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Analysis of the quality of broccoli leaf powder treated by blanching and drying

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ABSTRACT

Brassica oleracea L. *italica, the scientific name for broccoli, is a vegetable that is frequently consumed for its florets, which have a number of health benefits. However, other portions of the plant, including the leaves, are almost always discarded despite being good for human health. The study was carried out with the purpose of investigating how the physicochemical characteristics of powdered broccoli leaves were affected by blanching and various drying techniques applied. Broccoli leaves were first blanched in hot water before being dried, which included sun drying, oven drying, cabinet drying, and vacuum drying. The findings demonstrated that blanching enhanced the powder's physical attributes while maintaining its phenolic and flavonoid contents. Blanching also reduced the breakdown of the chlorophyll content in all drying techniques, although this process made it harder to keep the goods' antioxidant function. In conclusion, vacuum drying method of blanched broccoli leaf powder showed the highest retention of physicochemical properties, phytochemical content, and antioxidant activity.*

Keywords:
Antioxidant activity, Blanching, Drying treatments, Pigment, Physicochemical properties

1. Introduction

Broccoli contains high concentrations of bioactive phytochemicals such as glucosinolates, phenolic compounds, vitamin C, and mineral elements. It has been long that broccoli (*Brassica oleracea* L. *italica*) being promoted as a nutritious food [1]. Additionally, broccoli has been discovered to possess antioxidant qualities that mitigate the oxidative stress linked to numerous different disorders [2]. Typically, the florets, which make up about 30% of the broccoli's weight, are the only part that can be consumed. In the past, only flour and fiber were produced from broccoli by-products [1]; however, researchers are now closely examining the prospect of exploiting these by-products as a substantial source of phytochemicals [2]. Broccoli is among the most widely consumed vegetables worldwide due to its benefits and high rate of production, but at the same time it produces a high number of underutilized parts that are considered as waste. This is due to the absence of efficient processing technology for the side streams broccoli. It was revealed that only roughly 10-15% of the plant's total aerial biomass are consumed [3]. This is one of the negative effects on the agricultural industry; thus, if more broccoli aerial parts could be utilized for human consumption, the quantity of waste produced during production might be drastically decreased, thereby increasing farmers' profits [2]. The productivity and sustainability of world's broccoli crops would be increased by raising output from 15% to as much as 62% [3]. Broccoli is considered as a functional food because of its high concentration of bioactive compounds, such as phenolic chemicals, especially hydroxycinnamic acids, and flavonoids, which are considered as nutraceuticals [4]. Glucosinolates are secondary metabolites, the most distinctive nutraceutical substances present in cruciferous vegetables like broccoli. When cruciferous vegetables are consumed raw, glucosinolates in these plants will be hydrolyzed by enzymes known as myrosinase to produce other metabolites such as isothiocyanates, nitriles, and other substances [5]. Using plants from the Brassica genus is the most popular way to produce glucosinolate dietary supplements and broccoli is commonly being used in this case [4].

Due to the fact that broccoli leaves are perishable, the conversion of broccoli by-products to powder form will decrease the losses caused by the decay of fresh produce and retain the nutrients [6]. However, food may experience loss of sensitive nutrient to heat during the food processing and colour hanging as well as physical characteristic, depending on the drying condition such as temperature and drying time. It has been shown that pre-treatment before drying process is one of the important factors that affect the quality of final products in terms of physicochemical properties that are responsible for any unwanted changes such as pigment modification, tissue softening, and nutrient loss during the drying process [7]. Pre-treatment such as blanching is one of the heat treatments that have been used for various vegetables before drying. The final product's quality is determined by the pre-treatment, and certain modifications occur during the drying process. Physical properties such as moisture content are affected by blanching and the drying method used. The drying rate and quality deterioration can be sped up and prevented, respectively by blanching process which causes removal of intracellular air from the tissues and softening of texture [8]. Colour plays an important role in a product because it emphasizes sensual attraction and the product's superiority [9]. Pre-treatment and different drying methods may affect the colour properties of the final products. Therefore, a comprehensive study is needed to understand the effects of blanching and the drying method on broccoli leaf powder and the best quality of the final product. This study also determines the quality parameters such as physicochemical properties, total antioxidant activity, total content of phenolic compounds, total content of flavonoids, and total content of chlorophyll. The different drying methods will be discussed and compared on pre-treated samples and samples without pre-treatment. The antioxidant activity of broccoli has been the subject of numerous studies [10], although most of these studies focused on the broccoli's florets and stems rather than its leaves and potential uses. A study indicated that beetroot powder gave the best quality by processing in combination of 5minute blanching and 50 °C for 6 hours at cabinet dryer [7].

The functionality of broccoli leaves can be decreased by the drying process, which can reduce important chemical substances like antioxidants and phenols. In addition, one of the elements that will impact the powder's characteristics in the final product is how it is dried in relation to food. Therefore, investigations on the effects of this pre-treatment method on the components of broccoli leaves and the quality of broccoli leaf powder are crucial. The drying of broccoli leaves has been studied using a variety of techniques, including sun, oven, cabinet, and vacuum drying. It is crucial to research how different drying techniques affect broccoli leaf powder and choose the method that will result in the best quality of final product with the best storage stability. This study attempts to determine the best drying method based on the physicochemical properties of broccoli leaf powder. It also aims to define how blanching affects the quality of broccoli leaf powder.

2. Methods

Broccoli leaves were washed thoroughly under tap running water and then subsequently cut into small fractions. After separating midribs from the leaves, the leaves were then blanched at different temperatures. Broccoli leaves without blanching acted as the control sample. Broccoli leaves were blanched in hot water for 1 minute while the midrib of broccoli leaves was blanched in hot water for 3.5 minutes. The treated, control leaves and midrib samples then underwent drying process with methods of sun drying, oven drying, cabinet drying and vacuum drying until constant weight was obtained in all samples. All the dried broccoli leaves were ground, followed by sieving with a 250-µm sieve. All samples were determined for their physicochemical properties for colour, moisture content, pH, total antioxidant activity, and total chlorophyll as followed [11]. The colour of the sample surface was determined as the colour reflected in CIELab (L, a, b) colour space with the aid of a tristimulus colorimeter fitted with a CR-300 measuring head. Moisture content of broccoli leaves powder was determined by drying in a hot air oven at 100°C until no successive significant changes occurred in weight. The pH of broccoli leaves powder was determined by using a pH meter where each 5 g of sample were suspended in 100 mL boiling distilled water and followed by shaking in an orbit shaker.

The total phenolic content (TPC) of broccoli leaf powder was determined by the Folin-Ciocalteu assay [12]. The centrifuge tube was filled with 10 mg of the dry crude extract which was then added with either 10 mL of distilled water or ethanol. After being shaken for 30 minutes, the samples were then centrifuged for 20 minutes at 5000 rpm. Different concentrations (0.1 mL) of extract, blank, and gallic acid standard solutions were prepared and mixed with distilled water (2.8 mL), sodium carbonate (2%, 2 mL) and pre-incubated for 4 minutes. Then, the solution was added with Folin-Ciocalteu (100 µL) and incubated for another 30 minutes in ambient conditions. By using a spectrophotometer with the wavelength (λ) of 760 nm, the measurement of the sample was done against the blank. TPC was expressed as mg gallic acid equivalent (GAE) in g of dry weight. The method employed for the determination of total antioxidant activity of broccoli leaf powder, that used the 2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging method was based on [12]. The extract solution was added with 3 mL of 0.004% methanolic solution of different concentration (1 mL), blank or standard solution. Then, the solutions were incubated at room temperature for 30 minutes in a dark environment. Measurement against the blank solution was carried out using a spectrophotometer at a wavelength (λ) = 517 nm, with the data expressed as the concentration of anti-radical activity required for 50% scavenging of DPPH radicals in the specified period (IC_{50}). The total flavonoid content (TFC) of broccoli leaf powder was measured by employing aluminum chloride assay [13]. A volume of 1 mL of extract, blank solution, or standard solution of quercetins (0–200 $g.mL^{-1}$) was with an aluminum chloride solution (2%, 2 mL). After that, the mixture was shaken thoroughly and followed by a 30-minute incubation at room temperature. Using a spectrophotometer at a wavelength (λ) = 415 nm, measurement against the blank was conducted. The TFC was calculated and expressed in mg of quercetin equivalent (QE) per gram dry weight of plant extract.

The Association of Official Analytical Chemists method was used to determine the total chlorophyll present in broccoli leaf powder with the aid of a spectrophotometer [13]. Avoiding direct exposure to sunlight, the pigment was extracted by shaking 30 mL of heptane/ethanol (3:1) for an hour. With the speed of 20,000 rpm, the homogenate was subsequently centrifuged at 15 °C for 15 minutes, pellets were re-extracted, the supernatant combined and followed by dehydration with sodium sulphate anhydrous before being dried by rotary evaporator and the residual was filled to 10-25 mL with diethyl ether. Using wavelengths of 660 and 642.50 nm, the pigment was quantified by a spectrophotometer.

The data represent the mean of all three-replicate analysis. Analysis of variances (ANOVA) was conducted by using SPSS software for all the experiments. Mean values were compared using the level of 5% significant differences. Tukey's post hoc test was carried out if there were no significant differences between the variables.

3. Results and Discussion

Effect of Blanching and Different Drying Methods on the Properties of Broccoli Leaves Powder

3.1. Physicochemical Characteristics

3.1.1. Colour

Higher hue angles were observed in the blanched powder than unblanched powder. Lower colour degradation was seen in blanched powder as compared to unblanched powder. In general, regardless of drying methods, higher brightness is seen in unblanched samples than blanched samples as the dominant cause of colour loss was due to light, oxidative and thermal degradation. Cabinet drying is better than other drying method and this can be proven by the highest hue angle value (214.23) found in the blanched cabinet drying method. The lowest hue angle of blanched sun-dried samples (110.75) as compared to other drying samples indicated that sun-dried samples had more colour loss than other drying samples. In general, pre-treatment successfully reduced colour degradation against thermal treatment, such as the drying methods that have been mentioned [13]. It was also found by other researchers that colour retention was improved in dried foods that were blanched due to enzyme inactivation [7].

Table 1. Effects of blanching and different drying methods on the moisture, colour, and pH of broccoli leaf powder

Treatments		Moisture (%)	Colour				pH
Drying methods	Pre-treatment		L*	a*	b*	Hue	
Sunlight	Control	$7.33±0.01^{a}$	$51.48±1.36^{a}$	$0.08±0.02^{a}$	$1.21±0.01^{a}$	$93.78±2.31^{c}$	$3.08±0.01^{d}$
	Blanched	$7.20±0.01^{b}$	$51.56±1.13^{a}$	$0.36±0.03^{b}$	$0.95±0.01^{b}$	$110.75±3.74^{b}$	$2.98±0.01^{d}$
Oven	Control	$7.19±0.01^{b}$	$37.19±1.87^{c}$	$0.96±0.01^{c}$	$0.37±0.02^{c}$	$201.10±10.01^{a}$	$3.84±0.01^{c}$
	Blanched	$7.17±0.01^{b}$	$38.53±2.26^{c}$	$1.12±0.01^{d}$	$0.66±0.01^{c}$	$210.51±9.55^{a}$	$3.76±0.01^{c}$
Cabinet	Control	$6.86±0.01^{c}$	$36.14±0.97^{c}$	$1.04±0.05^{cd}$	$0.56±0.01^{c}$	$208.30±9.46^{a}$	$4.53±0.01^{b}$
	Blanched	$6.84±0.01^{c}$	$37.57±2.01^{c}$	$1.22±0.03^{d}$	$0.83±0.02^{cd}$	$214.23±10.26^{a}$	$4.40±0.02^{b}$
Vacuum	Control	$4.74±0.01^{d}$	$38.56±3.11^{c}$	$1.22±0.01^{d}$	$0.61±0.01^{c}$	$206.57±7.33^{a}$	$4.96±0.01^{a}$
	Blanched	$4.68±0.01^{d}$	$41.51±1.16^{b}$	$2.02±0.03^{e}$	$1.07±0.01^{d}$	$207.91±8.57^{a}$	$4.75±0.01^{a}$

Different letters superscript in the mean values within the row indicate the significant difference ($p<0.05$)

3.1.2. Moisture Content

Both pre-treatment and drying methods resulted in significant differences ($p<0.05$) in their moisture contents as can be viewed from the data in Table 1. The unblanched samples have had the highest moisture content after sun drying (7.33), followed by oven drying (7.19), cabinet drying (6.86), and vacuum drying (4.74). Less variation in moisture was detected in blanched samples regardless of drying method. In comparison to the other methods, sun drying took longer to dry and exposed a larger area, as explained by [9]. Similarly, blanched powder reduced the moisture content more in all three drying techniques than non-blanched powder.

3.1.3. pH

Table 1 shows the pH of powdered broccoli leaves, blanched and unblanched, as well as different drying methods. As can be viewed from the results, pre-treatment and drying processes significantly affected the pH of extracts ($p<0.05$), with values ranged from 3.08 to 4.96. The blanched samples had a lower pH value compared to the unblanched samples. The lowest pH value of the sample was blanched, sun-dried broccoli leaf powder (2.98), and the highest pH value of the sample was unblanched, vacuum-dried broccoli leaf powder (4.96).

The pH values showed significantly difference in treatments used due to evaporation rate process and formation of secondary metabolic compounds as found in dried tomatoes [5]. The pH values of dried tomato were evaluated by different drying methods, including air drying, solar drying, and microwave drying, with different temperature and electricity powers used. Results obtained indicated that the lowest pH value was seen in tomatoes dried in microwaves (3 $w.g^{-1}$, 57 °C) compared to the other drying methods [5]. Another study stated that significant variations in the pH values of dried broccoli florets were observed when using various drying procedures, such as cabinet drying, sun drying, freeze drying and solar drying. The results revealed that fan-dried broccoli had the lowest acidity due to a lower concentration of total phenol content [4].

3.2. Antioxidant Activity

The antioxidant activity of the broccoli leaf powder is shown in Table 2. The results show that the pre-treatment blanched and unblanched method as well as different drying method significantly ($p<0.05$) affected the antioxidant properties of the samples. The DPPH antioxidant values varied from 22.22 to 45.55 $\mu g.mL^{-1}$ in dried broccoli leaf powder. The highest antioxidant capacity was obtained from unblanched vacuum drying (45.55 $\mu g.mL^{-1}$) in the DPPH assay. The lowest antioxidant capacity was determined in blanched sun drying (22.22 $\mu g.mL^{-1}$) in DPPH assay. This is probably due to the low total phenolic content value in the blanched samples. In a prior study, TPC and DPPH assays of ginger extracts were found to have a positive connection; stronger antioxidant activity was found in samples with higher content of phenolics. This meant that plant phenolic chemicals influence and contribute to antioxidant activity [8].

Generally, phenolic compounds, especially flavonoids have antioxidant activity and have a significant role in the prevention of lipid peroxidation and scavenging of free radicals [14]. In general, plant materials, conditions of treatments, and the method used for measurement affect the effects of hydrothermal treatments on antioxidant activity. The

Table 2. Effects of blanching and different drying methods on the antioxidant activity and phytochemical compounds of broccoli leaves powder

Treatments		Analysis			
Drying methods	**Pre-treatment**	**Antioxidant Activity (μg.mL^{-1})**	**Total Phenolic (mg GAE.100 g^{-1})**	**Total Flavonoids (mg QE.100 g^{-1})**	**Total Chlorophyll (mg.100 g^{-1})**
Sunlight	Control	25.11±1.35^{d}	321.08±10.11^{d}	26.43±0.47^{d}	7.30±1.56^{d}
	Blanched	22.22±1.61^{d}	274.02±9.33^{e}	22.38±1.02^{d}	19.64±1.43^{b}
Oven	Control	35.46±1.14^{c}	437.51±7.98^{b}	33.64±1.61^{c}	13.33±1.66^{c}
	Blanched	32.61±1.11^{c}	407.03±17.41^{c}	32.21±1.10^{c}	21.45±1.48^{b}
Cabinet	Control	39.47±2.16^{b}	476.28±11.16^{a}	35.78±1.87^{b}	15.32±1.97^{c}
	Blanched	37.52±1.82^{b}	435.76±10.55^{b}	34.58±2.13^{b}	26.36±1.22^{a}
Vacuum	Control	45.55±1.77^{a}	505.21±6.65^{a}	47.53±1.36^{a}	19.18±0.76^{b}
	Blanched	42.74±1.66^{a}	470.26±8.22	45.96±1.55^{a}	29.27±0.95^{a}

Different letters superscript in the mean values within the row indicate the significant difference ($p<0.05$)

total maximum reducing power (TMP) in this study increased with blanching, whereas DPPH decreased. A past research depicted a drastic reduction in the reducing power as well as the DPPH scavenging activity of blanched Darsan yam peel [14]. Total phenolic content, reduction power, and DPPH radical-scavenging activity of the Darsan yam peel were reduced by blanching technique, according to the findings. Heat treatment of yam has been demonstrated to affect the stability of phenolic components and antioxidant activity. As a result, the loss of total phenolic components and antioxidant activity in the peel because of blanching could possibly be linked to the heating treatment [15].

3.3. Total Phenolic Content

The total phenolic content of the broccoli leaf powder is shown in Table 2. The results obtained shows that pre-treatment (blanched and unblanched) as well as the drying process significantly affected the samples in this aspect ($p<0.05$). Unblanched vacuum-dried product had the highest phenolic content in both treatments (blanched and unblanched), which had 505.21 mg GAE.g^{-1} and 470.26 mg GAE.g^{-1}, respectively, compared to other drying methods. Cabinet-dried (blanched) showed phenolic content of 476.28 mg GAE.g^{-1}, which was non significantly different ($p>0.05$) from the value of unblanched vacuum dried samples, which was 435.76 mg GAE.g^{-1}. Oven-dried product has similar results in terms of phenolic content to both blanched and unblanched samples of cabinet drying, which had 437.51 mg GAE.g^{-1} and 407.03 mg GAE.g^{-1}, respectively. Sun-dried samples, both blanched and unblanched, showed phenolic contents of 321.08 mg GAE.g^{-1} and 274.02 mg GAE.g^{-1}, respectively, which were significantly different ($p<0.05$) from the values of other drying methods. Sun-dried samples had the lowest phenolic levels, which could be attributed to enzymatic degradation because the technique was done outside in the sun, and it took several days for the samples to dry [8]. Oven- and cabinet-dried samples have less phenolic content than vacuum-dried samples because many phenolic compounds are heat sensitive that was confirmed through observation by [14].

3.4. Total Flavonoid Content

Aluminium chloride in a colourimetric method was used as the method to determine the flavonoid contents of dried broccoli leaf powder as a basis for quantitative determination,. The results were derived from the calibration curve (y = 0.0057 + 0.0127, R^2 = 0.9973) of quercetin (0–199 g.mL^{-1}) and expressed in quercetin equivalents (QE) per gramme dry powder weight shown in Table 2. The data show that pre-treatments (blanched and unblanched) and the different drying processes significantly affected the total flavonoid content ($p<0.05$).

The flavonoid content of blanched broccoli leaves in different drying methods ranges from 22.38 to 45.96 mg QE.g^{-1}, that represented a variation of approximately six-fold. Unblanched for both vacuum dried and cabinet dried powder had the greatest flavonoid content, at 47.53 and 35.78 mg QE.100g^{-1}, respectively, while the significantly lower amounts of flavonoids were found in blanched oven dried and sun dried samples powder, at 32.21 and 22.38 mg QE.g^{-1}, respectively. In both blanched and unblanched samples, their total flavonoid contents were significantly affected by the drying process. In the study of Heras-Ramírez et al. [16], the flavonoid content losses in blanched apple pomace samples were in the order of 50% when compared with unblanched apple pomace samples before drying. This is due to the deactivation of polyphenol oxidases by blanching which are also polyphenolics. Furthermore, the same study's findings imply that shorter drying times at higher temperatures (80 °C) may minimize the rate of polyphenol and flavonoid degradation [16]. Besides, Mehta et al. [15] also mentioned that at temperatures of 75-80 °C, a shorter heat exposure time is required for the inactivation of enzyme polyphenol oxidase, which causes the destruction of flavonoids content.

3.5. Total Chlorophyll

The total chlorophyll content in dried broccoli leaf powder is shown in Table 2. The results show that the pre-treatment blanched and unblanched method as well as different drying method significantly affected the total chlorophyll content of the samples ($p<0.05$). Overall, unblanched samples with different drying methods showed a lower chlorophyll content compared to the blanched samples with different drying methods. The highest chlorophyll content was obtained in a blanched, vacuum-dried sample (29.27 mg.100g^{-1}) and the lowest in unblanched, sun-dried broccoli samples (7.30 mg.100g^{-1}), which was significantly lower than that of other untreated samples ($p<0.05$). The enhanced preservation of chlorophyll content in vegetable samples may be due to the greater drying rate of vacuum drying. Vacuum drying was shown to be more efficient than other drying methods in terms of maintaining chlorophyll content. Furthermore, removing moisture by vacuum drying boosts nutritional concentration and bioavailability.

When compared to unblanched samples dried by vacuum, hot water blanching increased the chlorophyll content that present in broccoli leaf powder. The color-related enzymes were inactivated by blanching in hot water prior to vacuum drying, thereby resulting dried vegetables with a maintained colour and chlorophyll content [17]. The lower results of chlorophyll content in cabinet-dried samples than in vacuum-dried samples may be due to leaching. A past research indicated that blanching treatments caused a significant reduction was found in hot water blanching of fenugreek leaves (86.59 mg.100g^{-1}) and the same study also found that 19% reduction in the sum of chlorophyll content was seen in samples that were subjected to longer heat processing time involving cooking and drying compared with the untreated materials [18]. Lower loss was observed in chlorophyll a

(17%) as compared to that of chlorophyll b (23%). Exposure of material coming into contact with the air and high temperature were the reasons that contributed to the loss of chlorophyll during drying in the research. In general, higher pigment loss is seen in vegetables subjected to a high drying temperature and a longer drying time. It showed the reduction of total chlorophyll pigment by 1% on average in hot air drying, but on average, the content of chlorophyll decreased by 15% [18].

4. Conclusion

The samples' physical attributes, including colour change, moisture content, and pH, are improved by blanching, which maintains the sample's quality by stopping all deterioration activity involved in chemical or enzymatic reactions. In terms of retaining desirable physical characteristics and chemical properties, vacuum drying and cabinet drying at lower temperatures have many benefits. The vacuum-dried, blanched sample showed the best results as it showed comparative physicochemical characteristics in comparison to the other samples and exhibited great antioxidant activity, owing to its greatest total chlorophyll content present in the sample as well as comparatively high contents of flavonoids and phenolics, where it showed the second and third highest total flavonoid and phenolic contents, respectively, regardless of drying techniques applied and application of blanching.

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