Illuminant D65) to determine CIE colour space co-ordinates, L^* , a^* and b^* values. Lightness value, L^* , indicates how dark/light the sample is (varying from 0: black to 100: white), a^* is a measurement of greenness/redness (varying from -60 to +60) and b^* is the gradient of blueness/yellowness (also varying from -60 to +60). Change of colour was estimated by

$$\Delta E = \sqrt{(L_i^* - L_0^*)^2 + (a_i^* - a_0^*)^2 + (b_i^* - b_0^*)^2} \dots\dots\dots(3)$$

where ΔE is colour change, L_0^* and L_i^* are lightness values at initial time and time i , respectively, a_0^* and a_i^* are greenness-redness values at initial time and time i , respectively, and b_0^* and b_i^* are blueness-yellowness values at initial time and time i , respectively.

Rehydration capacity

Rehydration experiments were carried out in distilled water at $80 \pm 5^\circ\text{C}$. About 4 g of the dried product was added to 400 ml distilled water for 2 min. The sample was immediately drained on a metal sieve for 5 min and weighed. The rehydration capacity was calculated as follows:

$$RC = \frac{Wr}{Wd} \dots\dots\dots(4)$$

where RC is the rehydration capacity, Wr is the total weight after rehydration (g) and Wd is the weight of dried material (g).

Experiments were carried out in 3 replications and the average of measurement was reported.

Statistical analysis

The data were analyzed using the SAS system. A multiple comparison of the treatment means was performed by Duncan's New Multiple Range Test. Significance of the difference was determined at $p \leq 0.05$.

Results and Discussion

Effect of drying and pre-treatments on drying characteristics of lettuce leaves

Figure 1 shows the drying curves for pre-treated and untreated lettuce leaves. It is clearly evident from these curves that the moisture content decreases continuously with drying time.

At the beginning of the drying process, lettuce leaves contained an average initial moisture content of $93.86 \pm 0.44\%$ wb ($1,551.95 \pm 135.93\%$ db). Final moisture content of all samples was similar ($14.7 \pm 4.91\%$ db). Change in drying rate is a result of the reduction of moisture content of samples during the drying process. From Figure 2 it can be observed that a constant drying rate period was not detected in the drying curves. The entire drying process took place in the falling rate period, which indicated that diffusion is the most likely physical mechanism governing moisture movement in lettuce leaves. This result was in agreement with previous studies on drying of food [6, 7, 8]. Nevertheless, this experimental result did not show that pre-treatments improved the drying rate of dried leaves as reported in previous studies.

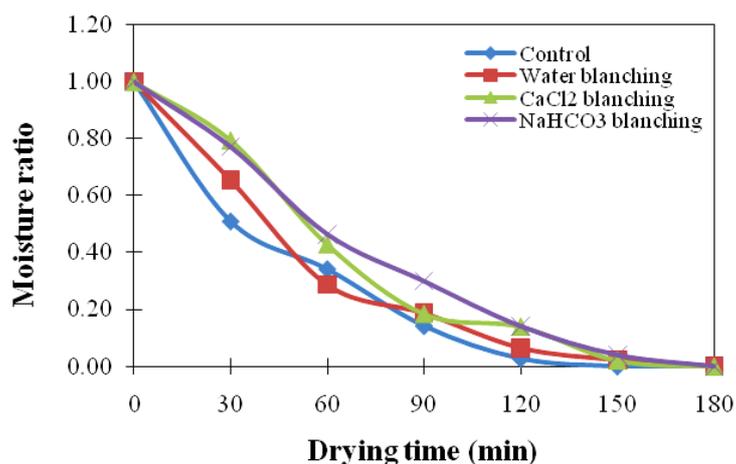


Figure 1. Variation of moisture ratio with drying time of pre-treated and untreated lettuce leaves at 70°C.

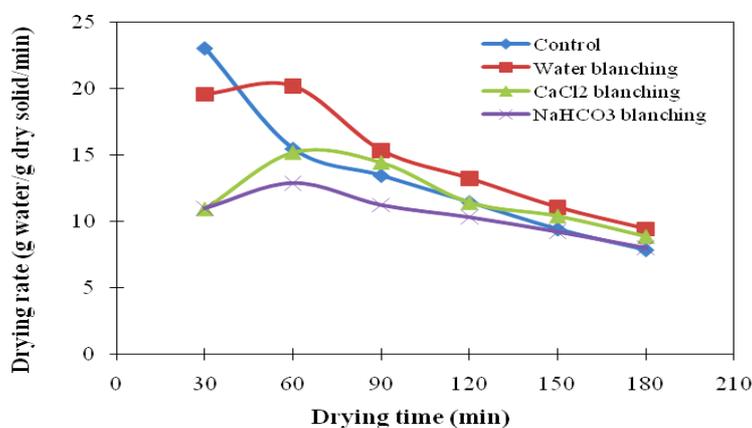


Figure 2. Drying rate of different pre-treated dried lettuce leaves.

Effect of drying and pre-treatments on the colour of lettuce leaves

Lightness (L^* -value), greenness (negative a^* -value) and yellowness (positive b^* -value) of fresh lettuce leaves were 68.53 ± 1.75 , -34.10 ± 1.09 and 51.90 ± 2.15 , respectively. After hot air drying at 70°C for 3 hrs, lightness and yellowness of dried lettuce leaves blanched in NaHCO_3 solution was significantly lower ($p \leq 0.05$) than that of control, while greenness of dried lettuce leaves blanched in water and CaCl_2 solution was significantly higher ($p \leq 0.05$) than control (Table 1). As shown in Figure 3, ΔE -value of pre-treated lettuce leaves was not significantly different from that of control ($p > 0.05$), except that of the sample treated by blanching in NaHCO_3 solution ($p \leq 0.05$). However, the NaHCO_3 treated sample gave darker green appearance as shown in Figure 4.

Table 1. Colour value of dried lettuce leaves.

	Treatments			
	Control	Water blanching	CaCl ₂ blanching	NaHCO ₃ blanching
L*	67.04 ± 2.92 ^a	66.74 ± 1.39 ^a	56.61 ± 19.74 ^{ab}	30.97 ± 23.15 ^b
a*	-14.74 ± 5.45 ^a	-26.39 ± 1.49 ^b	-24.15 ± 2.67 ^b	-9.78 ± 3.89 ^a
b*	44.96 ± 0.45 ^a	38.53 ± 3.40 ^a	40.63 ± 6.39 ^a	10.53 ± 2.47 ^b

The superscripts indicate significant difference amongst values within each row ($p \leq 0.05$).

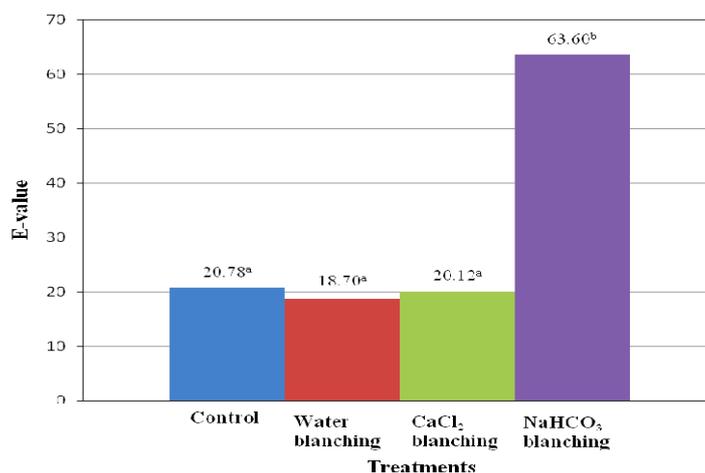


Figure 3. Change of colour (ΔE-values) of lettuce leaves during hot air drying at 70°C.

The superscripts indicate significant difference amongst values ($p \leq 0.05$).

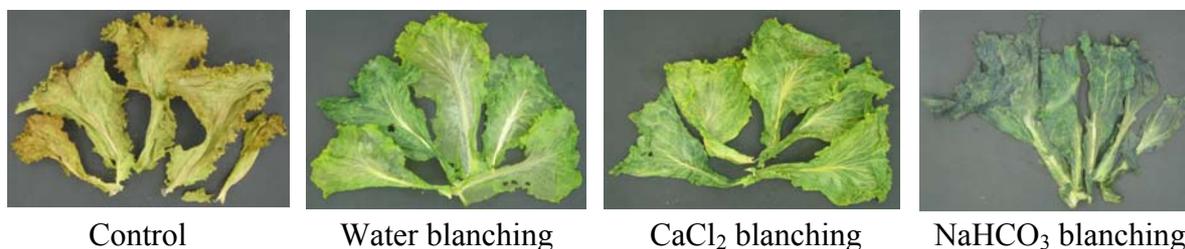


Figure 4. Colour of dried lettuce leaves.

Hue angle (Fig. 5) of pre-treated dried lettuce leaves was significantly different from untreated dried lettuce leaves. All pretreatments gave products with higher hue angle (121.03° - 132.10°). This result indicated that colour of pre-treated dried lettuce leaves were greener than untreated dried lettuce leaves. Blanching is the process inactivating enzymes involved in chlorophyll degradation resulting in retention of green colour of dried leaves.

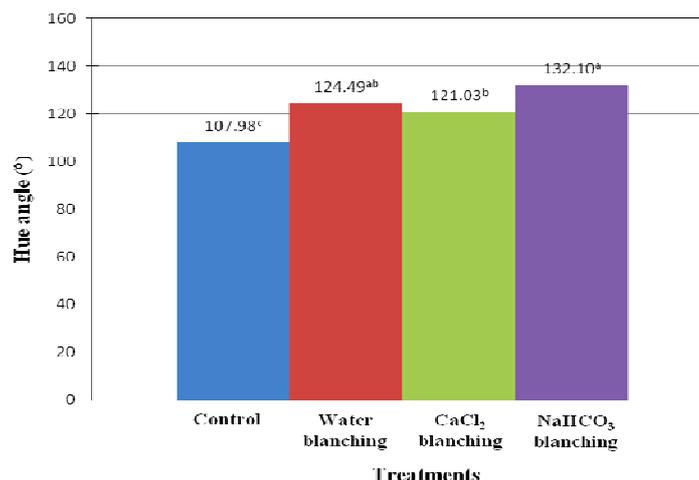


Figure 5. Effect of pre-treatments on hue angle of dried lettuce leaves.

Note: The superscripts indicate significant difference amongst values ($p \leq 0.05$).

Rehydration characteristics of dried lettuce leaves

If pre-drying treatment and drying itself would not induce any changes in the material, rehydration could be treated as a reversible process of dehydration. In practice most of the changes are irreversible and rehydration cannot be considered simply as a process reversible to dehydration [9]. Rehydration can be considered as a measure of the injury to the material caused by drying and treatment preceding dehydration [10]. Rehydration capacity (RC) of dried lettuce leaves was found to vary from 6.56 to 11.90 as shown in Table 2. It was found that RC of dried lettuce leaves was significantly influenced by the NaHCO₃ blanching. Water blanching and CaCl₂ blanching gave desirable effects on rehydration properties of dried lettuce leaves and were not different from the control sample, while samples treated by NaHCO₃ blanching showed minimum rehydration capacity. This could be possibly caused by damage of lettuce leaf tissues leading to loss of permeability and water absorption. This result was in contradiction with that of Doymaz [7] reporting an increase of RC of blanched leeks.

Table 2. Rehydration capacity (RC) of dried lettuce leaves.

Treatment	RC
Control	11.90 ± 0.41 ^a
Water blanching	11.31 ± 1.44 ^a
CaCl ₂ blanching	11.09 ± 0.40 ^a
NaHCO ₃ blanching	6.56 ± 0.20 ^b

Note: The superscripts indicate significant difference amongst values ($p \leq 0.05$).

Conclusion

Experimental results showed that pre-treatments by blanching did not improve the drying rate and rehydration capacity of dried leaves but influenced the colour of the final product. Blanching as a pre-treatment could reduce the greenness degradation of dried lettuce leaves. Nevertheless, blanching with NaHCO₃, despite being the best in preserving greenness of dried lettuce leaves, resulted in reduction of rehydration capacity.

Acknowledgment

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