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**RESEARCH ARTICLE**

# PRODUCTION OF DIETARY FIBER POWDER FROM WHITE CABBAGE OUTER LEAVES

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**ABSTRACT**

The study was conducted to develop dietary fiber powder (DFP) from white cabbage outer leaves since they are rich in dietary fiber but are generally discarded as waste. The chemical and microbiological parameters of DFP were studied at each step of production and storage. The cabbage outer leaves were blanched and both blanched and unblanched leaves were dried at 80°C and 90°C. The effects of hot-water blanching and hot air drying temperature on the quality of DFP obtained were investigated in terms of moisture content, proximate composition (protein, crude fat, crude fiber, ash and carbohydrate content), vitamin C content, total phenolic content (TPC), total antioxidant activity (TAA) and acidity. Also their effect on the microbiological quality and the rehydration ratio was analyzed. The study was conducted in the premises of Lady Irwin College. Data was analyzed statistically using ANOVA and DMRT tests. The result showed that both blanching and drying has affected the composition of fiber i.e., blanching the leaves has resulted in better retention of nutrients due to inactivation of the enzyme peroxidase. Drying on the other hand has resulted in loss of nutrients which has increased with the increase in drying temperature.



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## INTRODUCTION

Cruciferous or *Brassica* vegetables belongs to the family Cruciferae or alternatively, Brassicaceae. Cruciferous vegetables contain a number of nutrients such as folate, fiber, carotenoids, chlorophyll and phytochemicals antioxidant and anticancer activities (Singh *et al*., 2006). Many researchers have shown an inverse correlation between consumption of *Brassica oleracea* (*B. oleracea*) vegetables risk of various cancers (Higdon *et al*., 2007; Keck & Finley, 2004; Stoewsand, Anderson, & Munson, 1988). This health beneficial effect of cruciferous vegetables could be due to the presence of phytochemicals, especially antioxidant vitamins such as Vitamin C, Vitamin E and β-carotene (Prior & Cao, 2000) and from phenolic compounds such as flavonoids, isoflavone, flavones, anthocyanin, catechin and isocatechin (Wang, Cao, & Prior, 1996). These dietary antioxidants helps to reduce free radical induced oxidative stress. Brassica vegetables like white cabbage has also been reported to contain a group of phytochemicals termed glucosinolates which have been known to protect animals against cancer (Verhoeven, Verhagen, Goldbohm, Brandtb, & Poppel, 1997). Cabbage (*Brassica oleracea* L. var. capitata) is a shallow-rooted, cool-season crop with a large leafy head. It was used as therapeutic purpose i.e., for treating headaches, gout, diarrhea and peptic ulcers for long years even before it was used as a food. Its main constituent include carbohydrate which comprise approximately 90% of the dry weight, with approximately one third contributed by dietary fiber and remaining by low-molecular- weight carbohydrates (LMWC) thus is a good source of dietary fiber (Wennberg, Ekvall, Olsson, & Nyman, 2006). Dietary fiber has various health benefits including blood glucose and cholesterol attenuation, regulation of intestinal function and gut health, protection against colon cancer, cardiovascular diseases, coronary heart diseases, type 2 diabetes and improved weight maintenance (European Food Safety Authority, 2010; Hauner *et al*., 2012) Research have shown that high consumption of *Brassica* vegetables, including cabbages and broccoli, results in reduced risk of certain cancers (Ciska & Pathak, 2004; Higdon *et al*., 2007) and they also have been reported to reduce the risks of coronary heart disease, cardiovascular disease, and hypertension. Despite of such health benefits of cabbage, outer leaves of white cabbage (*Brassica oleracea* L. var. capitata) are usually discarded as waste and in many cases upto 40% of outer leaves and core of cabbages are discarded (Nilnakara, Chiewchan, & Devahastin, 2009). Even though it is rich source of dietary fiber and phytochemicals, it is either used as fertilizer or as animal feed (Nilnakara *et al*., 2009; Tanongkankit, Chiewchan, & Devahastin, 2010). Thus, it has been reported that such low-value industrial can be transformed into value added products such as antioxidant dietary fiber powder (Jongaroontaprangsee

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*et al*., 2007). A conventional process for production of dietary fiber powder involves many successive unit operations such as washing, cutting, blanching, drying etc which may severely affect some of the phytochemical or bioactive compounds which were otherwise present in the by-product. For example, drying results in change in physico-chemical properties of dietary fiber as a result of which physiological effects may also be changed. Blanching causes significant reduction in antioxidant activities of kale, spinach and swamp cabbage after 1 min of blanching (Ismail, Marjan, & Foong, 2004). Drying has also been reported to degrade many phytochemicals in fruits and vegetables (Nicoleti, Silveira, Telis-Romero, & Telis, 2007; Gong, Zhang, & Sun, 2007). Mrkı`c *et al*., 2006 has reported that higher drying temperature resulted in higher losses of phenolic compounds and ascorbic acid in broccoli. Drying may also result in excessive discoloration, and destruction of the cellular system (Yadollahinia, Latifi, & Mahdavi, 2008). Thus, the aim of the present study was to produce dietary fiber powder from outer leaves of white cabbage (*Brassica oleracea* var. capitata golden acre) and to study its antioxidant properties.

## MATERIALS AND METHODS

### Raw Materials

Outer leaves of cabbage (*Brassica oleracea* var. capitata golden acre) were procured from the kitchen garden of Lady Irwin College. The dark green colored leaves, outer to the inner head of the cabbage and free from any kind of mechanical damage were used to produce dietary fiber.

### Preparation of dietary fiber powder

After procurement cabbage outer leaves were washed thoroughly under running tap water to remove all the dust and dirt adhering to it followed by chopping them in sizes of 0.5 cm x 5 cm. Chopped leaves were then blanched in water at 93±2°C for 2 minutes. (cabbage leaves: water: 1:7) as used by (Nilnakara *et al*., 2009). The unblanched and blanched leaves were dried using a laboratory scale tray dryer at 80°C and 90°C. At each temperature 1 kg of unblanched and blanched leaves were dried until the desired final moisture content of 0.1 kg water/ kg dry matter was reached. Gravimetric method was used to determine moisture content of dried samples at 105°C (AOAC, 1999). The dried samples were ground to the fine powder using a grinder (Maharaja Whiteline Food Processor Supremo) at a medium speed for 2 minutes and then packed in vacuum pack plastic containers and stored at room temperature (~ 25°C) in dry and dark place.

### Analysis of dietary fiber powder obtained

Crude protein was estimated by Kjeldahl method, Crude fat was analyzed using soxhlet apparatus, Ash content was measured by incinerating in muffle furnace. All these determinations were carried out using AOAC, 1999 standard protocols. Crude fiber was analyzed by acid and alkali digestion method following BIS standard [IS 1155 : 1968]. Carbohydrate content was estimated by subtracting protein, lipid, crude fiber and ash content from 100.

### Vitamin C

Vitamin C was estimated by titrating the sample against indophenols standard solution (AOAC, 1999). Ascorbic acid was taken as standard. Formula used for calculating results is: mg Ascorbic acid/g = (X – B) x (F / E) x (V / Y), where, X is average ml for sample titration; B is average ml for sample blank titration; F is mg ascorbic acid equivalent to 1.0ml indophenols standard solution; E is g of sample assayed; V is volume of initial assay solution; and Y is volume sample aliquot titrated.

### Total Phenolic Content

Folin-Ciocalteau method was used to estimate total phenolic content of the samples (Yu, Zhou, & Parry, 2005). Briefly, 5g of the sample was extracted with 50 ml of acetone-water solution (1:1, v/v) for 15 h at room temperature and filtered. 50µl of the sample extract, 250µl of Folin-Ciocaleau reagent, 0.75ml of 20% sodium carbonate solution and 3ml of distilled water were taken in a test tube, mixed and incubated for 2 hours in dark and then absorbance was measured at 765nm using UV-vis spectrophotometer. Gallic acid was used as a standard. The results were expressed as Gallic Acid Equivalent (GAE) per 100g of the sample (dry matter).

### Total Antioxidant Activity

The total antioxidant activity of the samples was estimated by using DPPH assay (Akowuah, Ismail, Norhayati, & Sadikun, 2005). Briefly, 200µl DFP extract (0.05mg/ml), 2ml of methanolic DPPH (0.1mM) and 0.8ml of methanol were mixed and incubated for 60min after which the absorbance was measured at 517nm using a UV-vis spectrophotometer. 2ml of 0.1mM DPPH and 1ml of methanol was used as control. Thus,

$$\text{Antioxidant activity (\%)} = \frac{A_c - A_s}{A_c} \times 100$$

where, $A_c$ is the absorbance of control after 60 min; and $A_s$ is the absorbance of sample after 60 min.

### Microbiological Analysis

The obtained DFP and unblanched and blanched cabbage outer leaves were analyzed, using standard protocols, for presence or absence of Total plate count, Coliform count, *Escherichia coli (E. coli,),* Coagulase-positive *Staphylococci* and Yeast and Mould Count. Microbiological counts were determined according to the procedure given in: IS 5402 : 2002 for total plate count, IS 5401 (Part 1) : 2002 for coliform count, IS 14397 : 1996 for *E.coli*, IS 5887 (Part 8/Sec 1) : 2002 for coagulase-positive *Staphylococci* and IS 5403 : 1999 for yeasts and mould count. 5g of the sample was removed aseptically and macerated using pestle and mortar. The sample was diluted with 45ml phosphate buffer. Appropriate serial dilutions (upto 1:10000) were prepared. Pour plate method was used for plating except for coagulase-positive *Staphylococci* for which spread plate method was used. Diluents used were phosphate buffer solution.

### Rehydration ratio

Method prescribed by (Ranganna, 1986) was used for determining rehydration ratio of DFP. For this, 2g of sample was taken in 500ml beaker and 80ml of distilled water was added and covered with watch glass. It was then brought to boil within 3 min on an electric heater and boiling was continued for 5 min and filtered until the drip from the funnel

has almost stopped and weighed. The test was repeated and six other 2-10g samples were rehydrated by boiling two for 10 min, two for 20 min, and two for 30 min.

Rehydration ratio = wt of rehydrated sample: wt of dehydrated sample

**Statistical Analysis**

All experiments were performed in duplicate. Results were expressed as mean ± standard deviation. The results were analyzed using one-way analysis of variance (ANOVA) and Duncan's multiple range test (DMRT) using SPSS. Values were considered at a significance level of 95% ($p < 0.05$).

## RESULTS AND DISCUSSION

**Analysis of DFP**

The moisture content of unblanched cabbage outer leaves before drying was approximately 6.71±2.44kg water/kg dry matter which has increased to 10.31±1.97kg water/kg dry matter after blanching. The time period for which the leaves were dried to reach the desired moisture content of less than 0.1kg/kg dry matter was the same as those used by (Nilnakara *et al*., 2009) for drying cabbage outer leaves as shown in Table 3.1. The results showed that the unblanched samples took more time to dry as compared to blanched samples as blanching may have caused structural softening resulting in easy water removal. Blanching or cooking makes plant tissue cells more permeable to moisture (Nilnakara *et al*., 2009). These results were in accordance with drying of cauliflower leaves by (Lopez, Iguaz, Esnoz, & Virseda, 2000). Desired moisture content has reached in shorter time at higher drying temperature than at lower drying temperature (Graph 3.1). This is because drying at higher temperatures provided larger driving forces for heat transfer, hence higher rates of mass transfer at higher temperatures. Furthermore, at a higher drying temperature, the moisture diffusivity is also higher (Leeratanarak, Devahastin, & Chiewchan, 2006). The moisture content of DFP of unblanched leaves dried at 80°C and 90°C was estimated to be 3.50±0.46g/100g dry matter and 4.16±0.10g/100g dry matter respectively where as moisture content of DFP of blanched leaves dried at 80°C and 90°C was estimated to be 2.11±1.16g/100g dry matter and 3.15±0.17g/100g dry matter respectively. Thus drying at higher temperature has resulted in less moisture content.

**Proximate Composition**

Cabbage outer leaves which are usually discarded as waste contains high amount of dietary fiber however they are really poor source of fat therefore they can be considered good for health. Results showed that after moisture, the second largest component of the cabbage outer leaves or of the DFP obtained are carbohydrates followed by crude fiber, protein, ash and crude fat. The unblanched COL has the maximum carbohydrate content of 45.32±0.19g/100g dry matter which has reduced to 32.12±2.12g/100g dry matter after blanching (Table 3.2). Blanching has caused a significant decrease in carbohydrate content of dried sample which could be due to loss of low molecular weight carbohydrates (LMWC) such as sugars like glucose, fructose and sucrose in blanching water. (Wennberg *et al*., 2006) has also reported the loss of about 45% of LMWC during blanching (at 100°C for 5min) of white cabbage. However, crude protein content of the blanched cabbage outer leaves was slightly higher than unblanched samples with blanched sample containing 21.84±0.49g crude protein/100g dry matter and unblanched sample containing 20.63±0.50g/100g dry matter. The same phenomenon was observed in case of dried samples as well (Table 3.2) the difference was not significant. The crude fat and crude fiber content of the cabbage outer leaves and DFP has shown pattern similar to crude protein i.e., it has increased upon blanching. However, in this case the increase was significant. Similar results were observed by (Phillips & Palmer, 1991) who has reported that blanching has caused loss of dry matter contributing to increased dietary fiber content in cooked carrots. Whereas, raw and dried unblanched samples does not differ significantly among themselves with respect to crude fat content. Similarly, the fat content among blanched samples was not significantly different. In contrast to protein, crude fiber and crude fat, the ash content of the leaves decreased after blanching with the unblanched leaves having 11.40±0.70g ash/100g dry matter and blanched leaves having 8.26±0.23g/100g dry matter of ash. Similar results were observed in case of dried samples i.e., ash content has decreased significantly after blanching. Loss of LMWC to blanching water may lead to an increase in crude fiber, protein and fat contents and decrease in the ash and carbohydrate contents after blanching.

**Vitamin C**

Vitamin C is an essential substance found mainly in fruits and vegetables including cruciferous vegetables. From the results it has been estimated that vitamin C content of raw unblanched cabbage outer leaves was 399.20±1.42mg/100g dry weight (23.95±0.17mg/100g wet weight) and of blanched leaves was 156.25±1.43mg/100g dry weight (Table 3.3). This shows that pre-processing operation like blanching has resulted in the significant reduction in vitamin C content. The vitamin C content of white cabbage outer leaves reported in this study was less than that published in previous studies i.e., 32 mg/100 g on wet basis, 27.32 mg/100 g on wet basis and 31.97mg/100g on wet basis reported by (Chu *et al*., 2002) (Kurilich *et al*., 1999) and (Nilnakara *et al*., 2009) respectively. Such difference might be because of difference in the variety of white cabbage used or the stage of harvesting. (Oboh, 2005) has reported that blanching green leafy vegetables in hot water at 100°C for 5min results in 47.5–82.4% loss of vitamin C. Drying also lead to vitamin C degradation. The results showed that Vitamin C content of the unblanched and blanched COL has decreased to 81.15±0.71mg/100 g dry matter and 69.46±1.56mg/100 g dry matter respectively upon drying at 80°C. Vitamin C content has decreased further to 75.80±1.14mg/100 g dry matter and 62.00±0.71mg/100 g dry matter in unblanched and blanched samples dried at 90°C. The degradation might have occurred due to both vitamin C oxidation and thermal destruction. Even during drying, more reduction has occurred in the blanched samples than in the unblanched samples which might be because much of the vitamin C has already leached out in the blanching water and drying operation has resulted in further degradation of the vitamin.Thus, drying operation at 80°C and 90°C has resulted in significant reduction in vitamin C content of COL with maximum loss occurred in the blanched sample dried at 90°C.

**Total Phenolic Content (TP Content)**

The TPContent of raw unblanched cabbage outer leaves was estimated to be 94.50±3.54mg GAE/100g dry matter. (Singh *et*

*al*., 2006) has reported that white cabbage heads contain 18.74mg GAE/100g fresh weight and particularly heads of Golden Acre contains 13.14mg GAE/100g fresh weight. This shows that outer leaves of white cabbage are rich source of TP Content. The TP content in dried white cabbage outer leaves is shown in Table 3.4. The total phenolic content of blanched cabbage outer leaves was estimated to be 91.00±2.83mg GAE/100g dry matter which was lesser than that estimated for unblanched cabbage outer leaves but the difference between the two is not significant. Ismail *et al*. (2004) reported 20% loss of TP content in cabbage after blanching in boiling water for 1 min. Price *et al*. (1997) reported 82% loss of phenolic compounds in cooking water for green leafy vegetables which were blanched for 15min. Drying operation has also resulted in significant drop in TP content in COL. The results shows that unblanched COL dried at 80°C contain 50.50±0.71mg GAE/100g dry matter while that dried at 90°C contain 48.00±0.00mg GAE/100g dry matter as compared to unblanched raw leaves which contain 94.50±3.54mg GAE/100g dry matter. This decrease in TP content upon drying could be due to the thermal degradation at higher drying temperatures. On the other hand, the COL which were first blanched and then dried has higher TP Content than those which were subjected to drying without prior blanching; this may be because enzymatic browning did not take place during drying in case of unblanched samples. However, within the blanched samples also, the dried samples has significantly less amount of TP content than the raw blanched sample with the blanched sample dried at 80°C containing 72.00±0.00mg GAE/100g dry matter and blanched sample dried at 90°C containing 67.00±2.83mg GAE/100g dry weight. Although, samples dried at different temperatures did not differ significantly in terms of their TP content. Chantaro *et al*. (2008) has reported that although higher drying temperatures would accelerate the degradation rate of total phenolics but shorter drying time required to dry the sample at higher temperatures would also has shorten the degradation reaction. This balance between these two factors has resulted in similar levels of TP content in samples obtained at different drying conditions (Nilnakara *et al*., 2009).

**Total Antioxidant Activity**

The total antioxidant activity of cabbage outer leaves were analyzed using DPPH assay and the results showed that the TAA of raw unblanched cabbage outer leaves was 104.67±1.89% which has decreased significantly to 98.50±1.65% upon blanching at 93±2°C for 2 min as shown in Table 3.5 which could be due to the degradation of phenolic compounds or other DPPH free radical scavanger components (Amin, Norazaidah, & Hainida, 2006). The effect of drying at 80°C and 90°C on total antioxidant activity of blanched and unblanched cabbage outer leaves were also studied and the results showed that the unblanched cabbage outer leaves dried at 80°C has 85.73±2.24% TAA and leaves dried at 90°C has 83.97±2.12% TAA against DPPH radicals indicating that TAA of COL has decreased significantly with the increasing temperature used for drying however the difference between the TAA of samples dried at two drying temperatures was not significantly different. The samples that were subjected to blanching prior to drying, however possess significantly higher percentage of TAA as compared to unblanched dried samples with blanched leaves dried at 80°C and 90°C possessing TAA of 97.83±0.24% and 97.16±0.71% respectively. The decrease in the TAA of blanched cabbage outer leaves increased with increase in drying temperature however all the three blanched samples was not significantly different with respect to their TAA.

**Microbiological Analysis**

Cabbage outer leaves, both unblanched and blanched, and DFP were tested for total plate count, coliform count, *E.coli*, coagulase positive *Staphylococci* and yeasts and moulds. The total plate count is one of the most common tests applied to indicate the microbiological quality of food. The results showed that TPC has reduced with increasing temperature since raw unblanched cabbage outer leaves has TPC of 4.083 log cfu/g and blanched COL has TPC of 4.018 log cfu/g which has decreased to 3.884 log cfu/g and 3.382 log cfu/g respectively upon drying at 80°C and further decreased to 3.613 log cfu/g and 3.215 log cfu/g respectively at even higher drying temperature i.e., upon drying at 90°C.Also blanched samples have less TPC count as compared to unblanched samples. This shows that drying the cabbage outer leaves at higher temperature has resulted in considerable reduction of total plate count. Thus the TPC of the DFP obtained by drying blanched leaves at 80°C and by drying unblanched and blanched leaves at 90°C are in accordance with FSSAI standards, 2011 i.e. less than 40,000 cfu/g. Both unblanched and blanched cabbage outer leaves has coliform count of 2.176 log cfu/g which has reduced upon drying to non-detectable levels in all the unblanched and blanched samples dried at 80°C and 90°C. Whereas *E.coli* count was non-detectable among all samples including unblanched and blanched COL indicating that proper hygienic conditions were followed during growth, washing and processing of cabbage.

Presence of *Staphylococci* in processed food or on food processing equipment is generally an indication of poor sanitation. Coagulase-positive *Staphylococci* has decreased to 1.576 log cfu/g after blanching of raw cabbage outer leases as compared to 1.954 log cfu/g present in raw unblanched leaves. However, in case of dried samples both blanched and unblanched the coagulase-positive *Staphylococci* was not detected indicating proper heat treatment was applied since they are vulnerable to destruction by heat treatment and nearly by all sanitizing agents. The yeast and mould count has also decreased after blanching the raw cabbage outer leaves at 93±2°C for 2 minutes. The yeast and mould count of raw unblanched COL was estimated to be 3.279 log cfu/g which has decreased to 2.000 log cfu/g in blanched COL. Drying the samples has further reduced the yeast and mould count to non-detectable levels for all the samples. Thus DFP obtained can be considered safe for human consumption.

**Rehydration Ratio**

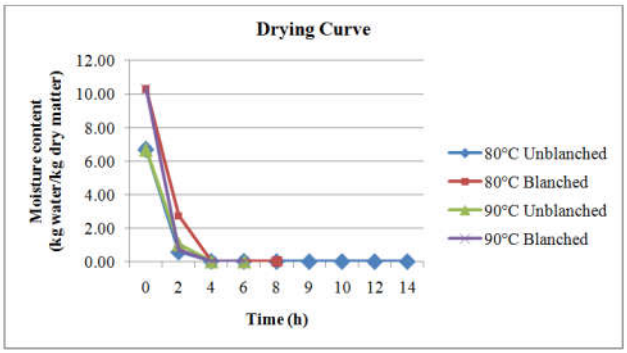
Rehydration ratio was defined as the ratio of weight of rehydrated samples to the dry weight of the sample (Giri & Prasad, 2007). Rehydration ratio is widely used as a parameter for dried sample quality. It indicates the physical and chemical changes during drying as influenced by processing conditions, sample pre-treatment and composition (FENG & TANG, 2006). The rehydration ratio was estimated to be in the range of 7.57-8.65 under various drying conditions. As expected the rehydration ratio of all the samples has increased with increased rehydration time. It can be seen from Graph 3.2 that the rehydration ratio was affected by the drying temperatures and by the pre-drying treatment i.e., by blanching. The

rehydration ratio has increased as the drying temperature was increased. This might be because that higher drying temperature has caused rapid evaporation of water, thus preventing the shrinkage and case hardening and improving the rehydration characteristics. Similar results were observed by (Sharma & Prasad, 2001) during drying of garlic (Allium sativum) cloves by microwave and hot air combination. Besides, it can be seen that the rehydration ratio of blanched samples resulted in the highest rehydration, compared to unblanched samples for both the drying temperatures.

**Table 3.1. Drying time of cabbage outer leaves with the final moisture content less than 0.1kg water/kg dry matter**

| Sample | Temperature (°C) | Drying time (h) |
|---|---|---|
| Unblanched | 80 | 14 |
| | 90 | 7 |
| Blanched | 80 | 8 |
| | 90 | 5 |

All data are the mean ± SD of duplicate readings. Mean ± SD followed by same letters in the same column are not significantly different ($p \leq 0.05$).




**Graph 3.1. Drying curves in terms of moisture content of unblanched and blanched cabbage outer leaves at temperature of 80°C and 90°C**

**Table 3.2. Proximate compositions of cabbage outer leaves subjected to various processing conditions**

| Condition | Composition (g/100g dry matter) | | | | |
|---|---|---|---|---|---|
| | Protein | Crude fat | Crude fibre | Ash | Carbohydrate |
| Unblanched | 20.63±0.50$^{a}$ | 1.16±0.00$^{a}$ | 21.49±0.39$^{a}$ | 11.40±0.70$^{b}$ | 45.32±0.19$^{c}$ |
| Blanched | 21.84±0.49$^{a}$ | 2.78±0.01$^{b}$ | 35.01±1.39$^{d}$ | 8.26±0.23$^{a}$ | 32.12±2.12$^{a}$ |
| Unblanched | | | | | |
| Dried at 80°C | 21.40±0.86$^{a}$ | 1.06±0.03$^{a}$ | 24.94±0.14$^{b}$ | 12.42±0.39$^{b}$ | 40.18±0.30$^{b}$ |
| Dried at 90°C | 21.42±2.36$^{a}$ | 1.01±0.25$^{a}$ | 24.09±1.18$^{b}$ | 13.08±0.72$^{b}$ | 40.40±3.08$^{b}$ |
| Blanched | | | | | |
| Dried at 80°C | 21.94±0.65$^{a}$ | 2.42±0.37$^{b}$ | 32.56±0.38$^{c}$ | 7.62±0.23$^{a}$ | 35.46±1.63$^{a}$ |
| Dried at 90°C | 22.06±1.60$^{a}$ | 2.75±0.62$^{b}$ | 33.52±0.12$^{cd}$ | 7.32±1.45$^{a}$ | 34.35±0.66$^{a}$ |

All data are the mean ± SD of duplicate readings. Mean ± SD followed by same letters in the same column are not significantly different ($p \leq 0.05$).

**Table 3.3. Vitamin C content of cabbage outer leaves subjected to various processing conditions**

| Drying Condition | Vitamin C (mg/100g dry matter) | |
|---|---|---|
| | Unblanched | Blanched |
| Raw | 399.20±1.42$^{a}$ | 156.25±1.43$^{a}$ |
| Dried at 80°C | 81.15±0.71$^{b}$ | 69.46±1.56$^{b}$ |
| Dried at 90°C | 75.80±1.14$^{c}$ | 62.00±0.71$^{c}$ |

All data are the mean ± SD of duplicate readings. Mean ± SD followed by same letters in the same column are not significantly different ($p \leq 0.05$).

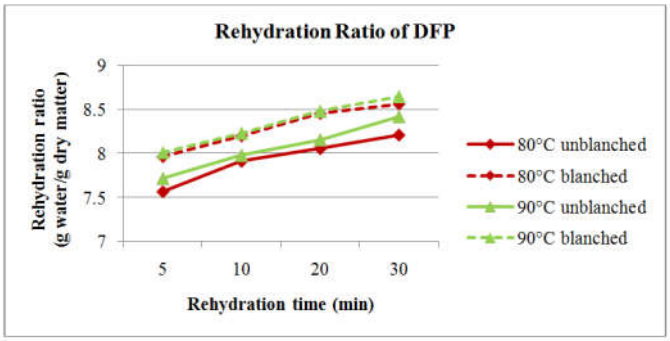
**Table 3.4. Total Phenolic Content of cabbage outer leaves subjected to various processing conditions**

| Drying Condition | TP Content (mg GAE/100g dry matter) | |
|---|---|---|
| | Unblanched | Blanched |
| Raw | 94.50±3.54$^{a}$ | 91.00±2.83$^{a}$ |
| Dried at 80°C | 50.50±0.71$^{b}$ | 72.00±0.00$^{b}$ |
| Dried at 90°C | 48.00±0.00$^{b}$ | 67.00±2.83$^{b}$ |

All data are the mean ± SD of duplicate readings. Mean ± SD followed by same letters in the same column are not significantly different ($p \leq 0.05$).

**Table 3.5. Total antioxidant activity of cabbage outer leaves subjected to various processing conditions**

| Drying Condition | TAA (%) | |
|---|---|---|
| | Unblanched | Blanched |
| Raw | 104.67±1.89$^{b}$ | 98.50±1.65$^{a}$ |
| Dried at 80°C | 85.73±2.24$^{a}$ | 97.83±0.24$^{a}$ |
| Dried at 90°C | 83.97±2.12$^{a}$ | 97.16±0.71$^{a}$ |




**Graph 3.2. Rehydration ratio of dietary fibre powder**

## Conclusion

In this study, dietary fiber powder was produced from white cabbage outer leaves (*Brassica oleracea* var. capitata golden acre). From the study it can be seen that blanching has resulted in a good appearance of the final product due to inhibition of peroxidase, the enzyme responsible for enzymatic browning reactions. Also, blanched leaves dried at 80°C retained the highest TP content, vitamin C, and TAA, although it has less amount of carbohydrate content and less rehydration ratio as compared to the sample prepared by drying the leaves at 90°C. Thus, white cabbage outer leaves which are generally discarded as waste can be utilized as a cheap source for production of dietary fiber although before using in any food product its functional properties in different food matrices needs to be studied in detail.

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