PHYTOCHEMISTRY OF KALE, BIOACTIVE COMPOUNDS, NUTRITIONAL AND ANTI-NUTRITIONAL FACTORS AND MEDICINAL PROPERTIES

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Contents

Summary

Kale is one of the oldest and highly nutritious but underrated green leafy vegetable that belongs to the *Brassicaceae* family. It is consumed both fresh as salad or cooked and also used as garnish material. Usually, kale is available in the market in canned and frozen forms. The cultivation and consumption of kale as food was so ancient that it was reported since 2000 BC from Mediterranean and Asian regions. Along with the traveler's footprint this crop spread to different locations of the world and now it is

famous in each continent including Africa, Europe, Asia and Latin America. Kale plant is an annual crop and its growth characteristics depend on the agricultural practices employed and as well as the geo-climatic conditions. Kale has wide range of variation including green kale, dwarf kale, marrow-stem kale, tronchuda kale, curly leaf kale, scotch kale, tree kale and bore kale.

Consumers believe that kale deserves its high nutritional status by virtue of its content of wide range of nutritional and bio-active components. Its nutritional status is so high that the calcium bio-availability from kale is even better than from milk. The nutrition composition of kale basically ensures the presence of prebiotic carbohydrates and higher amounts of potassium and calcium in it. Kale contains balanced amino acid compositions and also unsaturated fatty acids. It is also a good source of vitamin A and β-carotenes and flavonoids like, Quercetin and Kaempferol. In addition, kale has good amounts of phenolic compounds like hydroxycinnamic acids. With better mineral compositions, kale contains high concentration of oxalates which form a major anti-nutritional component. Kale also is composed of glucosinolates along with tannins, phytates and nitrogen compounds (Nitrates and Nitrites).

Kale consumption is positively correlated with better health for its combo action by providing needful nutrition and also having medicinal properties in it. These include good eye care, reduction of risk factor for malignancy, cardio protective properties, anti-inflammatory as well as anti-microbial potential and also maintaining gut health.

This chapter introduces the general issues of kale related to both its agricultural and food and nutritional aspects. It presents information on the nutritional, medicinal and anti-nutritional components of the kale. Later parts will place special emphasis on the medical applications of kale. Finally, the chapter concludes outlining some gaps and future prospects.

1. General Introduction

The role of plant based food in supporting and promoting human health has been understood since ancient times. Fruits and vegetables in particular are nutritionally rich foods containing high amounts of dietary fibers as well as different vitamins, minerals and phytochemicals (β-carotene and flavonoids). Green leafy vegetables play a special role in providing the daily nutritional requirements and are considered as safe, healthy if used in human diet in fresh (salad) and cooked forms. Leafy vegetables are ideal for weight management due to their low fat and energy content. Also, green leafy vegetables are rich source of dietary fiber, folate, ascorbic acid, vitamin K, Mg, K and phytochemicals such as β-carotene and flavonoids. The balanced nutritional profile of green leafy vegetables is beneficial in lowering the risk of cardiovascular diseases and certain types of cancers.

Some green leafy vegetables like spinach and lettuce are very common throughout the world and widely consumed. Some underutilized species are often considered as ‘minor crops’ because they are less important than staple crops and agricultural commodities in terms of global production and market value. However, local populations mainly depend on these crops for their food security and nutrition. Many underutilized crops

are nutritionally rich and do not need any cumbersome agricultural practices for their cultivation. With the passing of time and increasing scientific outlook of the common people towards food and diet, people are getting attracted to different underrated fruits and vegetables, which were regarded as minor so far. This is also encouraging the researchers to know about the inside story of nutrition and phyto-chemistry of some underutilized crops which may fill the nutritional gap.

Kale (*Brassica oleracea var. acephala*), basically a green leafy vegetable belonging to the *Brassicaceae* family, with a high content of different health-promoting phytochemicals is becoming popular among the researchers and common people for reasons of nutrition. Although kale was reported to be a food crop since about 2000 B.C. people were unaware of its great phytochemical properties that make it a strong competitor among the food crops that have combo actions- antioxidant and antimicrobial, and are sources of minerals and vitamin. Phytochemical study of kale basically includes the biosynthetic pathways, nature, functions and mechanisms of action of different phytochemicals that is helpful for the discovery of new health benefits for the consumer, new drugs and study about the evolution of phytochemical nature of the plant itself.

Kale is considered as a cruciferous vegetable as it belongs to the botanical family *Brassicaceae* and genus Brassica with a large number of accessions. Many cruciferous vegetables commonly consumed throughout the world include

- Bok choy (*Brassica rapa* subsp. chinensis), and
- Broccoli (*Brassica oleracea* var. italica),
- Brussels sprouts (*Brassica oleracea* var. gemmifera),
- Cabbage (*Brassica oleracea* var. capitata),
- Cauliflower (*Brassica oleracea* var. botrytis),
- Chinese cabbage (*Brassica rapa* subsp. pekinensis),
- Collard greens (*Brassica oleracea* var. viridis),
- Horseradish (*Armoracia rusticana*),
- Kale (*Brassica oleracea* var. sabellica),
- Kohlrabi (*Brassica oleracea* Gongylodes),
- Mustard,
- Radish (*Raphanus sativus*),
- Rutabaga (*Brassica napus* Napobrassica Group),
- Swiss chard (*Beta vulgaris flavescens*)
- Turnips (*Brassica rapa* subsp. rapa),
- Wasabi (*Wasabia japonica*), and
- Watercress (*Nasturtium officinale*).

Cruciferous vegetables received good attention recently among the consumers due to their positive health benefits. The health benefits are attributed to the wider nutritional and bio-active components. They are a good source of minerals (Se, Ca, Fe and K) and different vitamins (B complex and C). In the case of bio-active components, sulfur rich compounds are very important. About 200 different types of glucosinolates are present in various vegetables of cruciferous family. Further, the glucosinolates are converted to the isothiocyanates in the human body in the presence of myrosinase. These

isothiocyanates have protective action against different cancers (breast, brain, blood, bone, colon, gastric, liver, lung, oral, pancreatic, prostate etc,). Methyl cysteine sulfoxides are other sulfur rich compounds present in different cruciferous vegetables which also show anti-cancer properties. In addition, other bioactive compounds like phytoalexins, phenolic acids (hydroxycinnamic acid, chlorogenic acid, ferulic acid, sinapic acid) and flavonols (Quercetin, kaempferol, isorhamnetin, and cyaniding) and terpenes are providing the therapeutic benefits to the consumers.

2. Origin and Spread

Historical information on the origin and spread of the kale is very limited. Scientific reports mention that kale originated from the eastern part of the Mediterranean and the south-western part of Asia and people considered it as food since at least 2000 B.C. In 350 B.C, philosopher Theophrastus described curled and wrinkled form of kale in his literature. Historians reported that by the 14th century kale was known in England and consumers separated them as head and non-heading ones. In the 19th century Russian traders brought Russian kale to Canada and then brought it to USA.

Vegetables belonging to Brassica family, which grow in all regions of the world as per climate adaptability are preferred by consumers. Among them *Brassica oleracea L*. secured an important place in global food status as leaf and root vegetable. According to the Food and Agriculture Organization (FAO) the global market for domesticated *B. oleracea* crops i.e. Broccoli (var. italica), Brussels sprouts (var. gemmifera), Cabbage (var. capitata), Cauliflower (var. botrytis), Kale (var. acephala), and Kohlrabi (var. gongylodes) was 70.1 million metric tons. About the origin of kale and other *B. olerecea* crops some hypotheses exist. Among them, single domestication with a single progenitor species, multiple domestications arising from multiple progenitor species and different wild species as the progenitors are widely noted**.** *B. montana, B. cretica, B. incana, B. rupestris*, *B. incana and B. insularis*, *B. oleracea and B. alboglabra* were mentioned as the wild relatives of kale. A phylogenetic relationship of kale with its close relatives is shown in the Figure1.

3. Cultivation and Use

With the increasing demand, farmers are getting more interested to grow kale in different parts of the world. Usually, kale requires temperate climate and can be cultivated in areas having cold winters also. Depending on the climate and environmental conditions agriculture experts recommend cultivation of the kale crop from August to October which is the best season in temperate climates. However, in colder climates in India it is recommended to cultivate from August to September. In other countries May and June are the best months for the cultivation. However, the seasonal variation usually depends on the geography of the locations. Sandy loam soil with well drained and good organic matter is the preferred soil for kale cultivation.

However, kale is considered as one of the tough crops as it can thrive in any soil having the good drainage conditions. Kale crop can tolerate salty soils also, however slightly acidic pH (5.5-6.5) results in good yields. Kale is mostly propagated by seeds. Initially seedlings preparation in a nursery is a common practice and the seedlings are

transplanted in the prepared fields. To obtain higher yields, supplementation of the farm yard manure is recommended at the time of land preparation. Chemical fertilizers like Phosphorous, Potassium and Nitrogen should be applied in split doses. The amounts of the farm yard manure and the other nutrients are generally dependent on land fertility, climatic conditions and type of kale that is cultivated. Usually, aphids, flea beetles, white flies and caterpillars are major pests reported in kale fields. Agriculture experts suggest that proper pest management strategies are very important for high quality kale yields.

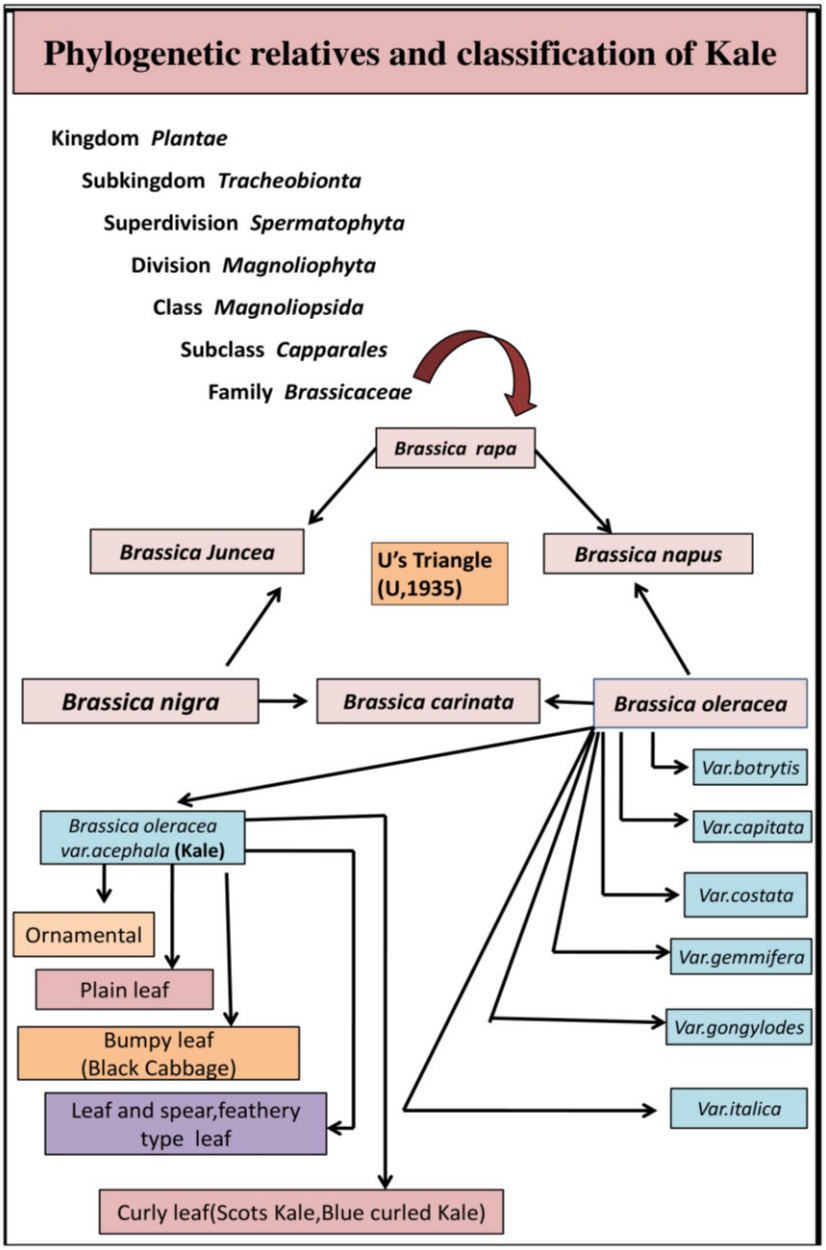

Figure 1. Phylogenic relatives and classification of kale

Researchers have been scientifically studying different agricultural aspects of kale cultivation. The need of the light hour effect on the cultivation practice of kale needs

more research and has profit oriented outcome. For higher yields of kale light is one of the important requirements. Treatment with 1h pulse of white or red light on daily basis in the case of purple kales can increase 40% of chlorophyll content and protein content along with 20% more antioxidant and soluble sugar content.

Additional information about the growing media was extensively reported. It has been concluded that hygromix prepared by Hygrotech Pvt. Ltd. was the best growth media for uniform, fast and more than 80% germination compared to other media like germination mix and cocopeat. Leaf area and leaf number were observed as the highest in hygromix, whereas, very poor performance and no significant leaf growth were observed in the case of cocopeat usage. Plant biomass (dry weight and fresh weight) was almost same in the two media studied (hygromix and germination mix). Hygromix exhibited higher biomass (fresh; 0.87 g and dry; 0.56 g) while, germination mix followed with 0.85g fresh matter and 0.55g dry matter.

Comparative studies were performed on the use of hydroponics and soil as the growing media for kale. It is reported that hydroponics is better in many aspects than soil media. Total flavonoids, vitamin C, tannins and β-carotene content in plants were higher in the plants that are grown in classical hydroponics system than in the plant that is grown in soil media. Also, plants cultivated in dry vermicompost had comparatively more polyunsaturated fatty acids like omega -3 fatty acid and oleic acids. On the other hand, total phenolic content and antioxidant capacity were highest in plants treated with K-humate. Kale can also be grown with the other crops in a well organized manner. For instance, under the rye grass cover, crop highest (42,846 kg/ha) biomass was observed in the case of organic kale cultivation whereas, kale produced after faba bean cover had higher levels of protein (4.7 g/100 g), minerals (Ca, Mg, P, and Mn), and prebiotic carbohydrates (mannose, nystose, arabinose, xylose, and lignin) than the rye grass covered kale crop.

The optimum environmental conditions for the cultivation of kale were observed to be temperature, relative humidity, and CO_2 which ranged as 20–23 °C, 85%, and 700–1000 ppm, respectively. The effect of environmental conditions on the composition of kale is as follows: total glucosinolates content decreased with the increase of temperature and relative humidity levels; in contrast, their levels increased with the increase in CO_2 concentration. Cold acclimatization can increase the soluble sugar content and also improve the taste but unsaturated fatty acid and glucosinolates acids content decreased.

Kale is labeled as a super food; it can be enjoyed as raw leaf in salad preparations and smoothies. It also can be consumed after being heat treated- steamed, sautéed, boiled or baked in regular cuisines. However, researchers tried to prepare value added foods from kale to preserve the nutritional properties and to ensure higher shelf life for the products of the kale to attract different consumers under wider age groups. Studies on the preparation of bread by incorporation of kale confirmed enhanced nutritional quality of the bread. A few researchers reported on the fermentation products of kale juice by probiotic Lactic acid bacteria like *L. plantarum* BFE 5092 and *L. fermentum* BFE 6620 and spontaneous fermentation. The value added beverages like apple blended kale juices and puree are also produced. To extend the shelf life of the kale leaf, drying was performed by convective hot air dryer to dry the kale leaf. Researchers studied the effect

of radiation on the shelf life extension of the gamma irradiation on the fresh kale juice and fresh ashitaba and kale juice treatment with gamma irradiation. Limited studies also reported on the preparation of whey protein isolate-kale leaves chlorophyll (WPI-CH) microcapsules.

4. Nutritional Composition of the Kale

The presence of sulfur-rich compounds like methyl cysteine sulfoxide and glucosinolates, coloring pigments (carotenoids and anthocyanins), minerals like Se, Fe, K, Ca, B complex and C Vitamins, dietary fiber, and other bioactive compounds (phytoalexins, terpenes, tocopherols, hydroxycinnamic acid, chlorogenic acid, ferulic acid, sinapic acid and flavonols) is responsible for the therapeutic potential of kale. The USCDC reported that kale can provide ≥10% RDA of 17 essential nutrients especially those that are strongly associated with reducing the risk of heart disease and other non-communicable diseases. This magical food is full of all major nutrients and some distinct sources of nutrients which are not readily available. The energy level of 100g kale is almost 58.46-66 kcal on the fresh weight basis.

4.1. Carbohydrates

Kale is a store house of different simple and complex carbohydrates. Among the complex carbohydrates, some prebiotic carbohydrates act as specific colonic nutrients which boost up the gut health by acting as biosynthetic activity modulators or simply support and harbor beneficial bacteria in gut. The total amount of prebiotic carbohydrates ranges between 336-743mg/100g in different cultivars of kale which is not only helpful for good gut health but also helps to fight against obesity. The sugars alcohol (sorbitol and mannitol), is a type of not fully digestible prebiotic carbohydrate present in kale which can be utilized by the gut bacteria. Generally, processing of food by different methods damages the prebiotic carbohydrates. So, consuming of raw kale in form of salad can give good quantity of the prebiotic carbohydrates. Along with the prebiotic carbohydrates, a serving bowl of kale (100g) provides only 49 calories of energy which is on the other hand helpful to fight against the obesity. Researchers mentioned about 5.7 to 8.7g/100g of prebiotic carbohydrate content in organic kale in only 0.7 to 2.7 g/100g is identified component of prebiotic carbohydrates and still 5.0 to 6.0 g/100 g are unidentified soluble prebiotic carbohydrates. The carbohydrate compositions and amounts of kale are presented in Figure 2.

Kale is also an excellent source of dietary fiber and helps to fight against different disorders like obesity. The clinical studies cleared that, dietary fiber in food provides enormous health benefit like inhibition, occurrence of colorectal cancer and breast cancer; helps to fight against cholesterol by reducing the total serum cholesterol and absorption of low-density lipoprotein cholesterols. In addition, dietary fibers have role in controlling the blood sugar levels and they can prevent type 2 diabetics. Moreover, they help in the obesity control and weight loss and weight management. Many researchers have mentioned about the dietary fibers in kale in the range of 3 to 8 g/100 g in fresh leaves, however, reported only 2 g/100g in dried kale leaf samples. The variation in the dietary fiber of the kale samples is attributed to the difference in variety,

maturity, growing location and variations in the agricultural practices employed in growing the kale plant.

Further, dietary fibers are classified into IDF and SDF. Among these, SDF are considered as the prebiotic carbohydrates which support the growth of gut microflora. Also, studies reported that SDF have protective action against CRP. The SDF provide the protection from Crohn's disease and ulcerative colitis by synthesis of short-chain fatty acids; these fatty acids also act as immunomodulators. Different studies mentioned that, SDF content as 3.62 and 4.44 g/100g in total fiber content of kale samples. In the case of fresh samples 4.36 to 5.05 g/100g were in reported in fresh weight basis. It is evident from the research that, the SDF ratio is higher in kale samples as compared to IDF and it makes kale as a good source of prebiotic carbohydrates.

CARBOHYDRATE CONTENT IN KALE (mg/100g)								
Sugar alcohol		**Simple sugar**		**RFO+FOS**		**Hemicellulose**		**Lignin**
Compound	**Content**	**Compound**	**Content**	**Compound**	**Content**	**Compound**	**Content**	**19**
Sorbitol	**2.2**	*Glucose*	**434**	*Sta+Raf*	**73**	*Arabinose*	**417**	
Mannitol	**0.1**	*Fructose*	**976**	*Ver+Kes*	**13**	*Xylose*	**25**	
		Sucrose	**38**	*Nystose*	**1.0**			
		Mannose	**26**					

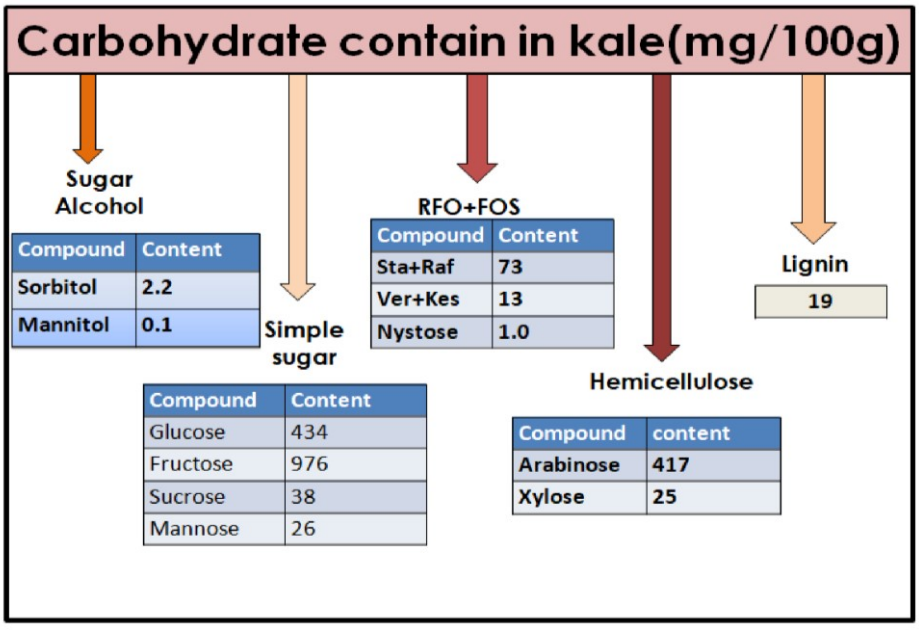

Figure 2. Carbohydrate types and amounts (mg/100g) in ka**le**

Insoluble fiber contains lignin as well as non-starchy polysaccharides. Lignin is not a polysaccharide but is a lipophilic phenolic polymer that can absorb bile acids. The IDF usually have high water-holding capacity which contributes to increased fecal bulk. Water-soluble dietary fiber forms viscous solutions in the intestine; this leads to slowdown of intestinal transit which further results in delay in gastric emptying. This slowdown of gastric emptying results in slower glucose and sterol absorption by the intestine. Viscous soluble fibers can lower serum cholesterol, postprandial blood

glucose, and insulin levels. The IDF content per 100 g fresh kale was mentioned as ranged between 0.12 and 0.74 g/100g.

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Biographical Sketches

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