Food Research 5 (2) : 393 - 400 (April 2021)
Journal homepage: http://www.myfoodresearch.com

FOOD RESEARCH

FULL PAPER

Impact of blanching pretreatment on physicochemical properties, and drying characteristics of cabbage (*Brassica oleracea*)

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Article history:
Received: 1 October 2020
Received in revised form: 4 November 2020
Accepted: 1 January 2021
Available Online: 25 April 2021

Keywords:
Blanching pretreatment,
Cabbage,
Color change,
DPPH radical scavenging activity,
Drying behavior

DOI:
https://doi.org/10.26656/fr.2017.5(2).556

Abstract

Cabbage (*Brassica oleracea*) is popular winter vegetables cultivated all over Bangladesh and contains essential nutrients. This study aimed to evaluate the efficacy of pre-blanching on the preservation of cabbage by drying. In this research work, cabbage was blanched at 80°C, 90°C, and 100°C temperature for 12, 8, and 2 mins, respectively. Then the samples were dried at 60°C maintaining 60% relative humidity. The moisture and ash content of untreated and treated dried samples was in the range of 16.07±0.04 to 10.80±0.01% and 5.71±0.06 to 3.81±0.02%, respectively. The total phenolic content in cabbage was 74.47±0.63 mg GAE/100g at 100°C blanching temperature for a short time of 2 mins, which was higher compared to 61.91±0.48 mg GAE/100g at 80°C for 12 mins. It was observed that the antioxidant activity and two water-soluble vitamins-ascorbic acid and beta carotene decreased in pre-blanched dried samples in contrast with fresh ones. Blanching at higher water temperature and a short period was found useful for the retention of total phenolic content and greenness of cabbage. Blanching pre-treatments were also found to have better color retention capacity than untreated dried cabbage. A proper combination of drying time and temperature, along with the incorporation of blanching pretreatment, might be useful to preserve cabbage for a long time.

1. Introduction

Cabbage is a healthy vegetable consumed throughout the world (Singh *et al.*, 2009). It is typically prepared as a green vegetable, eaten fresh, and often processed as a pickle (Munger, 1988). It is one of the most commonly grown and popular winter crop of Bangladesh and comprises several minerals and vitamins A, B1, B2, C, and dietary fiber (Hossain *et al.*, 2017). The post-harvest losses of vegetables are almost 43% in Bangladesh (Sharma, 1987). So, a standard post-harvest preservation protocol for most of the vegetables is essential. Drying is considered a well-known strategy utilized to expand the shelf life and ideal quality attributes of a product (Ali *et al.*, 2019). On the contrary, it has a detrimental effect on a dried product's consistency (Alam *et al.*, 2020). During most of the drying processes, color and texture degradation happens. Consequently, it is necessary to develop a drying protocol that reduces the destructive effects of drying on foodstuffs (Chiewchan *et al.*, 2010). Several pretreatment methods can be used following the drying process to keep up or enhance the dried product's quality (Hossain, Mitra, Belal *et al.*, 2020; Sarkar *et al.*, 2020). Blanching is one of the most frequent among them and is normally done before drying, which destroys enzymes responsible for multiple detrimental enzymatic activities. It also tends to retain color and adjust the shape of the substance (Maté *et al.*, 1999; Ahmed *et al.*, 2001).

In addition, before drying, water blanching is a reliable technique that can inhibit enzymatic activity and retain color and nutrients (Xiao *et al.*, 2017). Meanwhile, blanching treatment can alter the food's texture, thereby speeding up the consequent drying process (Castro *et al.*, 2008; Deng *et al.*, 2019). It is also in our interest to incorporate water blanching and drying to conserve cabbages and investigate drying processes and improve consistency. However, it causes undesirable product consistency, e.g., texture loss, soluble nutrients, pigment, and aroma. It may hamper the product's quality by reducing the biochemical compounds in fruits and vegetables through leaching losses. As cabbages are very important sources of the water-soluble vitamin C and some natural antioxidants (Hossain *et al.*, 2017), hence it is obvious to measure the amount of biochemical components in blanched and dried products and compare them with the fresh produce. Novel blanching techniques

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eISSN: 2550-2166
Published by Rynnye Lyan Resources

such as microwave, ohmic heat blanching etc. can reduce nutrient loss and are more efficient. In a previous study, Mo *et al.* (2006) experimented with the effects of blanching pretreatment on the drying of cabbage enriched with selenium. They found that blanching at 95°C for 60 s retained the vitamin C and selenium in cabbage. However, very few pieces of literature have been found to use different hot-water blanching temperature and time, and dried cabbage at relatively low temperature to explore suitable blanching and drying condition.

In this context, the primary objective of this research is to implement three different blanching temperature as pretreatment before the drying of cabbage to preserve as many nutrients as possible and to evaluate the impact of blanching on the final product. Three different drying models such as Lewis (Newton), Henderson and Pabis, and Page model were studied to evaluate the drying characteristics of cabbage. Besides, changes in the various quality attributes, including moisture content, antioxidant activity, vitamin C, rehydration capability, and color, were investigated.

2. Materials and methods

2.1 Collection of raw materials

Fresh and mature cabbages were collected from the Madina market of Sylhet, Bangladesh. The shape and size of each cabbage were carefully selected to avoid large differences. Visual blemishes, diseased, damaged cabbages were discarded.

2.2 Sample preparation

Fresh cabbages were cut into 4×1.5 cm slices using a stainless-steel cutter. The cabbages were then kept inside airtight zip polythene bags before blanching to avoid oxygen.

2.3 Blanching and drying operation

The prepared cabbage samples were blanched at 80° C, 90°C, and 100°C temperature with a duration of 12, 8, and 2 mins, respectively, by plunging in a water bath (WB-100D). The blanching pretreatment was done to aid in drying and inactivate the peroxidase enzyme found in cabbage, which may cause alterations of cabbages' quality. The specimens were put in a tray after pretreatment. A constant temperature and humidity chamber (Model: VS-811H-150, Vision Scientific Co. Ltd., South Korea) was used to carry out the drying operation at 60ºC temperature maintaining 60% relative humidity (Mo *et al.*, 2006). To calculate the drying characteristics of cabbage, the weight changes were reported at every 1 hr until the difference between two consecutive weights was about 0.01 g. The entire

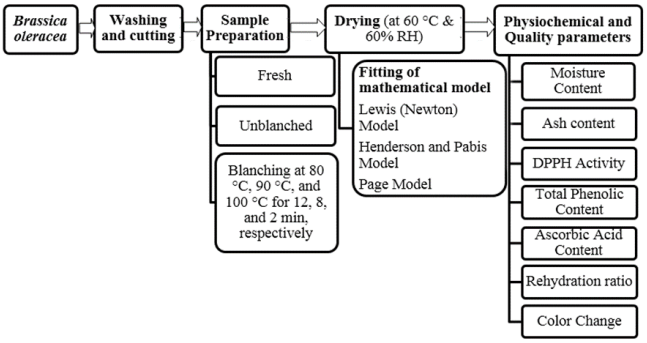

Figure 1. Schematic representation of research design

research design has been illustrated in Figure 1.

2.4 Determination of moisture content

By drying a sample at a specific elevated temperature, and disclosing weight loss employing moisture, cabbage's moisture content (dry basis, w/w) was determined by the process of Helvich (1990).

2.5 Determination of ash content

The AACC (2000) method was used to estimate the total ash content in cabbage.

2.6 Determination of DPPH activity

The modified methods stated by Saikia *et al.* (2015) and Rahman *et al.* (2016) were used to determine DPPH activity. About 200 µL extracts were added to a 2.8 mL DPPH solution. Solutions were set in a dark position for half an hour after stirring for 30 s on the vortex system. The absorbances of the extracts were determined at 517 nm by using a Spectrophotometer.

$$\text{DPPH Activity} = \frac{\text{Absorbance of blank} - \text{Absorbance of sample}}{\text{Absorbance of blank}} \times 100\% \quad (1)$$

The following empirical formula was used to determine the DPPH radical scavenging activity:

2.7 Estimation of total phenolic content

The method described by Slinkard and Singleton (1977) was used to estimate the total phenolic content. In short, 20 µL of extract were taken into different test tubes. After that, 1.58 mL of distilled water was added to each of the tubes, accompanied by 100 µL of Folin-Ciocalteu reagent, combined well enough, and finally, 300 µL Na_2CO_3 was applied within 8 mins. After stirring the samples using a vortex machine, the tubes were kept in the darkness for half an hour at 40°C. The absorbances of the solutions were then taken at 765 nm using a T-60 spectrophotometer (PG Instruments Ltd., UK). The

findings were represented in mg equivalent gallic acid (GAE)/100 g. There was a selection of standard gallic acid solution taken as blank.

2.8 Determination of ascorbic acid

The suggested method of Ranganna (1986) was used to determine the ascorbic acid. 2,6-dichlorophenol indophenols was reduced by ascorbic acid. In this process, the pigment, a blue alkaline solution and red in acid solution, was reduced to a colorless form by ascorbic acid.

2.9 Determination of β-Carotene

The method of Biswas *et al.* (2011) was used to estimate the Beta Carotene content. An exact 0.025 g of standard Beta-Carotene was mixed with 5 mL acetone, and the mixture was kept for 10 mins at a dark place to make the standard solution. Both solutions' absorbance was measured by using a T60-V Spectrophotometer (PG Instruments Ltd., UK) at 450 nm wavelength.

2.10 Determination of rehydration ratio

The dried cabbage samples rehydration ratio (RR) was determined using the method mentioned by Rajkumar *et al.* (2017). A sample of 2.5 g was dissolved in boiling water for 10 mins and afterwards moved to a funnel equipped with filter paper Whatman No. 1. With gentle suction, water was withdrawn from the sample until no oozes have been released.

2.11 Measurement of color change

The method of Xiao *et al.* (2012) was used to measure the color change. The color of specimens was measured by utilizing a colorimeter (PCE-CSM 4). L, a, and b values reflect the lightness, redness/greenness, and yellowness/blueness, respectively of the color of

$$C = \sqrt{(a^2 + b^2)} \quad (2)$$

$$\alpha = \tan^{-1} b/a \quad (3)$$

$$\Delta E = \sqrt{(L^* - L_0)^2 + (a^* - a_0)^2 + (b^* - b_0)^2} \quad (4)$$

dehydrated samples, whereas L_0*, a_0*, and b_0* represent the color of the fresh samples. C, α, and ΔE represent the chroma, hue angle, and total color differences, respectively.

2.12 Mathematical modeling of drying data

Three different mathematical models viz. Lewis

$$MR = \frac{Mt - Me}{Mo - Me} \quad (5)$$

(Newton): MR = exp(-kt), Henderson and Pabis: MR = aexp(-kt), Page model: MR = ($-kt^n$) were used to predict the drying behavior. The moisture ratio (MR) of the samples was calculated using the following empirical formula:

$$R^2 = \frac{\sum_{i=1}^{N}(MRexp,i - MRexp,mean,i)^2 - (MRpre,i - MRexp,i)^2}{\sum_{i=1}^{N}(MRexp,i - MRexp,mean,j)^2} \quad (6)$$

$$\text{RMSE} = \sqrt{\frac{\sum_{i=1}^{N}(MRip - MRie)^2}{N}} \quad (7)$$

Where, Mt, Mo and Me represents the moisture content at a particular time, the primary moisture content and equilibrium moisture content (g water/g dry matter), respectively (Izli *et al.*, 2017).

Fitting of mathematical model:

The correlation coefficient (R^2) and root mean square of error (RMSE%) were estimated in conjunction with the process of choosing a mathematical formula that explains the moisture content and time data (Gamli, 2014).

2.13 Statistical analysis

All the quantifications were performed in triplicates. The data obtained from the experiments were calculated and analyzed by the SPSS program (Version 20). Data analysis was done by using one-way variance analysis (ANOVA) and Duncan's multiple range test (DMRT) was applied for mean comparison. The data were considered statistically significant among treatments with a p value < 0.05. Data has been expressed as mean ± SD.

3. Results and discussion

3.1 Physicochemical properties of fresh and dried cabbage with blanching pretreatment

The moisture and ash content of fresh cabbage was 91.67±0.02% and 0.463±0.06%, respectively. The result represents the loss of moisture content with a higher blanching temperature. This result complies with Taiwo and Adeyemi (2009), which states that the higher the temperature of drying, the greater the moisture loss.

It was found that a rise in blanching temperature caused a decrease in the amount of ash content. The ash content was also reduced in blanched samples in contrast with untreated dried samples. This might be because of the leaching out of minerals from the cabbages during hot water dipping pre-blanching treatments. The result is in line with Makanjuola *et al.* (2013), who suggest that irrespective of the leafy vegetable under consideration, there was a gradual decrease in ash values during blanching (Table 1).

Table 1. Physiochemical properties of different cabbage samples

Properties	Fresh	untreated	Blanched 80°C	Blanched 90°C	Blanched 100°C
Moisture content (%)	91.67±0.02[a]	16.07±0.04[b]	13.92±0.07[c]	11.92±0.13[d]	10.80±0.01[e]
Ash content (%)	0.463±0.06[d]	5.71±0.06[a]	5.77±0.09[a]	4.91±0.11[b]	3.81±0.02[c]

Values are expressed as mean±SD of three independent determinations. Values with the same superscript within the row are not significantly different ($p<0.05$).

3.2 Effect of blanching pretreatment and drying on the bioactive compounds of cabbage

The results show a significant fall in DPPH radical scavenging activity after drying from the fresh sample (187.13±1.07%). There are little differences in untreated and blanched samples that mean the effect of blanching temperature on the loss of antioxidant activity was the minimum. A similar conclusion was drawn by Abu-Ghannam and Jaiswal (2015). Most of the antioxidant compounds are heat sensitive. Increased blanching temperature may accelerate the chemical breakdown of bioactive compounds that eventually decrease the production of antioxidants. A similar observation was found by Hossain, Evan, Moazzem *et al.* (2020), who showed that increasing extraction temperature dramatically reduces the DPPH radical scavenging activity in jackfruit. The general pattern reported is that losses in DPPH activity during the initial blanching process are more noticeable than later, and the factors causing these losses are blanching strategy, variety of cabbage, and blanching time. Though it was reduced slightly, the blanching temperature has a tiny influence, particularly if the applied temperature is within 80 –100° C range (Table 2).

The total phenolic content in untreated dried cabbage (109.43±0.51 mg GAE/100 g) was comparatively low than fresh cabbage (147.36±0.41 mg GAE/100 g). Furthermore, blanching caused more loss in total phenolic content at 80°C (61.91±0.48 mg GAE/100 g). Blanching resulted in a significant decrease in the TPC due to thermal deterioration and water leaching (Gonçalves *et al.*, 2010). Joubert (1990) stated that blanching induces the phenolics' solubilization and thus results in a decrease of TPC. Interestingly, the higher blanching temperature indicated a rise in the total phenolic compounds in line with the results of Yamaguchi *et al.* (2003), blanching at 95°C temperature for 12–14 mins contributed to an enhancement of 5–12% in the phenolic content. A homogenous trend at 100°C was noticed. Blanching can inactivate the polyphenol oxidase enzyme, thus suppressing the oxidation of polyphenols (Table 2).

Vitamin C removal has been observed during drying. Blanching pretreatment caused a drastic loss of vitamin C. With the rise in blanching temperature, the loss of ascorbic acid was higher than the untreated sample (34.64±0.85 mg/100 g). Drying at 60°C temperature did not cause much destruction of vitamin C from the fresh sample (37.23±0.55 mg/100 g) (Table 2). This result reflects the loss of vitamin C during blanching pretreatment. The water solubility, as well as destructive high temperature, might be responsible for more destruction of vitamin C. A similar result was obtained for pineapple and tomato juice as described by El-Ishaq and Obirinakem (2015).

Dried cabbage samples showed a significant loss in β -carotene content. Rather than blanching pretreatment, the drying operation was more responsible for this loss. According to the study of Nascimento *et al.* (2007), where blanching and drying operation was applied on sweet potato and cassava, blanching did not alter sweet potato's β-carotene concentration but decreased cassava concentration (16% loss). Blanching, however, improved β-carotene stability when dried sweet potato and cassava were stored at room temperature. However, blanching at a higher temperature of 100°C for a short duration of 2 mins showed slightly less destruction of β-carotene (3.29±0.15 mg/100 g) (Table 2). A similar finding was drawn by Shivhare *et al.* (2009), where carrot was blanched using 80°C, 85°C, 90°C, 95°C, and 100°C temperatures. Maximum beta carotene was found at 95° C. This might be because of the inactivation of enzymes

Table 2. Effect of blanching pretreatment and drying on the bioactive compounds of cabbage

Samples	DPPH scavenging activity %	Polyphenol content (mg GAE/100 g)	Ascorbic acid (mg/100 g)	β-Carotene content (mg/100 g)
Fresh	187.13±1.07[a]	147.36±0.41[a]	37.23±0.55[a]	38.45±0.80[a]
Untreated	86.05±0.80[bd]	109.43±0.51[b]	34.64±0.85[b]	2.22±0.07[d]
Blanched (80°C)	87.34±1.43[bc]	61.91±0.48[e]	8.48±0.35[c]	1.54±0.13[e]
Blanched (90°C)	83.61±1.27[cd]	69.16±0.73[d]	6.23±0.10[d]	2.49±0.11[c]
Blanched (100°C)	82.68±0.61[d]	74.47±0.63[c]	4.14±0.07[e]	3.29±0.15[b]

Values are expressed as mean±SD of three independent determinations. Values with the same superscript within the row are not significantly different ($p<0.05$).

at 95°C blanching temperature for 5 mins. From the results, it can be said β-carotene is heat-sensitive, but blanching can retain more of it. The reason behind higher β-carotene retention at higher temperatures conceivably related to the shorter blanching time. Negi and Roy, (2001) stated that blanching before drying improves the preservation of beta-carotene during storage, which might be because of the destruction of the endogenous enzymes.

3.3 Rehydration ratio of dried cabbage

Considering that most dehydrated products are rehydrated at their final use (soups, corn flakes, etc.), it is essential to know their compression behavior during rehydration. The rehydration ratio of blanched cabbage at 80°C, 90°C, and 100°C was 8.56±0.03%, 6.67±0.01%, and 4.18±0.02%, respectively. With the increase in blanching temperature, there was a decrease in the rehydration ratio. This can be due to the severe structural change in higher blanching temperatures. This complies with the results found by Krokida and Maroulis (2000), who stated that the material's rehydration characteristics are determined by preparation environments, sample constituents, and the nature of the drying-induced chemical and structural alterations.

3.4 Effect of blanching pretreatment and drying on the color change of cabbage

The color changes of cabbage subjected to blanching and drying treatment are shown in Table 3. L_0^*, a_0^*, and b_0^* values of fresh cabbage were 79.68±0.03, -7.7±0.05, and 23.74±0.007, respectively. The reduced L^* value in higher temperatures led to dehydrated cabbage becoming a dark color in contrast with a fresh sample. In the meantime, the untreated sample showed a higher value of L^* than the blanched samples. The negative value of a^* implies the greenness of the fresh sample. The untreated sample showed higher values of a^* (5.75±0.02), which indicate red hues. Blanching at 100ºC showed the lower value of a^*, which means the cabbages' greenness was retained more in this blanching treatment. The untreated sample showed the least value of b^* (21.11±0.10), which means it was the least yellow. The C values and b^* values have a good correlation. This indicates the vulnerability of the yellow color in cabbage. Blanching at 100ºC caused a higher value of α, mainly due to the lower value of a^* this indicates retention of green from an orange-red color. Increased blanching temperature showed increased values of ΔE. The impact of higher temperatures on heat-sensitive products can be attributed to this. The result is in line with Ihl *et al.* (1998).

3.5 Validation of empirical models for drying kinetics

Based on the maximum R^2 and minimum RMSE values, the most suitable model(s) designed to predict the drying data were chosen from untreated and pretreated samples. The Page model showed good data fit for all the tested cabbage samples employing $R^2 > 0.97$ and RMSE < 0.007. The Lewis model showed the R^2 value of >0.95 and RMSE <0.010. For the Henderson and Pabis model, the value of R^2 and RMSE was >0.94 and <0.012, respectively. The page model is, therefore, suggested as the best model explaining the drying characteristics of untreated and pretreated cabbage samples dehydrated at 60°C and 60% relative humidity (Table 4). Similar findings were recorded for red pepper drying (Doymaz and Pala, 2002; Simal *et al.*, 2005; Vega *et al.*, 2007).

Table 3. Effect of blanching pretreatment and drying on color change of cabbage

Samples	Color Parameter					
	L^*	a^*	b^*	C	α	ΔE
Fresh	79.68±0.03 ^{a}	-7.7±0.05^{e}	23.74±0.007^{b}	24.94±0.02^{b}	72.02±0.03^{c}	-
Untreated	72.63±0.03 ^{b}	5.75±0.02^{a}	21.11±0.10^{d}	21.85±0.02^{c}	74.76±0.01^{c}	15.41±0.03^{c}
Blanched (80˚C)	67.90±0.04 ^{c}	2.43±0.02^{c}	26.76±0.06^{a}	26.93±0.02^{a}	84.81±0.04^{ab}	15.82±0.10^{c}
Blanched (90˚C)	60.07±0.03 ^{d}	3.63±0.02^{b}	24.42±0.02^{b}	24.74±0.03^{b}	81.54±0.01^{b}	22.65±0.07^{b}
Blanched (100˚C)	56.40±0.05 ^{e}	0.47±0.07^{d}	22.29±0.01^{c}	22.30±0.04^{c}	88.79±0.04^{a}	24.71±0.09^{a}

Values are expressed as mean±SD of three independent determinations. Values with the same superscript within the row are not significantly different ($p<0.05$).

Table 4. R^2 and RMSE values of different drying models

Blanching Condition	R^2			RMSE		
	Lewis (Newtonian) model	Henderson and Pabis model	Page model	Lewis (Newtonian) model	Henderson and Pabis model	Page model
Untreated	0.965	0.942	0.976	0.0034	0.0014	0.0008
Blanched (80°C)	0.965	0.949	0.978	0.0049	0.0037	0.003
Blanched (90°C)	0.974	0.964	0.981	0.0083	0.0028	0.0017
Blanched (100°C)	0.981	0.973	0.992	0.0104	0.012	0.0079

4. Conclusion

In this research, an attempt was made to develop an effective preservation technique for fresh cabbages. Drying operation with blanching pretreatment induced the loss of some bioactive compounds of cabbage. Specifically, ascorbic acid and beta carotene content were mostly affected. It was found that higher temperatures and shorter blanching time retained the greenness of cabbage. At 100ºC blanching temperature, the green color retention was the highest. The Page kinetic model represented the best values. A proper combination of time and temperature, along with the incorporation of modern techniques, might be useful. This information may help to establish an applicable blanching procedure that can be suitable for cabbage and other food products.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgements

Authors are thankful to the research centre of Shahjalal University of Science and Technology for their financial support (Project ID:AS/2019/1/28) to conduct the research successfully.

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