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Lagna Choudhury
Department of Food Science and Nutrition, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India

Corresponding Author:
Lagna Choudhury
Department of Food Science and Nutrition, School of Agriculture, Lovely Professional University, Phagwara, Punjab, India

Processing and its effect on kale leaves: A review

Lagna Choudhury

Abstract
This review aims to discuss about the changes occur in kale (*Brassica oleracea*) after it gone through various types of processing techniques as this vegetable is a good source of nutrients. This review reveals the changes occurs in vitamin B, C, E, protein and amino acid content, antioxidant activity and pigments such as carotenoid and chlorophyll after treated with the type of pre-treatment (blanching or cooking), the method of preservation (freezing or canning) under various storage conditions. The review was written using references from a number of review and research articles written by authors and researchers in order to determine the best and cheapest methods of processing that will minimise nutrient loss while preserving sensory characteristics, as well as the impact of various processing and preservation methods on the mineral composition and sensory properties of *Brassica oleracea*.

Keywords: Kale, processing, nutrient, freezing, blanching

1. Introduction

Kale, scientifically known as *Brassica oleracea*, is a leafy vegetable from the cabbage family that is harvested throughout the fall and winter (Wu *et al*., 2022) [20]. Now a days kale is gaining popularity among health conscious because of its high nutrient and mineral content. Kale contains a variety of minerals as well as additional constitutional metabolites such as glucosinolates, flavonoids, and carotenoids (Hahn *et al*., 2016) [7]. Scientifically proven that kale is a rich source of vitamin C which also accelerate antioxidant activity of kale. Kale is also rich in vitamin B complex and E which possess various health benefits including beneficial for Beri Beri, good skin and hair health, brain development, growth of red blood cells etc. The bright and vibrant colour of kale leaves is due to the pigment found in kale; chlorophyll and carotenoid. The protein and amino acid content in kale plays an important role in body growth and cell repair.

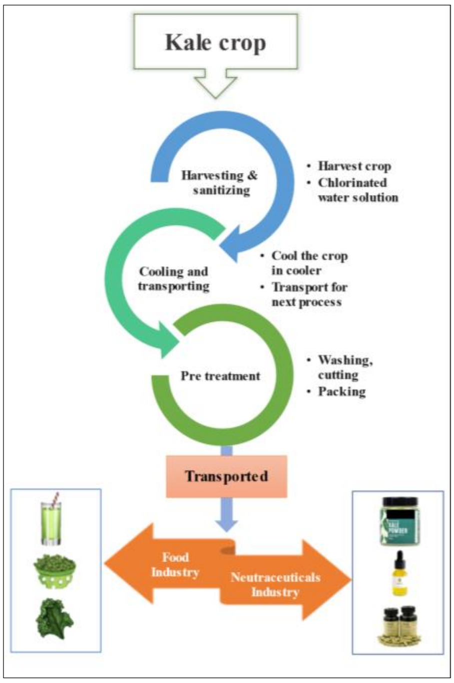

Fig 1: Diagram of kale processing and uses

Food processing can be defined as the techniques used to convert perishable fruits and vegetables into safe, delicious and stable eatable food products. The scope for food processing industries has grown in recent years in this fast-growing world. Processing of food especially green leaves includes cooking, blanching, canning, freezing etc or alternative methods such as pulsed electric fields (PEF) and high-pressure processing (HPP) which are quite advance technology used in food preservation. With increased use and importation of fresh leafy vegetables, as well as massive foodborne outbreaks due to consumption of contaminated leafy greens, microbiological safety has become a top focus for processors and consumers worldwide. Accepting new technology and learning about production techniques used throughout the world can significantly enhance the microbiological safety of leafy crops (Matthews, 2014) [13].

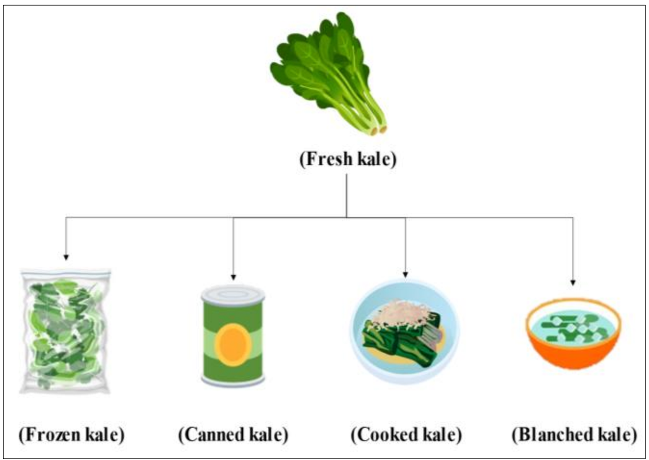

Fig 2: Figure showing various types of processing methods in kale: freezing, canning, cooking, blanching

Fruits and vegetables are vibrant, flavourful, and nutritious components of our meals, and they are frequently at their most appealing and health-promoting when picked at their optimum maturity (Rickman *et al*, 2007) [15]. Leafy vegetables are perishable foods that require particular preparation to avoid post-harvest losses. Leafy vegetables that are to be canned, frozen, or dehydrated are usually blanched to ensure high quality (Mepba *et al*., 2007) [14]. In terms of food processing, the popularity of greens is growing. In recent years, the popularity of juices and their combinations has risen steeply. Food and drinks with possible health benefits have been more popular in recent years, as has the need for freshness. As a result, emerging alternative preservation methods such as pulsed electric fields (PEF) and high-pressure processing (HPP) have gotten a lot of interest since they have demonstrated that they can yield goods with improved nutritional and functional quality. These methods have been studied and compared to untreated and thermally treated items on several occasions. When compared to typical thermal processing, they were commonly recognised for having the ability to prolong the shelf-life of fresh juices while also better keeping the fresh flavour and important constituents for possible health advantages. In comparison to minerals, the majority of vitamins found in plant raw materials are sensitive to light, oxygen, and, in particular, high temperatures.

2. Nutrients and effect of processing on them

2.1 Vitamin B complex and E content

Kale is known for its excellent vitamin source especially vitamin B1, B2 and E. Vitamins B1 and B2 are required for optimal bodily development and growth. They control the metabolism of neurotransmitters, which helps to prevent depression. Beri-beri is a vitamin deficiency disorder caused by an absence or considerable shortage of thiamine in the diet (Whitfield *et al*., 2018) [19]. Vitamin E naturally found in two forms such as tocopherol and tocotrienols. Vitamin E has been shown antioxidant activity and also proved to be useful in the treatment of a variety of diseases and disorders, including cancer, age-related problems, arthritis, and cataracts (Rizvi *et al*., 2014) [16].

2.1.1 Effect on vitamin B complex and E content

Vitamin B1 and B2 both are water soluble and heat sensitive that's the primary reason behind the reduction in the concentration of these two vitamins in cooked or blanched vegetables (Korus, 2020) [10]. According to Rickman *et al*. (2007) [15], blanching causes the loss of water-soluble B vitamins. Because of its water solubility, vitamin B1 is susceptible to leaching when cooked or processed. Because vitamin B2 is light-sensitive, its concentration is affected by processing and storage conditions. Furthermore, several B vitamins, particularly vitamin B1, are vulnerable to heat deterioration (Korus, 2020) [10]. Vitamin E is also get influenced by heat. When heat treatment is done to kale it was shown that there was a loss in the concentration of vitamin E which depends on the ratio of the vegetable weight to water quantity during heat treatment (Davey *et al*., 2000; Lešková *et al*., 2006) [3, 11].

Korus, 2020 [10] conducted a study on the various changes in the concentration of B-group and vitamin E in kale leaves which showed there was a degradation in vitamin content when its cooked. There was a drastic degradation in the concentration of vitamin B1, B2 and E, 42%, 67%, 12-58% respectively and blanching reduced the concentration by 26%, 50% and 2-57% respectively.

Freezing is said to be the finest technique of food preservation since it allows for fast preservation of the product with minimal nutritional loss. Frozen items made from blanched raw materials were shown to contain considerably more vitamins. During the storage of freezed kale for 12 months, there was a reduction in vitamin B1, B2 and E recorded 9%, 11% and 9% respectively.

Table 1: Changes in the concentration of vitamin B1, B2 and E in raw, blanched and cooked kale (Korus, 2020) [10]

Vitamin	Concentration in kale (mg/100gm)		
	Raw	Blanched	Cooked
B1	0.136	0.101	0.079
B2	0.255	0.128	0.083
E	2.700	2.404	2.172

Table 2: Changes in the concentration of vitamin B1, B2 and E in frozen kale (Korus, 2020) [10]

Type of processing	Storage temperature (̊C)	Concentration (mg/100gm)		
		Vitamin B1	Vitamin B2	Vitamin E
After 0 month storage				
Frozen blanched leaves	-20	0.097	0.124	2.355
	-30	0.101	0.127	2.368
Frozen cooked leaves	-20	0.075	0.081	2.103
	-30	0.075	0.082	2.151
After 12 months storage				
Frozen blanched leaves	-20	0.089	0.114	2.102
	-30	0.096	0.119	2.299
Frozen cooked leaves	-20	0.060	0.069	1.858
	-30	0.070	0.075	1.953

2.2 Carotenoid and chlorophyll content

Carotenoids are the plant pigments which gives the bright colour to all fruits and vegetables. It's colour and biological activities are inextricably linked to their structures. The carotene content of kale is high. β-carotene and lutein are the two primary carotenoid compounds present in kale. In the year 2005, De Azevedo and Rodriguez-Amaya conducted a study on kale, it shown that in comparison to young leaves, mature kale leaves have more β-carotene and lutein. Two more important carotenoid found in kale are violaxanthin and neoxanthin. The young leaves exhibited an extremely high content of violaxanthin but in both young and mature leaves, the concentration of neoxanthin was nearly same (De Azevedo and Rodriguez-Amaya, 2005) [4].

2.2.1 Effect on carotenoid and chlorophyll content

The carotenoid concentration of kale varies depending on the growing season as kale grown in the summer has a substantially greater carotenoid content than kale grown in the winter. According to the study done by De Azevedo and Rodriguez-Amaya, As the production of carotenoids improves with exposure to sunshine and high temperatures, the carotenoid concentration rises (De Azevedo and Rodriguez-Amaya, 2005) [4].

The procedures used to turn fresh produce into edible food items are known as food processing which may includes cooking, blanching, freezing, drying etc. Cooking is a coommon processing method used worldwide to consume kale but it was shown that the amount of total carotenoids and β-carotene in kale leaves was unaffected by cooking (Korus, 2013) [9]. Due to a relatively high amount of chlorophyll pigments, frozen leaves of both blanched and cooked kale had a bright green color. In the food processing industry, freezing is also a prevalent procedure and quitre popular in the vegetable industry.

Thermal storage of kale leaves, particularly in an aqueous setting, resulted in significant chlorophyll pigment losses. Carotenoid pigments, on the other hand, were found to be more stable. De Azevedo *et al.* found that over 5 days of storage at 7-9 °C, carotene, Leutine, violaxanthin, and neoxanthin were decreased by 14, 27, 20, and 31%, respectively, in minimally processed kale (De Azevedo and Rodriguez-Amaya, 2005) [4].

Table 3: Changes in the concetration of carotenoids after mininal processing, (De Azevedo and Rodriguez-Amaya, 2005) [4]

Time after processing (days)	Concentration of carotenoid (µg g−1)			
	β-carotene	Lutein	Violaxanthin	Neoxanthin
0	28.7	44.8	20.5	13.2
1	24.8	37.1	16.7	9.5
2	22.8	35.1	16.1	8.9
3	24.0	33.4	16.1	9.2
5	24.7	32.9	16.1	8.8

Table 4: Changes in the concentration of chlorophyll and carotenoid in frozen kale leaves (Korus, 2013) [11]

Type of processing	Storage temperature (̊C)	Concentration (mg/ 100gm)	
		Chlorophyll	Carotenoid
After 0 month storage			
Frozen blanched leaves	-20	117 ± 5	28.0 ± 0.9
	-30	117 ± 4	28.0 ± 1.1
Frozen cooked leaves	-20	97 ± 4	28.6 ± 1.6
	-30	97 ± 3	28.7 ± 1.2
After 12 months storage			
Frozen blanched leaves	-20	106 ± 4	24.8 ± 1.0
	-30	112 ± 4	26.7 ± 1.4
Frozen cooked leaves	-20	88 ± 5	25.8 ± 1.4
	-30	93 ± 4	27.7 ± 1.2

2.3 Amino acid content

The fresh kale contains a decent amount of amino acid. In fresh kale leaves with midribs removed, the dominant amino acids were glutamic acid, proline and aspartic acid; their proportion of the total amino acid content was 12%, 12% and 10%, respectively. The ratio of leucine to other amino acids, in the range of lysine, valine, arginine, and alanine 6–8%; tyrosine, phenylalanine, threonine, histidine, and other amino acids. The percentages of serine and glycine were 3–5%. Sulphur-containing amino acids, such cystine, have the lowest proportions 1.6% and methionine (2%) (Lisiewska *et al.* 2008) [12] However, it was found that glutamic acid covers a high proportion of the total amino acid content in kale.

2.3.1 Effect on amino acid content
In 2008, Lisiewska *et al.* conducted a study on the composition of amino acid in kale before and after various types of processing methods. Kale leaves were an excellent supply of amino acids in both fresh and processed forms. Glutamic acid, proline, and aspartic acid were the most abundant amino acids in all of the samples, with lysine and leucine being the least abundant. Cooked leaves had 78% of the total amino acid content of fresh leaves, although conventional and modified frozen leaves were equally productive.

As compared to fresh kale leaves, cooked kale leaves contain less amount of amino acids per 100 gm of fresh kale leave samples. The cooked traditional frozen product had similar levels of amino acids as cooked fresh kale, with the exception of an increase in methionine and a reduction in proline. In comparison with the protein in the raw material, that in cooked fresh leaves contained significantly less isoleucine, valine and proline and significantly more lysine, histidine, glutamic acid and arginine. (Lisiewska *et al.*, 2008) [12].

Table 5: Changes in the concentration of amino acid in raw, blanched, cooked and frozen kale (Lisiewska *et al.* 2008) [12]

Amino acid	Concentration (mg/100gm)			
	Raw leaves	Cooked leaves	Frozen blanched leaves	Frozen cooked leaves
Total amino acid	3621	2837	2761	3198
Total non-essential amino acid	2030	1617	1502	1723
Isoleucine	156	98	104	133
Leucine	299	236	239	282
Lysine	221	192	196	230
Cystine	58	41	45	54
Methionine	72	53	67	66
Tyrosine	122	95	91	110
Phenylalanine	186	139	143	168
Threonine	164	133	135	156
Valine	207	138	143	176
Histidine	106	95	96	100

2.4 Protein content and antioxidant activity
Vitamin C, polyphenols show activity equivalent to antioxidant activity and kale is considered as an excellent source of vitamin C and polyphenols. Protein–polyphenol interactions may be influenced by processing and altering product stability, digestion destiny, and shelf-life stability of proteins and polyphenols (Stübler *et al.* 2019). Antioxidants are responsible for the protective effect of vegetables (Zhou & Yu, 2006). When Cao, Sofic, and Prior conducted a study in 1996, it was concluded that kale have the second highest antioxidant activity as compared to other 22 vegetables (Cao, Sofic, and Prior, 1996).

2.4.1 Effect on protein content and antioxidant activity
A study was conducted by Korus in 2011 [8] on the effect of processing on the antioxidant level of kale which showed that there was a decline in the content of vitamin C and polyphenols when it undergone various types of processing (Korus, 2011) [8]. Thermal exposure results in the degradation of naturally occurring antioxidant properties (Anese, Manzocco, Nicoli, & Lerici, 1999; Eichner, 1981). When compared to the original content, blanching before drying resulted in statistically significant reductions in vitamin C and polyphenols levels of 15% and 32%, respectively.

Air-drying and freeze-drying of non-blanched kale leaves resulted in polyphenol content reductions of 60% and 49%, respectively. In the case of blanched leaves, the losses were lower: 49% and 28%, respectively. However, due to the significant loss of these compounds induced by blanching, both dry products derived from blanched raw materials contained fewer polyphenols than those obtained from non-blanched raw materials (Korus, 2011) [8]. After heat processing, there was a statistically significant drop in soluble protein, however after HPP and PEF, there was no statistically significant decrease (Stübler *et al*, 2019).

3. Conclusion
The results of the investigation showed that the there is a variation in nutrient content in kale while treated with various types of processing treatments. Processing, storage, and cooking have a wide range of consequences depending on the product. The thermal storage of kale leaves, particularly in an aqueous environment, resulted in significant chlorophyll pigment losses. Carotenoid pigments, on the other hand, proved to be more stable. Antioxidants decrease significantly during early processing, preservation methods, and long-term storage. Essential amino acids were 44% and 43% of total amino acids in fresh and cooked leaves, respectively, and 46% in each of the frozen products. Most macro- and microelements, as well as vitamins, were much greater in frozen goods than in canned products, especially those made from blanched raw material.

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