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Blanching as a treatment process: Effect on polyphenols and antioxidant capacity of cabbage

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Abstract.

Cabbage is considered an excellent source of polyphenols with substantial antioxidant properties associated with the alleviation of oxidative stress and the prevention of free-radical mediated diseases. Many cabbage varieties are typically blanched prior to consumption mainly to enhance associated sensory attributes. Conventional hot water (80-100°C) or steam blanching are the most industrially applied methods. Blanching causes adverse losses in the antioxidant capacity of cabbage with over 70% resulting within the first few minutes. Blanching time, water to cabbage ratio and cabbage variety are the main determinants of the extent of antioxidant losses. The effect of the blanching temperature is of a less significance particularly within 80-100°C. High temperatures and short blanching times would reduce antioxidants degradation in cabbage while also resulting in optimized sensory and quality attributes. The chapter concludes on the importance of antioxidant considerations when specifying time-temperature combinations for cabbage blanching.

Key words.

Antioxidant; Blanching; Cabbage; Leaching; Polyphenols; Time-temperature combinations.

Introduction.

The family Brassicaceae or Cruciferae is a large group with 3500 species and lies within 350 genera including *Arabidopsis, Brassica, Camelina, Crambe, Descurainia, Glaucocarpum, Sinapis* and *Thlaspi*. The genus Brassica is the most important within the Brassicaceae family which includes some crops and species of valuable economic importance in the human diet worldwide such as *Brassica oleracea* L., *Brassica napus* L. and *Brassica rapa* L. *B. oleracea* includes several types of edible crops such as cauliflower, broccoli, kohlrabi, kale, cabbage and Brussels sprouts. Among these, cabbage is one of the oldest vegetables and has been used in culinary applications in Europe for over than 4,000 years.

Cabbage is grown in most major temperate vegetable growing areas and is available year-round. It can be classified as green (York Cabbage, Round Cabbage, Savoy Cabbage), white (Coleslaw cabbage) and red or purple, although colour could range from nearly white to reddish-purple. The cabbage shape is broadly divided into two categories as round or conical. York cabbage has mainly conical heads and the edible head is a terminal bud composed of many tightly packed overlapping leaves. White cabbage is light to dark green in colour and has thick leaves with round, tightly-wrapped heads and with a smooth plain leaved 'ball head'.

Epidemiological and clinical investigations thus far have demonstrated that a high consumption of fruits and vegetables, including cabbage, is positively associated with the prevention of cardiovascular diseases, cancer, aging, diabetes, osteoporosis, hypertension, and stroke (Maritess *et al*., 2005). Recent research is indicating that the health protective effects associated with Brassica vegetables such as in cabbage could be attributed to the presence of several types of antioxidants.

Antioxidants in cabbage.

Cabbage is rich in several nutritive and non-nutritive bioactive compounds, which are well recognized for their antioxidant properties and potential health benefits (Jaiswal *et al*., 2012 a, b). These include polyphenols such as flavonoids, hydroxycinnamic acid derivatives, hydroxybenzoic acid derivatives, carotenoids and vitamins such as ascorbic acid and α-tocopherol (Jaiswal *et al*., 2011; Podsedek *et al*., 2006). The antioxidant properties of polyphenols are suggested to play a positive role in the alleviation of oxidative stress and the prevention of free-radical mediated diseases (Halvorsen *et al*., 2002). In addition, polyphenols have been associated with a wide range of health promoting properties, including anti-obesity, anti-diabetic, anti-hypertensive, anti-mutagenic and anticancer (Pandey and Rizvi, 2009; Varoni *et al*., 2012). It is well established that the content of antioxidants in cabbage varies with cultivar type, climatic conditions, maturity at harvest and storage conditions (Kusznierewicz *et al*., 2008; Šamec *et al*., 2011; Singh *et al*., 2007).

Cabbage as a source of polyphenols.

Polyphenols are a large group of secondary metabolites that are widespread in the plant kingdom, including cabbage, and are well known for their free radicals scavenging capacity, metal chelating capacity and lipid peroxidation properties (Jaiswal *et al*., 2011; Jaiswal *et al*., 2012 a, b). Polyphenols from different cabbage varieties have been characterized in a number of studies. Nielsen *et al.* (1998) reported that white cabbage leaves contain more than 20 types of phenolic compounds, including glucosides of kaempferol and quercetin with/without further acylation with hydrocinnamic acid. York cabbage (*Brassica oleracea* var. *capitata* alba subvar. *conica*) and white cabbage (*Brassica oleracea* var. *capitata*) have significant amounts of phenolic acids such as hydroxycinnamic acid derivatives and hydroxybenzoic acid derivatives; however, the

concentration of these compounds are cultivar dependent (Jaiswal *et al*., 2011). Seventeen phenolic compounds were identified in Tronchuda cabbage (*Brassica oleracea* L. var. *costata* DC) mainly belonging to derivatives of quercetin and kaempferol while anthocyanins derivatives were associated with coloured varieties of cabbage such as red cabbage (Ferreres *et al.*, 2006; McDougall *et al*., 2007; Scalzo *et al*., 2008).

Antioxidant properties of cabbage.

Free radicals play an important role in causation and generation of several diseases such as cardiovascular diseases, inflammatory diseases, neurodegenerative disorders, cancer and aging because they are highly reactive to biomolecules and thus causing damage to DNA, proteins, carbohydrates and lipids (Gutteridge and Halliwell, 1993) . Diets rich in foods containing antioxidants such as cabbage can exert health benefits by inhibiting these free radicals. Antioxidants are defined as ‘‘any substance that, when present at low concentrations compared with that of an oxidizable substrate, significantly delays or inhibits oxidation of that substrate’’ (Halliwell *et al*., 1995). Several methods have been recommended for antioxidant capacity estimation such as 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity, hydroxyl ($OH^{\bullet}$) radical scavenging activity, hydrogen peroxide (H_2O_2) radical scavenging activity, ferric reducing antioxidant power (FRAP), oxygen radical absorbance capacity (ORAC), 2,2-azinobis-3-ethylbenzothiazoline-6-sulfonic acid (ABTS) radical scavenging activity, superoxide anion radical (O_2^{-}), peroxyl radical ($ROO^{\bullet}$) scavenging capacity and lipid peroxides inhibitory ability. Variations within these methods are attributed to the reaction mechanisms and type of free radicals being targeted.

Numerous studies reported on the antioxidant potential of cabbage (Amin and Lee, 2005; Jacob *et al*., 2011; Jaiswal *et al*., 2011; Jaiswal *et al*., 2012 a, b; Kusznierewicz *et al*.,

2008; Šamec *et al*., 2011). Red cabbage exhibited 2.2 to 5 fold higher antioxidant capacity than Savoy and white cabbage (Podsedek *et al*., 2006). Jacob *et al.* (2011) reported that red cabbage contains a higher antioxidant capacity as compared to its green counterpart in different antioxidant systems; similarly green cabbage showed a higher antioxidant capacity than white cabbage (Jaiswal *et al*., 2011). In general, red cabbage have the highest antioxidant activity, followed by green cabbage, mustard cabbage, Chinese cabbage and Chinese white cabbage (Amin and Lee, 2005) which could be attributed to the presence of different antioxidant components such as phenolic compounds and also being influenced by the genotype, environment and growth conditions (Singh *et al*., 2007).

Typically, most of cabbage varieties would undergo some form of heat treatment for a certain time period prior to consumption mainly to attain an acceptable sensory texture. Antioxidants are widely known for their heat labile properties suggesting potential losses in their bioactivity and associated health promotion properties upon the application of heat treatments. It is relevant then to evaluate the effects of heat processing conditions on the antioxidant content and capacity of cabbage and to propose suggestions to minimize heating effects. Such findings would be off importance not only for the food industry, but also from a public health perspective as health professionals strive to enhance the population health using practical and feasible approaches.

Blanching

Blanching is a short heat treatment that is typically applied to vegetables prior to further processing with the aim of enhancing both safety and quality attributes. It imparts benefits such as the destruction of surface microflora on vegetables and the enhancement of the colour, texture and also the keeping quality of vegetable products (Jaiswal *et al*.,

2012 c). In addition, blanching is essential for vegetable products destined for further storage such as freezing or drying in order to inactivate certain enzymes including lipoxygenase, polyphenololoxidase, polygalacturonase and chlorophyllase which are associated with losses in quality and nutritional properties. Apart from blanching, other processing methodologies of vegetables, including drying and freezing, are insufficient to inactivate these enzymes thus leading to deteriorations in texture, colour and flavour during storage.

The quality of blanched products depends significantly on the time-temperature combinations of blanching and also on the vegetable type. Under-blanching speeds up the activity of enzymes and is worse than no blanching (Jaiswal *et al*., 2012 c). Over-blanching causes losses in texture, colour, phytochemicals and minerals. Typically, industrial blanching processes utilize temperatures ranging from 70 to 95°C and times are usually within 10 min (Morales-Blancas *et al*., 2006); whereas for domestic purposes vegetables are generally blanched, or given an extended blanching period which ultimately leads to cooking, for 10-15 min in water at temperatures ranging from 95-100°C.

Generally, blanching is carried out by the application of a wet medium such as steam or hot water in order to provide uniform heating and a high-heat transfer rate. Both in domestic and industrial processing, several blanching methods may be employed such as conventional water blanching, microwave or steam blanching; the regime being dictated by the nature of the raw material and the desired properties of the final product. Traditionally, blanching is carried out either at a low temperature (55-75°C) for long-time, typically referred to as LTLT or high-temperature short-time (80-100°C) for less than 10 min, referred to as HTST depending upon the type of vegetable (Abu-Ghannam

and Crowley, 2006). Conventional water blanching usually imparts more uniform processing. However, prolonged water blanching results in considerable losses in phytochemicals and antioxidant properties (Jaiswal *et al*., 2012 c).

Microwave heating is 3-5 times faster than conventional heating and relies on the application of dielectric heating. This is accomplished by using microwave radiation to heat water and other polarized molecules within the food, leading to heat generation in the entire volume at the same rate due to internal thermal dissipation of water molecules vibrations in the food (Kamel and Stauffer, 1993). It has advantages over the conventional heating methods such as precision timing, speed, and energy saving.

Steam blanching is generally carried out in a steam blancher where the vegetable product is exposed directly to a food-grade steam typically at a temperature close to 100ºC. Steam blanching results in minimum losses in phytochemicals and antioxidant capacity (Faller and Fialho, 2009; Podsędek *et al*., 2008; Turkmen *et al*., 2005; Wachtel-Galor *et al*., 2008), furthermore, it requires less time than conventional blanching because the heat transfer coefficient of condensing steam is greater than that of hot water and proved to be comparatively economical as it saves energy (De Corcuera *et al*., 2004).

Effects of blanching on the antioxidant content of cabbage

A number of studies have investigated the effect of blanching on the polyphenolic content of cabbage (**Table 1**). Different effects have been reported depending upon differences in process conditions and systems applied in the blanching process. A detailed study was carried out by Jaiswal *et al*. (2012 c) to evaluate the effect of conventional water blanching on the polyphenols of York cabbage. A range of blanching temperatures (80, 85, 90, 95 and 100°C) for 0 to 14 min with 2 min interval was studied with the aim of including both low and high blanching temperatures (**Fig. 1a, b**).

Table 1. Summary of literature findings on the effects of blanching on losses of cabbage polyphenols content.

Cabbage type	Mode of blanching	Conditions	Reported outcomes	Reference
York cabbage	Conventional blanching	14 min (80-100°C)	75 to 80% reduction in total phenolic content	(Jaiswal *et al*., 2012 c)
Red cabbage	Conventional blanching	1 min (94-96°C)	43% reduction in total phenolic content	(Volden *et al*., 2008)
Red cabbage	Conventional blanching	15 min	37% reduction in total phenolic content	(Amin and Lee, 2005)
Chinese white cabbage	Conventional blanching	15 min	82% decrease in total phenolic content	(Amin and Lee, 2005)
Mustard cabbage	Conventional blanching	15 min	54% reduction in total phenolic content	(Amin and Lee, 2005)
Chinese Cabbage	Conventional blanching	15 min	23% reduction in total phenolic content	(Amin and Lee, 2005)
York cabbage	Conventional blanching	14 min (80-100°C)	74 to 78% reduction in total flavonoid content	(Jaiswal *et al*., 2012 c)
Red cabbage (Koda and Kissendrup)	Conventional blanching	20 min	57-71% reduction in Anthocyanins	(Podsędek *et al*., 2008)
Red cabbage (Koda and Kissendrup)	Conventional blanching	20 min	60-70 % reduction in hydroxybenzoic acids	(Podsędek *et al*., 2008)
Red cabbage (Koda and Kissendrup)	Conventional blanching	20 min	20-27 % reduction in hydroxycinnamic acids	(Podsędek *et al*., 2008)
Red cabbage	Conventional blanching	1 min (94-96°C)	59% reduction in total monomeric anthocyanin content	(Volden *et al*., 2008)
Red cabbage	Boiling	10 min	16% reduction in total phenolic content	(Volden *et al*., 2008)
Organic and conventional retail vegetables (white cabbage)	Boiling	5 min	0 to 14 % reduction in soluble polyphenols	(Faller and Fialho, 2009)
Organic and conventional retail vegetables (white cabbage)	Boiling	5 min	60 to 65% reduction in hydrolysable polyphenols	(Faller and Fialho, 2009)
Red cabbage	Boiling	10 min	49% reduction in total monomeric anthocyanin content	(Volden *et al*., 2008)
Red cabbage	Steaming	10 min	No reduction in total	(Volden *et*

			phenolic content	*al*., 2008)
Organic and conventional retail vegetables (white cabbage)	Steaming	10 min	50 to 64% reduction in soluble polyphenols	(Faller and Fialho, 2009)
Organic and conventional retail vegetables (white cabbage)	Steaming	10 min	0 to 63% reduction in hydrolysable polyphenols	(Faller and Fialho, 2009)
Red cabbage (Koda and Kissendrup)	Steaming	20 min	25-26 % reduction in Anthocyanins	(Podsędek *et al*., 2008)
Red cabbage (Koda and Kissendrup)	Steaming	20 min	35-40% reduction in hydroxybenzoic acids	(Podsędek *et al*., 2008)
Red cabbage (Koda and Kissendrup)	Steaming	20 min	10-13% increase in hydroxycinnamic acids	(Podsędek *et al*., 2008)
Red cabbage	Steaming	10 min	21% reduction in total monomeric anthocyanin content	(Volden *et al*., 2008)
Organic and conventional retail vegetables (white cabbage)	Microwave	3.5 min at 2450 W	39 to 41% reduction in soluble polyphenols	(Faller and Fialho, 2009)
Organic and conventional retail vegetables (white cabbage)	Microwave	3.5 min at 2450 W	44 to 45% reduction in hydrolysable polyphenols	(Faller and Fialho, 2009)

Reductions in the total phenolic content up to 45% were reported at the lower blanching temperatures (80-90°C) within 2 min of blanching and reached up to 50% at high blanching temperatures (95-100°C) for the same blanching period of 2 min. Degradation in total phenolic content continued up to 76% within 6 min at high blanching temperatures; however, no significant reductions in total phenolic content were reported after this for up to 14 min, a stage at which the cabbage was considered to be completely processed. (**Fig. 1a**). Jaiswal *et al*. (2012 c) also reported similar observations for the effects of blanching time on the degradation of total flavonoid content of York cabbage

(**Fig. 1b**). These findings highlight the deleterious effects of blanching in compromising the significance of cabbage in being one of the richest vegetable sources of antioxidants.

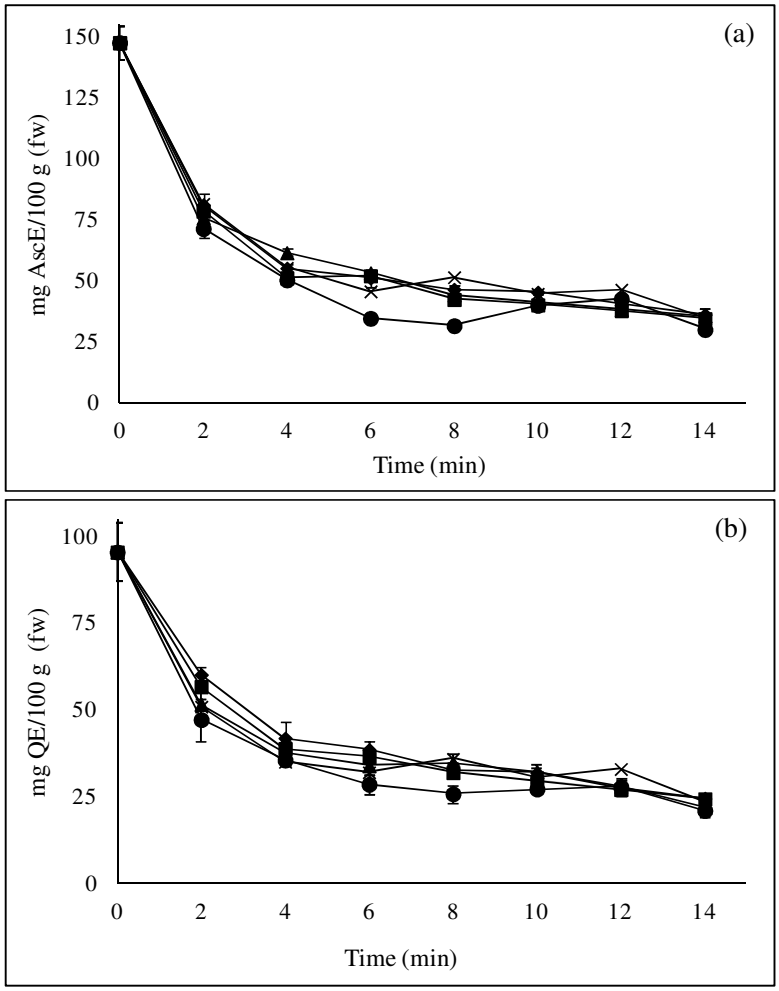

Figure 1. Effect of blanching temperature [80 (◆), 85(■), 90 (▲), 95 (✕) and 100°C (●)] and time combination on (a) total phenolic content and (b) total flavonoid content of York cabbage. Figures adapted from Jaiswal *et al*. (2012 c).

Amin and Lee (2005) applied conventional blanching methods for red, green, mustard, Chinese and Chinese white cabbage for 5, 10 and 15 min. A significant reduction in the total phenolic content was observed irrespective of cabbage type. Mustard cabbage showed a steady trend in phenolic contents loss and with up to 25, 51 and 54% reported to be lost after blanching for 5, 10 and 15 min, respectively. Similarly, Chinese white

cabbage was blanched for 5, 10 and 15 min and correspondingly 58, 63 and 82% reductions in total phenolic content were reported (Amin and Lee, 2005). The previous studies indicate that blanching has a detrimental effect on the phenolic content of cabbage with losses in general exceeding 50% of the initial content in raw cabbage. Losses in polyphenol content are attributed to the disruption of the plant tissue due to the heating effect, leading into polyphenols leaching out into the blanching water environment (Gonçalves *et al*., 2010). Furthermore, the reciprocal interconversion of insoluble phenolics into more soluble forms can also occur, which may lead to additional losses in polyphenols.

Podsędek *et al.* (2008) examined the effects of water to cabbage ratio and blanching time on the polyphenol content of Kissendrup and Koda red cabbage varieties upon the application of conventional water blanching. Reductions up to 50% in water volume led to better retention of phenolics as compared to when blanching was carried out using 2:1 ratio of water to cabbage. On the other hand, shortening the conventional blanching time from 20 to 10 min increased the retention of phenolics by only 3.8-6.7%. This suggests that polyphenols losses upon blanching could be attributed to their respective solubility and stability, which would be highly influenced by the type of the blanching environment (steam or hot water) and also its corresponding volume to facilitate the leaching and transfer of phenolic compounds from the cell interior to the blanching environment. Also it is worth noting that free polyphenols leach out faster in the water as compared to bound polyphenols. As blanching temperatures increase, a higher loss in phenolic compounds is expected, however, the effect of blanching time does not necessarily follow a similar trend. It seems that for a given blanching treatment, losses in phenolic compounds initially increase as blanching time proceed, but up to a certain point, after which a state of plateau is attained and longer blanching times do not correspond to higher losses in

phenolic compounds. This highlights the role of heat in degrading cabbage cellular material leading to the leaching of polyphenols. A higher level of phenolic losses would require the application of a higher temperature rather than a longer blanching time for a given blanching treatment, thus emphasizing the role of heat in causing phenolic mass transfer. On the other hand, blanching times profiling with respect to polyphenol losses would be of significant importance to identify those times that correspond to minimum polyphenols losses while also attaining appropriate quality attributes such as colour and texture. At a domestic or industrial level, the first 6 to 8 minutes of blanching are detrimental with respect to a number of quality parameters including phenolic content, and there is a need for more detailed studies at both processing and consumer levels to examine if the polyphenols, with their established health benefits, are being largely compromised by perceived consumer quality attributes for attaining certain textures and colours of vegetables upon blanching.

Effects of blanching on the antioxidant capacity of cabbage

A summary of the effects of blanching on the antioxidant capacity of a range of cabbage varieties is illustrated in **Table 2**. There were variations in the applied antioxidant methodologies in those reported studies suggesting that specific inferences regarding the antioxidant capacity, for a given blanching treatment and a cabbage variety, might require more in depth considerations. In general, conventional blanching of cabbage can result in high reductions in antioxidant properties.

Jaiswal *et al*. (2012) studied the effects of a range of blanching times and temperatures on the antioxidant capacity of York cabbage by reporting on the H_2O_2 radical scavenging capacity (**Fig. 2a**), lipid peroxidation ability (**Fig. 2b**), ferric reducing antioxidant

potential and DPPH free radical scavenging capacity, which collectively are methods employed to characterise properties of antioxidants.

Table 2. Summary of literature findings on the effect of blanching on the antioxidant properties of cabbage.

Cabbage type	Mode of blanching	Conditions	Consequence	Reference
York cabbage	Conventional blanching	14 min (80-100°C)	80 to 82% reduction in DPPH scavenging capacity	(Jaiswal *et al*., 2012 c)
Red cabbage	Conventional blanching	15 min	40% reduction in DPPH scavenging capacity	(Amin and Lee, 2005)
Chinese cabbage	Conventional blanching	15 min	38% reduction in DPPH scavenging capacity	(Amin and Lee, 2005)
Mustard cabbage	Conventional blanching	15 min	23% reduction in DPPH scavenging capacity	(Amin and Lee, 2005)
Chinese white Cabbage	Conventional blanching	15 min	11% reduction in DPPH scavenging capacity	(Amin and Lee, 2005)
York cabbage	Conventional blanching	14 min (80-100°C)	73 to 75% reduction in H_2O_2 scavenging capacity	(Jaiswal *et al*., 2012 c)
York cabbage	Conventional blanching	14 min (80-100°C)	72 to 78% reduction in lipid peroxidation (LPO) in a haemoglobin-induced linoleic acid system	(Jaiswal *et al*., 2012 c)
Red cabbage	Conventional blanching	1 min (94-96°C)	42% reduction in ferric reducing antioxidant potential	(Volden *et al*., 2008)
York cabbage	Conventional blanching	14 min (80-100°C)	67 to 75% reduction in ferric reducing antioxidant potential	(Jaiswal *et al*., 2012 c)
Red cabbage	Conventional blanching	1 min (94-96°C)	51% reduction in oxygen radical antioxidant capacity	(Volden *et al*., 2008)
Red cabbage (Koda and Kissendrup)	Conventional blanching	20 min	38 to 42% reduction in ABTS radical scavenging activity	(Podsędek *et al*., 2008)
Red cabbage	Conventional blanching	15 min	4% reduction in β-carotene bleaching	(Amin and Lee, 2005)

			activity	
Chinese cabbage	Conventional blanching	15 min	40% reduction in β-carotene bleaching activity	(Amin and Lee, 2005)
Mustard cabbage	Conventional blanching	15 min	9% reduction in β-carotene bleaching activity	(Amin and Lee, 2005)
Chinese white Cabbage	Conventional blanching	15 min	19% reduction in β-carotene bleaching activity	(Amin and Lee, 2005)
Organic and conventional retail vegetables (white cabbage)	Boiling	5 min	34 to 69% reduction in DPPH scavenging capacity	(Faller and Fialho, 2009)
Red cabbage	Boiling	10 min	17% reduction in ferric reducing antioxidant potential	(Volden *et al*., 2008)
Red cabbage	Boiling	10 min	19% reduction in oxygen radical antioxidant capacity	(Volden *et al*., 2008)
Organic and conventional retail vegetables (white cabbage)	Steaming	10 min	45 to 81% reduction in DPPH scavenging capacity	(Faller and Fialho, 2009)
Red cabbage	Steaming	10 min	2% reduction in ferric reducing antioxidant potential	(Volden *et al*., 2008)
Red cabbage	Steaming	10 min	13% reduction in oxygen radical antioxidant capacity	(Volden *et al*., 2008)
Red cabbage (Koda and Kissendrup)	Steaming	20 min	12 to 20% reduction in ABTS radical scavenging activity	(Podsędek *et al*., 2008)
Organic and conventional retail vegetables (white cabbage)	Microwave	3.5 min at 2450 W	8 to 47% reduction in DPPH scavenging capacity	(Faller and Fialho, 2009)

The study highlighted that maximum losses up to 70% in antioxidant capacity were observed in the initial period of blanching (mainly within 6 min) with the blanching temperature playing a minor effect. For example, lower blanching temperatures in the range of 80-90°C resulted in up to 60% losses in H_2O_2 scavenging capacity within 6 min

as compared to 68% for the same period when blanching was carried out at the higher temperatures of 95 to 100°C. Only minimal losses were reported when blanching time was extended beyond the first 6 min as seen in **Fig. 2a**.

A similar pattern was also observed with respect to reductions in the lipid peroxidation inhibitory ability of blanched York cabbage with losses ranging between 60-67%, being slightly high for the higher blanching temperatures but without a significant difference. The same trend was also observed for the other measured antioxidant systems such as DPPH free radical scavenging capacity and ferric reducing antioxidant potential.

The extent of antioxidant losses during cabbage blanching can also be attributed to the cabbage variety. Cabbage varieties have different leaf morphology with respect to colour, texture and thickness. It is expected then, that there will be variations in the effects of blanching on cellular disruptions and the consequences of polyphenol losses and reductions in antioxidant capacity. Amin *et al*. (2005) studied the effects of blanching at 98°C for red cabbage, Chinese cabbage, mustard cabbage and Chinese white cabbage. Losses in β-carotene bleaching activity were reported to be the highest in Chinese cabbage (40%) within 15 min of blanching, followed by Chinese white cabbage (19%), mustard cabbage (9%) and red cabbage (4%). However, in the case of DPPH scavenging capacity, red cabbage showed maximum activity losses at 40% followed by Chinese cabbage (38%), and mustard cabbage at 23%.

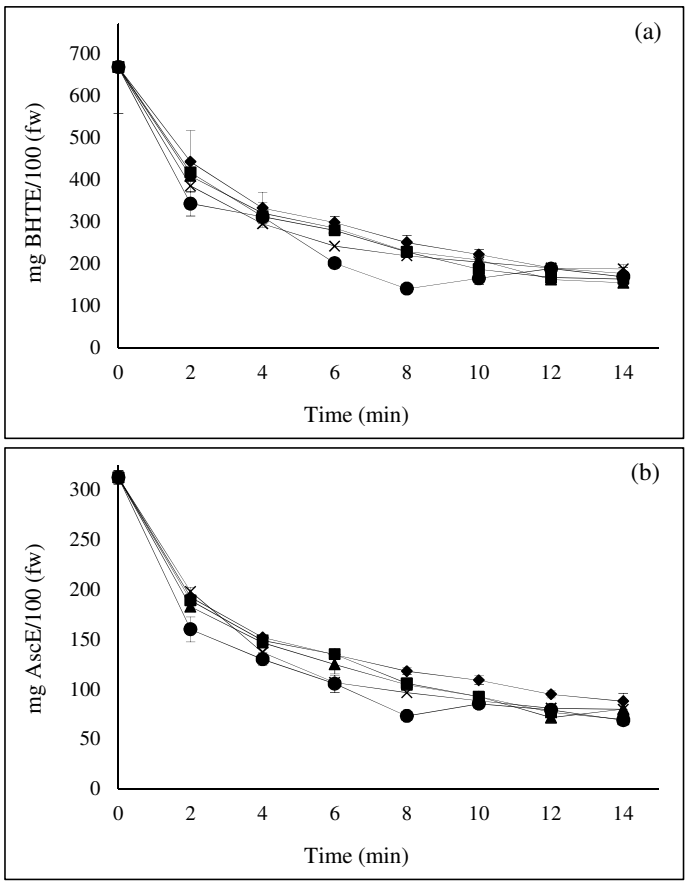

Figure 2. Effect of blanching temperature [80 (-◆-), 85(-■-), 90 (-▲-), 95 (-✕-) and 100°C (-●-)] and time combination on antioxidant capacity (expressed as relative standard equivalent) on (a) H_2O_2 radical scavenging capacity (b) Lipid peroxidation inhibitory ability of York cabbage. Figures adapted from Jaiswal *et al*. (2012 c).

Overall, there is an obvious correlation between antioxidant content and antioxidant capacity or activity of blanched cabbage regardless of the variety. The general trend observed is that losses are more pronounced within the initial phase of blanching, and the factors influencing such losses are blanching methodology, cabbage variety and blanching time. The blanching temperature effect is not of significant influence particularly if the temperature applied is within the range of 80-100°C. From a food safety perspective and quality retention requirements, higher blanching temperatures

would be recommended in order to eliminate surface microflora, and to inactivate enzymes associated with quality deteriorations during further storage such as freezing.

Steam blanching produces smaller volumes of waste and lower disposal charges than water blanchers, however, uneven blanching can occur if the vegetable product is piled too high in addition to possibilities of limited cleaning of vegetable surfaces which is essential for the elimination of surface microflora. Conventional blanching using hot water operates at lower capital costs and better energy efficiency as compared to steam blanching. On the other hand, the costs of large volumes of potable water and charges for large volumes of dilute effluent treatment are drawbacks to this processing method.

As cabbage, with its wide available varieties, is considered as a rich source of antioxidants, it is then important to provide accurate quantifications of antioxidant capacity losses during blanching. However, it should be noted that the methodologies and procedures employed to estimate antioxidant capacities vary considerably in the reported literature and there is a need for standardization in order for comparisons to be meaningful and useful for both the consumer and the food industry.

The rationale for the industrial treatments adopted for vegetable blanching has been mainly based on achieving a high quality product with acceptable sensory attributes from consumer perspective. The findings presented in this chapter regarding cabbage blanching, highlight the importance of including the nutritional aspect, specifically antioxidants content and activity, when specifying blanching methodologies and time-temperature combinations employed. This is particularly important as the majority of cabbage varieties require only blanching as a processing step prior to consumption. Due to the substantial losses in antioxidant capacity that occur as very early stages of

blanching, it is strongly suggested that a review of the sensory attributes resulting upon blanching should be in parallel considerations with antioxidant losses.

Summary points.

- Cabbage is grown in temperate climate areas and is available throughout the year.
- Cabbage is an excellent source of several phytochemicals such as, phenolic acids, flavonoids and glucosinolates, with more than 20 phenolic acids being identified. Phytochemicals are characterized as being rich sources of antioxidants.
- The photochemical composition in cabbage varies with cultivar type, climatic conditions, maturity at harvest and storage conditions.
- Blanching is an essential step in cabbage processing in order to ensure both safety and quality requirements for either immediate consumption or further storage. In addition blanching of cabbage renders this vegetable suitable for human consumption with respect to colour, texture and flavour.
- Blanching methods rely on the usage of either conventional hot water or steam blanchers and utilize temperatures in the range of 80-100°C and for periods of time not exceeding 15 min. Time-temperature combinations and blanching methods employed are controlled to a great extent by the variety of cabbage. Conventional hot water blanching continued to be the most preferred industrial method due to low capital costs and blanching uniformity of the product.
- Cabbage blanching causes significant losses in its photochemical content leading to substantial reductions in its antioxidant potential. Losses could be reduced if using steam blanchers, however, losses in conventional blanching could be minimized by reducing the water to cabbage ratio.
- Blanching time is a major factor in determining antioxidant losses than temperatures, with up to 70% losses in the antioxidant capacity of cabbage taking place within the

initial phase of blanching (first 6 minutes) regardless of the applied blanching temperature.

- There is a need for standardization of antioxidant capacity methods in order to provide meaningful and useful comparisons for the effects of blanching on the content of polyphenols in cabbage and their respective antioxidant activities.
- While the attainment of specified safety and quality parameters in food processing are of paramount important, it is strongly suggested that specific nutritional components of significant relevance to a product (in this case cabbage being an excellent source of antioxidants) should also be included in the processing criteria parameters.

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