Satheesh & Workneh Fanta, *Cogent Food & Agriculture* (2020), 6: 1811048
https://doi.org/10.1080/23311932.2020.1811048

cogent food & agriculture

FOOD SCIENCE & TECHNOLOGY | RESEARCH ARTICLE

Kale: Review on nutritional composition, bio-active compounds, anti-nutritional factors, health beneficial properties and value-added products

Neela Satheesh[1*] and Solomon Workneh Fanta[1]

Received: 05 March 2020
Accepted: 13 August 2020

*Corresponding author: Neela Satheesh, Faculty of Chemical and Food Engineering, Bahir Dar Institute of Technology, Bahir Dar University, Bahir Dar, Ethiopia
E-mail: neela.micro2005@gmail.com

Reviewing editor:
Fatih Yildiz, Middle East Technical University, Food Engineering and Biotechnology, Ankara, Turkey

Additional information is available at the end of the article

Abstract: There has been an increasing trend in recent times for taking more of green leafy vegetables (GLV) portion in the human diet. Among various GLVs available for human consumption, some are confined to a specific region and few are available in many parts of the world. Kale (*Brassica oleracea* L. *var. acephala*) is among the latter group which belongs to Brassicaceae family. This review summarizes the nutritional composition and anti-nutritional factors of kale available in different parts of the world. Consideration was also given for summarization of the studies reported on health benefits, pharmacological activities and different food products. It is noted from the literature that kale is a good source of fiber and minerals like potassium with higher calcium bioavailability than that of milk. Kale also contains prebiotic carbohydrates, unsaturated fatty acids and different vitamins while the anti-nutritional factors such as oxalates, tannins and phytate are present in higher concentrations. Research studies are reported different health beneficial activities of the kale like protective role in coronary artery disease, Anti-inflammatory activity, Antigenotoxic ability, gastro protective activity, inhibition of the carcinogenic compounds formation, positive to gut microbes, anti-

Neela Satheesh

ABOUT THE AUTHOR

Dr. Neela Satheesh is an Associate Professor in Faculty of Chemical and Food Engineering, Postharvest Technology Department, Institute of Technology, Bahir Dar University, Ethiopia. He obtained his PhD degree from JNTU (Jawaharlal Nehru Technological University) Anatapur, India. His research areas include Postharvest Management, Technology, Food Product Development and Food Quality and Safety, Processing and Handling of Perishables and Durables.
Dr. ir. Solomon Workneh Fanta is an Associate Professor in faculty of Chemical and Food Engineering, Postharvest Technology Department, Institute of Technology, Bahir Dar University, Ethiopia. He obtained his PhD degree from KU Leuven, Belgium, working in the area of Postharvest Technology, Development and modeling of Thermal and non-thermal storage structures for perishables and durables, Transportation phenomenon, Food Quality and Safety.

PUBLIC INTEREST STATEMENT

Kale is widely consumed Green leafy vegetable in worldwide; it is providing high bioavailability of calcium, better than milk and good concentration of the Iron. In addition, kale reported better concentrations of the probiotic carbohydrates, organic acids, unsaturated fatty acids, carotenoids, phenolic acids and different vitamins. The *in vitro* and *in vivo* studies reported various health benefits for the consumers like coronary artery disease, anti-inflammatory activity, anti-genotoxic ability, gastro protective activity etc. However, value-added products from the kale was reported in very limited areas and the most common foods reported are bread incorporate with kale, juice, puree. With all the reported nutritional and health benefits, kale reported good concentrations of the Anti nutritional components.

microbial against specific microorganisms. However, in case of value-added products kale was reported limited usage like, in baked products and beverages. Finally, concluded that, kale has good potential to use in different food and nutritional applications.

Subjects: Food Chemistry; Food Analysis; Fruit & Vegetables

Keywords: Flavonoids; glucosinolates; kale; prebiotic carbohydrates; polyphenols

1. Introduction

Kale (*Brassica oleracea* L. var. *acephala*) is a green leafy vegetable in Brassicaceae family (Fahey, 2003). Initial evidence of kale is from the eastern Mediterranean and Asia Minor regions. Kale was considered as the food crop since 2000 B.C, this is evidenced by the Theophrastus report in 350 B.C. on curved and wrinkled kale. Leonard (2019) reported that, kale has spread over the centuries across the world through immigrants, travelers and merchants. Kale plant is an annual crop and its size and nutritional variation depends on the variety and growing conditions (Lefsrud et al., 2007). The growth of this plant depends on the agricultural practices employed and geo-climatic conditions and generally, it will be ready after two months of sowing. Different varieties of kale are available they include, green kale, dwarf kale, marrow-stem kale, tronchuda kale, curly leaf kale, scotch kale, tree kale and bore kale. Kale leaves are generally consumed as fresh and unprocessed as salad or cooked and used as garnish and they are usually sold in fresh, canned and frozen forms (Fahey, 2003).

The vegetables of Brassicaceae family have specially gained attention due to their sulfur containing phyto-nutrients that promote health. In Africa, kale is regarded as nutritious and its consumption provides good health (Emebu & Anyika, 2011). Popular articles have described about the health benefits, its nutritional composition (Megan, 2020) and consumer acceptance (Bryan, 2020). The Brassicaceae exhibit positive cardiovascular protective roles preventing gastrointestinal tract cancer (Raiola et al., 2018). Glucosinolates, flavonoids (glycosylated flavanols) and phenolic (kaempferol, quercetin and isorhamnetin) compounds are responsible for antioxidant and free radical scavenging properties (Cartea et al., 2011; Lin & Harnly, 2009). The United States Center for Disease Control has assessed the vegetables for their nutritional quality with ≥10% Recommended Daily Allowance (RDA) of 17 essential nutrients especially those are strongly associated with reducing risk of heart disease and other non-communicable diseases. Among those, kale has been ranked as the 15th (Di Noia, 2014).

Although kale has been widely studied for its nutritional highlights, reviews on the consolidation of the research findings are hardly find. Hence, the objective of the present paper is to review the nutritional composition, bio-active compounds, anti-nutritional factors present in kale and health beneficial properties and value-added products of kale reported from different researchers around the world.

2. Proximate composition of kale

As indicated in Table 1, protein% in kale on fresh weight basis is 3.28%–11.67% (Emebu & Anyika, 2011; Manchali et al., 2012; Sikora & Bodziarczyk, 2012; Thavarajah et al., 2019) and 30.83%-36.8% on dry weight basis (Acikgoz, 2011; Kahlon, Chiu and Chapman, 2008). The variation in protein concentration is higher in fresh weight basis compared to that of dry, however, kale is reported to have much higher protein than other brassica family vegetables (Cleary, 2003) and other GLVs like spinach (2.9% in fresh weigh basis). The concentration of the protein is also much higher compared to other GLVs (Ayaz et al., 2006; Gupta & Rana, 2003; Roy & Chakrabarti, 2003).

The energy levels of kale vary from 58.46–66 kcal per 100 g on fresh weight basis (Emebu & Anyika, 2011; Thavarajah et al., 2019) which is higher compared to other salad crops (Gupta & Rana, 2003) and vegetables of brassica family (Fahey, 2003) as well as other temperate vegetables cultivated in different parts of the world (mean 23.18 kcal per 100 g on fresh weigh basis) (Roy & Chakrabarti, 2003). For low energy requirements, the nutrition experts always suggest to consume more amount of GLVs as they are rich source of moisture with low amount of the carbohydrates and fats (Pandey et al.,

https://doi.org/10.1080/23311932.2020.1811048

Table 1. Proximate composition of the kale leaf reported by different authors

Nutrient	Talwinder, et al., (2008)[1] (DW)	Acikgoz (2011)[2] (DW)	Thavarajah et al (2010)[3](FW)	Emebu and Anyika (2011)[4] (FW)	Sikora and Bodziarczyk (2012)[5] (FW)	Manchali et al. (2012)[6] (FW)
Protein (%)	36.8	30.83	4.2	11.67	4.16	3.28
Energy (kcal/100 g)	NR	NR	66	58.46	NR	NR
Ash (%)	15.8	NR	ND	1.33	2.11	NR
Fat (%)	11.8	NR	ND	0.26	0.67	0.74
Carbohydrates (%)	38.6	NR	ND	2.36	10.14	10.0
Dietary fiber (%)	36.8	NR	ND	3.00	8.39	1.94
Moisture (%)	NR	NR	85	81.38	82.92	NR

Where: FW = Fresh Weight; DW = Dry Weight; NR = Not Reported.

[1]Samples collected from local grocery from California, USA

[2]Kales cv. Karadere 077 grown in Turkey

[3]Kale genotypes grown in South Carolina, USA

[4]Samples collected from local market of Asba, Delta state, Nigeria.

[5]Kale from Krakow, Poland.

[6]The values are consolidated by the author reported from different studies

2006; Sheetal et al., 2005). Kahlon Chiu and Chapman, (2008) reported higher ash content of 15.8% in dry weight base and 1.33–2.11% in fresh samples by Emebu and Anyika (2011) and Sikora and Bodziarczyk (2012). This deviation can be attributed to the variations in the agro-geological conditions of the growth and variation in the moisture contents of the studied kale samples.

The dry samples have high fat 11.8% (Talwinder, et al., 2008) than in fresh samples reported as 0.26–0.74% (Emebu & Anyika, 2011; Manchali et al., 2012; Sikora & Bodziarczyk, 2012). The low percentage of fat in fresh kale is similar to that of fruits (pomes) and vegetables (salad and temperate) (Fahey, 2003).

The percentage of carbohydrates is high in dry kale which is equal to 38.6% (Kahlon , Chiu and Chapman, 2008) whereas in fresh kale, the percentage varies between 2.36%-10.14% (Emebu & Anyika, 2011; Manchali et al., 2012; Sikora & Bodziarczyk, 2012) as shown in Table 1. These values are higher compared to other salad vegetables (Gupta & Rana, 2003) as well as vegetables of brassica family (Fahey, 2003) and GLVs of temperate climate (Roy & Chakrabarti, 2003).

A high moisture percentage of 81.38%-82.92% (Sikora & Bodziarczyk, 2012; Thavarajah et al., 2019) is found in kale which is more than other crucifer vegetables. However, it is less than spinach which is 94.2% (Kawatra et al., 2001). This percentage of moisture in kale matches with other salad crops like asparagus, artichoke, beet greens, mustard, rhubarb and it is less compared to that of broccoli, brussels sprouts, cabbage, pakchol, cauliflower etc. (Fahey, 2003). This higher moisture content, low energy (Pandey et al., 2006) and low dry matter will help in enhancing the metabolic functions of human body (Sheetal et al., 2005).

3. Sugar alcohols, carbohydrates and organic acids in kale

It can be noted from Table 2 that the sugar alcohols are 24.5 mg/100 g and sorbitol as 17.9 mg/100 g reported in kale (Thavarajah et al., 2016). Sorbitols are the sweeteners; they provide only half

Table 2. Sugar alcohols, Carbohydrates, prebiotic carbohydrates and selective organic acids (mg/100 g) in kale leaf reported by different authors

Component	Ayaz et al. (2006)[1] (DW)	Thavarajah et al. (2016)[2] (FW)	Wang (1998)[3] (FW)	Hagen et al. (2009)[4] (FW)
Sugar alcohol	NR	24.5	NR	NR
Sorbitol	NR	17.9	NR	NR
Glucose	1056	993	3040	5800
Fructose	2011	545	5950	7200
Sucrose	894	39.3	300	3400
Arabinose	NR	73.5	NR	NR
Mannose	NR	241	NR	NR
Xylose	NR	59.9	NR	NR
Total identified prebiotic carbohydrates	NR	1900	NR	NR
Other prebiotic carbohydrates	NR	5500	NR	NR
Citric acid	2231	NR	386	NR
Malic acid	151	NR	124	NR

Where: FW = Fresh Weight; DW = Dry Weight; NR = Not Reported

[1]Kale (*B. oleraceae* L. var. acephala Dc.) from six different fields of Trabzon, Turkey.

[2]Mean of 25 genotypes of kale grown in South Carolina, USA

[3]Local farms Beltsville, Maryland, USA

[4]Curly Kale (*B. oleracea* L. var. acephale, cv. Reflex) from Norwegian University Life Sciences, Norway

of the energy compared to other carbohydrates due to the inability of small intestine to absorb sugar alcohols properly (Grembecka, 2015; Mäkinen, 2016). These are widely used in food products for people with diabetes (Manisha et al., 2012). The sorbitals are non-carcinogenic (Hayes, 2001) and prevents the formation of the teeth cavities (Anonymous, 2011). Very few common fruits and vegetables are reported with sorbitols (Lee, 2015). Kale has other common sugars like, glucose and fructose and sucrose, arabinose (73.5 mg/100 g), mannose (241 mg/100 g) and xylose (59.9 mg/100 g) (Thavarajah et al., 2016). Xylose is generally found in smaller concentrations in many fruits and vegetables like berries, oats and mushrooms (Hassan et al., 2011).

Glucose, fructose and sucrose are the major soluble sugars found in kale. The glucose ranges from 993 to 5800 mg/100 g, fructose 545–7200 mg/100 g and sucrose 39.3–3400 mg/100 g (Ayaz et al., 2006; Hagen et al., 2009; Thavarajah et al., 2016; Wang, 1998). This broad range in carbohydrates may be attributed to the difference in species, agricultural practices and other agro-climatic conditions. It is reported that kale grown at temperatures above 25° C is bitter in taste compared to the one grown at temperatures between 7–21 °C (Thavarajah et al., 2016; Wang, 1998). The kale grown under cooler temperatures is reported to contain higher concentration of the water-soluble prebiotic and have sweeter taste and superior nutritional quality.

The non-digestible carbohydrates and lignins are known as the dietary fiber (Cleary, 2003; El Khoury et al., 2012) which stimulates immunity and enhances mineral absorption (Lee & Mazmanian, 2010; Whisner & Castillo, 2018) and reduces the risk of colon cancer (Pool-Zobel, 2005) and risks due to the obesity (Cerdó et al., 2019; Ejtahed et al., 2019). It is reported that prebiotic carbohydrates can reduce excess circulation of glucose in blood (Davani-Davari et al., 2019), reduce cholesterol levels (Nakamura &Omaye, 2012) and improve insulin sensitivity. Table 1 indicates that the percentage of dietary fiber in dry kale is 36.8% (Kahlon , Chiu and Chapman, 2008) whereas in fresh kale, it is found to be 1.94–8.39% (Emebu & Anyika, 2011; Manchali et al., 2012; Sikora & Bodziarczyk, 2012). This variation in fresh base may be attributed to maturity and the proportion of the moisture removed in the dry samples (Barrett et al., 2010). Recommended Dietary Allowance (RDA) for dietary fiber is 25 g/day for adults 18 years and above for normal bowel function and human gut health (Anonymous, 2010; Phillips & Cui, 2011).

Thavarajah et al. (2016) have reported a total identified prebiotic carbohydrates of 1900 mg/100 g and other pre-biotic carbohydrates of 5500 mg/100 g (Table 2) in kale. Dietary prebiotics are considered as non-digestible fiber and can pass through the upper part of the intestine and promotes the growth of beneficial microbes settled in large intestine by acting as substrate (Scantlebury & Rgibson, 2004). The prebiotic carbohydrates are categorized from dietary fiber lactulose (disaccharide), inulin (polysaccharide), fructo-oligosaccharides, gluco-oligosaccharides (Lannitti & Palmieri, 2010).

Organic acids like citric, malic and oxalic acids are usually found in GLVs (Flores et al., 2012). Citric acid in kale was reported to be 386–2231 mg/100 g and malic acid 124–151 mg/100 g (Ayaz et al., 2006; Wang, 1998). In GLVs, the organic acid concentration depends on degree of maturity of the plant with variations in different parts of the plant (Batista-Silva et al., 2018). Further, the content of organic acid in GLVs also depends on the gene expression in the seeds due to the environment and agronomic practices (Kader, 2008); Mu et al. (2018) have reported that the concentration of organic acids govern the organoleptic properties especially the sourness in different fruits and vegetables. Oxalic, malic and citric acids act as antioxidants due to their ability to chelate metals (Kayashima & Katayama, 2002).

4. Minerals in kale

Mineral composition of kale is presented in Table 3. The highest concentration of potassium (Fahey, 2003) was found between 4.16–1350 mg/100 g, followed by Ca 2.6–1970 mg/100 g and Mg 0.36–44 mg/100 g (Acikgoz, 2011; Ayaz et al., 2006; Emebu & Anyika, 2011; Manchali et al., 2012; Sikora & Bodziarczyk, 2012; Thavarajah et al., 2016). Among all the vegetables grown in temperate

https://doi.org/10.1080/23311932.2020.1811048

Table 3. Mineral composition (mg/100 g) of kale leaf reported by various authors

Mineral Type	Manchali et al. (2012)[1] (DW)	Ayaz et al. (2006)[2] (DW)	Thavarajah et al. (2016)[3] (FW)	Acikgoz (2011)[4] (FW)	Emebu and Anyika (2011)[5](FW)	Sikora and Bodziarczyk (2012)[6] (FW)
Potassium	446	1350	488	4.16	7.03	440.2
Calcium	13.5	1970	106	2.61	4.05	384.8
Magnesium	34	240	44	0.36	6.69	34.9
Iron	16	7.26	1.1	12.19	8.94	NR
Zinc	0.045	3.94	0.7	2.08	2.16	0.83
Manganese	0.75	5.35	0.8	14.77	NR	0.86
Copper	0.3	0.51	0.055	0.18	NR	0.05
Selenium	0.0009	NR	0.0023	ND	NR	NR
Phosphorus	56	573	NR	0.52	NR	NR
Sodium	43	170	NR	NR	4.69	38.5
Cobalt	NR	0.02	NR	NR	NR	NR
Aluminium	NR	2.93	NR	NR	NR	NR
Arsenic	NR	0.07	NR	NR	NR	NR
Barium	NR	1.59	NR	NR	NR	NR
Cadmium	NR	0.01	NR	NR	NR	NR
Chromium	NR	0.26	NR	NR	NR	NR
Lead	NR	0.02	NR	NR	NR	NR
Lithium	NR	0.01	NR	NR	NR	NR
Molybdenum	NR	0.29	NR	NR	NR	NR
Nickel	NR	0.2	NR	NR	NR	NR

(*Continued*)

https://doi.org/10.1080/23311932.2020.1811048

Table 3. (*Continued*)

Mineral Type	Manchali et al. (2012)[1] (DW)	Ayaz et al. (2006)[2] (DW)	Thavarajah et al. (2016)[3] (FW)	Acikgoz (2011)[4] (FW)	Emebu and Anyika (2011)[5](FW)	Sikora and Bodziarczyk (2012)[6] (FW)
Strontium	NR	25.2	NR	NR	NR	NR
Tin	NR	0.04	NR	NR	NR	NR

Where: FW = Fresh Weight; DW = Dry Weight; NR = Not Reported

[1]The values are consolidated by the author reported from different studies

[2]Kale (*B. oleraceae* L. var. acephala Dc.) from fields of Trabzon, Turkey.

[3]Mean of 25 genotypes of Kale grown in SC, USA

[4]Kales cv. Karadere 077 (Istanbul Tohumculuk co.) from Turkey

[5]Samples are collected from the local market of Asba, Delta state, Nigeria.

[6]Kale varieties (*Brassica oleracea* L. var. acephala) was used for investigations from Krakow, Poland

climate, kale is reported to have highest potassium concentration (Roy & Chakrabarti, 2003). Dietary potassium effects on blood pressure (Bazzano et al., 2013), and reduces the blood pressure (Binia et al., 2015) particularly in high-sodium diet (Susan Hedayati et al., 2012).

In case of Calcium, kale is appreciated for its high concentrations and excellent absorbability compared to other salad crops (Gupta & Rana, 2003) and brassica vegetables (Fahey, 2003; Heaney et al., 1993). Kale was reported to have 58.8% of absorption in calcium which is higher than milk (32%). This fractional absorption percentage of kale is comparable to cauliflower (58.6%), but lesser than Brussels sprouts (63.8%) (Connie & Aren, 1994). However, availability of vegetables like Cauliflower and Brussels sprouts is difficult for poor people in under developed countries, while kale is the best source for the calcium at low cost. Kale is also reported to have high amount of magnesium compared to other vegetables of brassica family (Fahey, 2003). The amount of potassium and magnesium in fruits and vegetables play a potential role in the management of bone mineral density (Tucker et al., 1999).

The GLVs were reported to be a good choice for iron in vegan food habits. However, it depends on the composition of ascorbic acid (promoter), dietary fiber, oxalates and tannins (inhibitors) (Chiplonkar et al., 1999). Kale is found to have 5–10 mg/100 g of iron (Gopalan et al., 1989), which is higher compared to spinach (2.71 mg/100 g) (Bhattacharjee et al., 1998) and other brassica vegetables (Fahey, 2003). Hence, kale is the best source for fortification to enhance the iron content. The iron content in kale ranges from 1.1 to 12.19 mg/100 g, Zn 0.045–394 mg/100 g and 0.8–14.73 mg/100 g (Emebu & Anyika, 2011; Manchali et al., 2012; Sikora & Bodziarczyk, 2012). Zinc content in kale is reported to be higher than in all other common brassica vegetables and spinach (530 μg/100 g) (Bhattacharjee et al., 1998). The deficiency of zinc is considered as a worldwide public health problem resulting in 1.4% deaths around the globe (Fischer Walker et al., 2009). People in sub-Saharan Africa are identified with iron and zinc deficiencies due to the consumption of cereal-based diets for energy and micronutrients (Joy et al., 2014) and GLVs provide contribution of zinc in human diet. Cereals are composed of considerable amount of anti-nutritional factors (phytate and tannins) which reduces the bioavailability of the iron and zinc in the diet (Hunt, 2003; Gupta et al., 2013; Kruger et al., 2015). Kale has a higher quantity of manganese compared to the vegetables of brassica family (Fahey, 2003) and spinach (Bhattacharjee et al., 1998).

Kale is found to have good amount of the selenium ranging from 0.009 to 0.0023 mg/100 g (Manchali et al., 2012; Thavarajah et al., 2016) compared to other brassica and green leafy vegetables (Fahey, 2003). According to the research of Navarro-Alarcon and Cabrera-Vique, (2000), this good amount of the Selenium is important in several selenoproteins with essential biological functions. Kale is reported as having good concentrations of phosphorus in rage of 0.52–513 mg/100 g compared to other salad vegetable crops (Gupta & Rana, 2003) except for Cress among the Brassica family vegetables (Fahey, 2003).

Sodium intake is necessary for humans and RDA may be vary from adequate intake and UL (Anonymous, 1998). It is indicated in Table 3 that, 4.69–170 mg/100 g of sodium (Emebu & Anyika, 2011; Manchali et al., 2012; Sikora & Bodziarczyk, 2012) is found in kale which is higher compared to other vegetables of brassica family (Fahey, 2003). Although, less than 500 mg/day Na is sufficient for physiological requirements, usually, the average consumption of sodium is more than recommendations (William et al., 2015).

Cobalt deficiency has not been reported generally and hence it is considered as a non-essential mineral (Yamada, 2013). The RDA of Cobalt is very low (2.4 μg/day) compared to other minerals (Bhattacharya et al., 2016). Cobalt is toxic to muscles with much exposure and higher concentrations will increase in red blood cells number (polycythemia) (Squires et al., 1994). It is reported that kale has 0.02 mg/100 g of Cobalt which is enough to achieve RDA (Ayaz et al., 2006).

Uriu-Adams and Keen (2005) have reported the RDA of copper as 9 mg/day for an adult with a tolerable upper intake level (UL) of 10 mg/day. Kale was reported to have optimum quantity of copper in the range of 0.18–0.51 mg/100 g which is higher compared to other vegetables of brassica family (Fahey, 2003).

The RDA of Lithium is 100 µg/day for adult human which helps in the stabilization of nerve system activities (Schrauzer, 2002). An amount of 0.01 mg/100 g of lithium (Ayaz et al., 2006) is found in kale which is higher than that is found in other brassica vegetables (Fahey, 2003). It is reported that kale is found to have optimum concentration of Molybdenum as 0.29 mg/100 g compared to the other brassica and leafy vegetables (Fahey, 2003).

Ayaz et al. (2006) have reported that kale contains the heavy metals like Arsenic (0.07 mg/100 g), Barium (1.59 mg/100 g) Cadmium (0.01 mg/100 g), Chromium (0.26 mg/100 g), Lead (0.02 mg/100 g), Titanium (0.04 mg/100 g), Strontium (25.2 mg/100 g) and Nickel (0.2 mg/100 g). All these metals are toxic when they reach higher concentrations (Jaishankar et al., 2014) but kale is reported to have very low concentrations within safety levels (Fahey, 2003).

Kale is usually consumed in fresh as salad or minimally cooked. Slow cooking has reported no change in the kale's mineral concentrations (Gupta & Rana, 2003). The broad range of minerals and variation of the results among the authors reports are attributable to genetic (Phuke et al., 2017), environmental and analytical differences (Howard et al., 1998). However, some authors are reported the mineral information on dry weight basis, which created much difficulty for comparison between different reports (Ayaz et al., 2006; Fadigas et al., 2010).

5. Amino acids in kale

Table 4 gives the composition of different amino acids in kale. Less amount of Cystine has been found in kale compared to other GLVs grown in Africa (Ntuli, 2019). Cysteine content in kale is in the range of 34.0–58 mg/100 g (Ayaz et al., 2006; Lisiewska et al., 2008). Large amount of cystine is found in animal foods, lentils and seeds (Piste, 2013). Apart from kale, cruciferous vegetables like, cabbages, broccoli and allium vegetables such as onions, leeks and garlic are the best source of this amino acid (Doleman et al., 2017).

It is reported in Table 4 that the concentration of Glutamic acid in kale ranges from 33.20–450 mg/100 g (Ayaz et al., 2006; Eppendorfer & Bille, 1996; Lisiewska et al., 2008), which is lower than that is found in *Hibiscus cannabinus* and *Haematostaphis barter* (Kubmarawa et al., 2009), Korean spinach (Yoon et al., 2016). But, the concentration of Glutamic acid in kale is higher than that of the Nigerian spinach (*A. hybridus*), Bitter leaf (*V. amygdalina*), Pumpkin leaf (*T. occidentalis*) and Water leaf (*T. triangulare*) (Arowora et al., 2017).

Serine is reported as having lower concentrations in kale ranging from10.49–163 mg/100 g (Ayaz et al., 2006; Eppendorfer & Bille, 1996; Lisiewska et al., 2008) and it is less than that of *Hibiscus cannabinus* and *Haematostaphis barter* (Kubmarawa et al., 2009). However, the serine concentration in kale is close to that exists in *Veronica amygdaline, Gnetum africana, Gongronema latifolium* and *Ocimum gratissimum* (Chinyere & Obasi, 2011).

The Glycine content in kale ranges from 11.30–190 mg/100 g by Ayaz et al. (2006), Eppendorfer and Bille (1996) and Lisiewska et al. (2008) whereas, it is less than those of spinach (*A. hybridus*), bitter leaf (*V. amygdalina*), pumpkin leaf (*T. occidentalis*) and water leaf (*T. triangulare*) (Arowora et al., 2017). The RDA of histidine is 10 mg/kg of body weight and kale contains 3.45–106 mg/100 g (Ayaz et al., 2006; Eppendorfer & Bille, 1996; Lisiewska et al., 2008) which is relatively less than those of other GLVs (Arowora et al., 2017; Ntuli, 2019). The amount of Arginine in kale is reported in the range of 14.02–229 mg/100 g (Ayaz et al., 2006; Eppendorfer & Bille, 1996; Lisiewska et al., 2008) which is less than that of spinach (Yoon et al., 2016). The vegetables like asparagus, onion, cabbage, brussels sprouts, spinach are reported for the good source of threonine (Fahey, 2003). Threonine content in kale is in the

Table 4. Amino acids (mg/100 g) and fatty acid (μg/g) compositions in kale leaf reported by different researchers

Amino acid type	Ayaz et al. (2006)[1] (DW)	Eppendorfer and Bille (1996)[2] (DW)	Lisiewska et al. (2008)[3] (FW)	Fatty acid type	Ayaz et al. (2006)[1] (FW)
Cys	34.0	NR	58	Myristic Acid (14:0)	0.70
Asp	27.60	20.03	349	Myristoleic Acid (14:1)	0.55
Glu	33.20	49.01	450	Pentadecylic Acid (15:0)	0.33
Ser	13.80	10.49	163	Palmitic Acid (16:0)	18.7
Gly	13.10	11.30	190	Palmitoleic Acid (16:1)	0.51
His	64.0	3.75	106	Hexadecatrienoic Acid (16:3)	15.7
Arg	20.60	14.02	229	Stearic Acid (18:0)	5.92
Thr	13.90	10.30	164	Oleic Acid (18: 1 n-9)	3.38
Ala	14.60	12.77	215	Vaccenic Acid (18:1 n-7)	1.10
Pro	17.50	19.24	434	Linoleic Acid (18:2 n-6)	18.6
Tyr	12.50	8.24	122	α- Linolenic Acid (18:3 n-3)	85.3
Val	17.10	12.04	207	Arachidic Acid (20:0)	0.72
Met	60.0	0	72	Gondoic Acid (20:1 n-9)	0.81
Ile	12.80	8.72	156	Eicosadienoic Acid (20:2 n-6)	0.34
Leu	20.30	16.32	299	Dihomo gamma-linolenic Acid (20:3 n-3)	0.50
Phe	14.60	10.94	186	Arachidonic Acid (20:4 n-3)	ND
Trp	89.00	NR	NR	Eicosapentaenoic Acid (20::4 n-3)	ND
Lys	15.00	12.91	221	Behenic Acid (22:0)	0.71
				Erucic Acid (22:1 n-9)	1.50
				Lignoceric Acid (24:0)	2.82
				TS	30.0
				TUS	129

Where: FW = Fresh Weight; DW = Dry Weight; ND = Not detected; NR = Not Reported; TS = Total saturated fat; TUS = Total unsaturated fats

[1]Kale (*B. oleraceae* L. var. acephala Dc.) from Trabzon, Turkey

[2]The samples were collected from Copenhagen, Denmark

[3]The kale from Agricultural University of Krakow from Poland

range of 10.30–164 mg/100 g (Ayaz et al., 2006; Eppendorfer & Bille, 1996; Lisiewska et al., 2008) which is considered as a moderate source for threonine, whereas, meat products are reported to have high concentration of the threonine (Coleman, 2015).

It is reported the concentration of Alanine is 12.77–215 mg/100 g of kale (Ayaz et al., 2006; Eppendorfer & Bille, 1996; Lisiewska et al., 2008) which is similar to other GLVs (Arowora et al., 2017; Yoon et al., 2016). Eggs, meet, fish, dairy products are the major sources of Alanine (Górska-Warsewicz et al., 2018). Proline is reported to be in the range of 17.50–434 mg/100 g of kale (Ayaz et al., 2006; Eppendorfer & Bille, 1996; Lisiewska et al., 2008), which is comparable with other GLVs and vegetables of brassica family (Fahey, 2003). Tyrosine is in the range of 8.24–122 mg/100 g of kale (Ayaz et al., 2006; Eppendorfer & Bille, 1996; Lisiewska et al., 2008). Usually, the plant based foods are not the best source of the tyrosine (Yoon et al., 2016).

The valine concentration in kale is reported as 12.04–207 mg/100 g (Ayaz et al., 2006; Eppendorfer & Bille, 1996; Lisiewska et al., 2008) which is similar to other GLVs (Ntuli, 2019). Higher concentrations of valine is reported in kidney beans, leafy vegetables, poultry and milk (Górska-Warsewicz et al., 2018). Methionine is reported in the range of 60.0–72.0 mg/100 g of kale (Ayaz et al., 2006; Eppendorfer & Bille, 1996; Lisiewska et al., 2008) which is similar to other GLVs (Arowora et al., 2017; Ntuli, 2019).

Isoleucine is reported in that kale has 8.72–156 mg/100 g (Ayaz et al., 2006; Eppendorfer & Bille, 1996; Lisiewska et al., 2008) which is comparable to other GLVs (Arowora et al., 2017; Ntuli, 2019). In case of Lucien, it exists in the range of 16.32–299 mg/100 g of kale (Ayaz et al., 2006; Eppendorfer & Bille, 1996; Lisiewska et al., 2008). The RDA of phenylalanine is 25 mg/kg of body weight (Traylor et al., 2018). Kale is providing a good concentration of phenylalanine compared to other GLVs (Arowora et al., 2017; Ntuli, 2019) and it is in the range of the 10.94–189 mg/100 g of kale (Ayaz et al., 2006; Eppendorfer & Bille, 1996; Lisiewska et al., 2008). Tryptophan is reported as the 89 mg/100 g of kale (Ayaz et al., 2006; Eppendorfer & Bille, 1996; Lisiewska et al., 2008; Ntuli, 2019) which is a moderate amount compared to other GLVs. Tryptophan deficiency leads to pellagra, and severe alterations of skin, gut and brain activity (Palego et al., 2016). Lysine is reported in the range of 12.9–221 mg/100 g of kale (Ayaz et al., 2006; Eppendorfer & Bille, 1996; Lisiewska et al., 2008). Kale is considered as a moderate source of the lysine in comparison with other GLVs (Arowora et al., 2017; Ntuli, 2019).

6. Vitamins and selected carotenoids in kale

Kale is reported to have high concentration of vitamin C than all other salad vegetables and vegetables of Brassicaceae family (Fahey, 2003; Gupta & Rana, 2003). Edelman and Colt (2016) have reported that the amount of vitamin C in kale is much higher than that of in Duck-weed and also other GLVs of Africa (Uusiku et al., 2010). It is in the range of 62.27–969 mg/100 g and is considered as the best source for vitamin C, satisfying the RDA for both males and females (Acikgoz, 2011; Hagen et al., 2009; Murtaza et al., 2006; Sikora & Bodziarczyk, 2012). Vitamin C RDA is 90 mg-120 mg/day (Aly et al., 2010). The deficiency of vitamin C leads to scurvy with disturbances in collagen metabolism and a tendency to bleed (Mayland et al., 2005).

B-complex vitamins are water soluble and composed of vitamin B1 (Thiamine), vitamin B2 (Riboflavin), vitamin B3 (Niacin), vitamin B5 (Pantothenate), vitamin B6 (Pyridoxal), vitamin B7 (Biotin), vitamin B9 (Folate) and kale has reported all the above vitamins except Vitamin B12 (Cyanocobalamin).

In case of Thiamine, it is reported to exist between 0.110–0.9 mg/100 g of kale as indicated in Table 5 which is comparable with those of other salad vegetables as well as vegetables of Brassicaceae family (Fahey, 2003; Gupta & Rana, 2003). Agte et al. (2000) reported that GLVs are the best source of Vitamin B1.Gupta, Gowri, et al., (2013) has reported that kale has high concentration of thiamine than *Amaranthus gangeticus, Chenopodium album, Centella asiatica, Amaranthus tricolor, Trigonella foenum-graecum*.

Table 5. Vitamin C, β-carotene, lutein, violaxanthin and neoxanthin compositions (mg/100 g) reported in kale (in fresh weight basis) by different authors

Component Type	Acikgoz (2011)[1]	Hagen et al. (2009)[2]	M. G. Lefsrud et al. (2005)[3]	De Azevedo and Rodriguez-Amaya (2005)[4]	M. Lefsrud et al. (2007)[5]	Sikora and Bodziarczyk (2012)[6]	Murtaza et al. (2006)[7]
Vitamin C	104.31	969	NR	NR	NR	62.27	151
β-carotene	NR	NR	10.97	3.887	8.92	6.40	44
Lutein	NR	NR	14.175	5.061	38.16	NR	NR
Violaxanthin	NR	NR	NR	3.316	NR	NR	NR
Neoxanthin	NR	NR	NR	1.694	NR	NR	NR

Where: NR = Not Reported

[1]Kale grown in South Carolina, USA.

[2]Curly Kale (*B. oleracea* L. var. acephale, cv. Reflex) from Norwegian University Life Sciences, Norway

[3]"Winterbore" kale from University of Tennessee, Knoxville, USA

[4]Kale (*Brassica oleracea*) of the common cultivar "Manteiga" from S˜ao Paulo, Brazil

[5]*Brassica oleracea* L. var. acephala DC cul. "Winterbor" were from USA.

[6]Kale (*Brassica oleracea* L. var. acephala) from Krakow, Poland

[7]*Brassica Oleracea cv gongilodes* kale from Kashmir, India

The concentration of Riboflavin reported in kale is considered to be reasonably good which varies between 0.13–0.9 mg/100 g (Fahey, 2003; Gupta & Rana, 2003) though it is lower than that of spinach and Duck-weed (Edelman & Colt, 2016). A similar concentration of vitamin B2 is found in vegetables of Brassicaceae family (Fahey, 2003). Agte et al. (2000) has analyzed 24 varieties of GLVs for riboflavin concentrations and reported that kale is better among all. Uusiku et al. (2010) has found that kale has the best concentration of vitamin B2 compared to several other GLVs from Africa.

Catak and Yaman (2019) has analyzed the profiles of vitamin B3 in several fruits and vegetables and kale showed a better concentration than in Broccoli, Brussels sprouts, Spinach and other brassica vegetables (Fahey, 2003). Similarly, it is reported that kale has better concentration of niacin than other common salad crops (Gupta & Rana, 2003). The concentration of niacin in kale was reported as 1.00 mg/100 g.

Kale is considered as a good source of vitamin B5 and it ranges from 0.091 to 0.9 mg/100 g. Hasan et al. (2013) have found no traces of Vitamin B5 in some of the indigenous GLVs of Bangladesh and Indian spinach. It is found that pantothenic acid in kale is lower than that of other brassica vegetables (Fahey, 2003)

Kale is considered as a good source of vitamin B6 among other GLVs and the amount of vitamin B6 in kale is reported to be 0.27–2.5 mg/100 g (Fahey, 2003), which is better than other commonly consuming Brassicaceae family vegetables. It is also reported that kale has better concentrations of the pyridoxine compared to Indian spinach, red and green amaranth leaves and duck weed (Edelman & Colt, 2016; Hasan et al., 2013).

Kale is reported to have higher concentrations of folic acid to the extent of 29 mg/100 g than amaranth, mint, spinach and other common brassica vegetables (Agte et al., 2000). However, it has smaller concentrations of vitamin B9 (Fahey, 2003). Takeiti et al. (2009) have reported that kale has better folic acid concentration than *P. aculeata* (OPN leaves), *Synanthera* (chomte), *Oleracea* (spinach), *L. sativum* (cress), *I. batatas* (sweet potato leaves), *A. graveolens* L. (dill), *Sagittifolium S*. (Taioba). Uusiku et al. (2010) have reviewed the composition of vitamins in GLVs in Africa and concluded that kale has the best concentration of the folate and a stated kale as a good source of Vitamin B9.

It is reported that kale is a moderate source of vitamin A having 8900 IU with the retinal equivalence (RE) as 890 µg/100 g (Fahey, 2003). The RE reported in GLVs from Africa is 99–1970 µg/100 g (Uusiku et al., 2010) and also vitamin A in *P. aculeata* (OPN leaves) is 2333 IU/100 g (Takeiti et al., 2009) which is lower than that in kale. Raju et al. (2007) have reported vitamin A (retinal equivalent) as 641–19,101 µg/100 g in medicinal plants which is higher than in kale.

β -carotene (BC) is the precursor for retinol and vitamin A in kale which is reported to be 3.887–44 mg/100 g as indicated in Table 5. Takeiti et al. (2009) have reported that 0.31–5.58 mg/100 g of BC is available among the GLVs like *P. aculeata* (OPN leaves), *L. synanthera* (Chomte), *S. oleracea* (Spinach), *L. sativum* (Cress), *I. batatas* (Sweet potato leaves), *A. graveolens* L. (Dill), *X. sagittifolium S*. (Taioba). Raju et al. (2007) have reported 3.85–92.82 mg/100 g of BC in the medicinally important GLVs from India. Gupta, Gowri, et al., (2013) have reported that *Amaranthus gangeticus, Chenopodium album, Centella asiatica, Amaranthus tricolor* and *Trigonella foenumgraecum* concentration have 2.7–5.46 mg/100 g of BC. According to WHO the RDA of vitamin A is 700 and 900 µg/day for females and males, respectively (Trumbo et al., 2001). Consumption of 100 g of kale will fulfill this requirement of vitamin A.

Vitamin E (α-tocopherol equivalent) is reported as 0.800 mg/100 g of kale (Fahey, 2003). Achikanu et al., (2013) have reported that *Ficus capensis, Solanum melongena, Mucuna prurient, Solanum macrocarpon, Solanum nigrum, Moringa oleifera lam, Solanum aethiopicum, Cridoscolus* *acontifolius* were have higher concentration of Vitamin E. Usually the best source of Vitamin E are the oils and fats and the GLVs are considered as its poor source (Choo et al., 1996).

From the samples of kale grown in Boston and Montreal, vitamin K is reported as 573 µg/100 g (Catani et al., 2005) and 6.21–16.57 µg/100 g (Booth Sarah et al., 1993), respectively. Compared to other fruits and vegetables, kale is reported to have good concentration of the vitamin K. Novotny et al. (2010) have reported that the bioavailability of phylloquinone from kale is 4 · 7%. However, kale is reported as one of the best sources of vitamin K compared to other commonly consuming vegetables (Booth Sarah et al., 1993).

Lutein, violaxanthin and neoxanthin are the major carotenoids and their concentrations in kale are presented in Table 5. Lutein is in the range of 5.06–38.16 mg/100 g (De Azevedo & Rodriguez-Amaya, 2005; M. G. Lefsrud et al., 2005; M. Lefsrud et al., 2007). Lutein cannot synthesize in humans and should be obtained through food composed of vegetarian diet (fruits and vegetables) (Calvo, 2005). Lutein, zeaxanthins are the stereo isomers which usually coexists in nature and GLVs like kale and spinach are their best sources (Shegokar & Mitri, 2012). Holden et al. (1999) have reported that 40 mg/100 g of lutein + zeaxanthin is available in kale. In contrast, only less than 1 mg is reported in 100 g of yellow-orange color food crops like carrots, peaches, corn, papaya and oranges. Researchers have reported that lutein acts as an antioxidant and it is very important for skin health (Shegokar & Mitri, 2012; Stahl & Sies, 2004). Finally, kale is reported as the best source of lutein than other orange to yellow fruits and vegetables.

Perera and Yen (2007) have reported that violaxanthin and neoxanthin are abundant in green parts of the plants like GLVs. They cannot be used by the humans but, their concentration can influence the total carotenoid intake of an individual. Biehler et al. (2012) have reported that yellow bell peppers were especially rich in violaxanthin (4.4 mg/100 g) followed by spinach (2.8 mg/100 g) and creamed spinach (2.5 mg/100 g) and kale is also reported to have similar amounts of the Violaxanthin (3.36 mg/100 g). De Azevedo and Rodriguez-Amaya (2005); Žnidarčič et al. (2011) have reported 0.35–1.07 mg/100 g of neoxanthin in five leafy vegetable and found that neoxanthin is lower than violaxanthin in all. Similar conclusions are reported by De Sá and Rodriguez-Amaya (2003) and also stated that Violaxanthin in GLVs usually surpasses neoxanthin. The same trend of the results was observed in the kale that 1.694 mg/100 g of neoxanthin is found (De Azevedo & Rodriguez-Amaya, 2005) which is less than the violaxanthins.

7. Flavonoids, phenolic compounds, glucosinolates in kale

Flavonoids are group of polyphenolic compounds found widely in plants (Cao et al., 1997) and possess strong antioxidant properties due to the phenolic hydroxyl groups (Subhasree et al., 2009). Different types of flavonoids presented in the kale are presented in Table 6. The flavonoids content of kale is reported as 661–892 of mg/100 g as shown in Table 6 (Olsen et al., 2009; Sidsel et al., 2009; Susanne et al., 2010). It is reported that GLVs are the good source of flavonoids and other anti-oxidant vitamins and compounds (Subhasree et al., 2009). Adefegha and Oboh (2011) have analyzed the *Talinum triangulare, Ocimum gratissimum, Amaranthus hybridus, Telfairia occidentalis, Ipomea batata, Cnidoscolus aconitifolius, Baselia alba* and *Senecio biafrae* leaves and reported the flavonoid content is in the range of 8.2–42.1 mg/100 g. Marinova et al. (2005) have analyzed the total flavonoid content of selected fruits and vegetables and reported it 20.2–190.3 mg/100 g. Bahorun et al. (2004) has reported the total flavonoid content of the Mauritian vegetables as 94.4–4.5 mg/100 g with its highest content in broccoli and the lowest in carrot. It can be concluded that kale is a good source of flavonoids compared to other commonly consuming vegetables.

Quercetin is a flavonoid found in GLVs having special biological functions which improves mental and physical performance, reduces the risk of infection, anti-carcinogenic, anti-inflammatory, anti-viral, antioxidant and psychostimulant activities (Y. Li et al., 2016). Kale is reported to contain Quercetin in the range of 44–319 mg/100 g (Olsen et al., 2009; Sidsel et al., 2009; Susanne et al., 2010). Andarwulan et al. (2010) have reported 0.30–51.3 mg/100 g of Quercetin in vegetables from the

Table 6. Total flavonoid, quercetin, kamempferol, total phenol, hydroxycinnamic acids reported in kale by different researchers

Constituent	Sidsel et al. (2009)[1] (DW)	Susanne et al (2010)[2]S (2012)[2] (DW)	Olsen et al. (2009)[3] (FW)	Sikora and Bodziarczyk (2012)[4] (FW)	Murtaza et al. (2006)[5] (FW)
Total flavonoids (mg/100 g)	661	892	646	NR	NR
Quercetin (mg/100 g)	319	272	44	NR	NR
Kaempferol (mg/100 g)	343	537	58	NR	NR
Total phenols (mg of GAE/ 100 g)	1167	NR	384	574.95	201.67
Hydroxycinnamic acids (mg RE/100 g)	NR	NR	204	NR	NR

Where FW = Fresh Weight; DW = Dry Weight; NR = Not Reported

[1]Curly kale (*B. oleracea L.* var. acephale, cv. Reflex) from Norwegian University, Norway.

[2]Kales from the Germany

[3]Kale from Norwegian University of Life Sciences, Norway.

[4]Kale varieties (*Brassica oleracea* L. var. acephala) from Krakow, Poland.

[5]Kale *(Brassica Oleracea cv gongilodes)* from Kashmir, India.

Indonesia. On the contrary, Quercetin in *Gnetum africanum* (Afang), *Lasianthera africana* (Editan) and *Gongronema latifolium* (Utazi) leaf extracts is reported as 429–546 mg/100 g (Nwanna et al., 2016). Sultana and Anwar (2008), had evaluated selected fruits, vegetables and medicinal plants and reported the content of Quercetin as 0.12–35.94 mg/100 g. Hence, kale is considered as having a reasonably best concentration of Quercetin contributing to the antioxidant properties.

Kaempferol is a natural flavonol, an active compound reported for antioxidant, anti-inflammatory, antimicrobial, anti-diabetic and anti-cancer activities (Calderón-Montaño et al., 2011). Kaempferol is reported in the range of 58–537 mg/100 g of kale samples (Olsen et al., 2009; Sidsel et al., 2009; Susanne et al., 2010). Bahorun et al. (2004) have reported that Kaempferol in Chinese cabbage (9.6 mg/100 g), onion (4.5 mg/100 g), Mugwort (12.5 mg/100 g), Broccoli (4.6 mg/ 100 g), Cauliflower (1.2 mg/100 g), Tomato (0.7 mg/100 g), Carrot (0.6 mg/100 g) and these concentrations are reported as lower than that of kale. Lako et al. (2007) have analyzed the Fijian fruits and vegetables and reported less than 1 to 34 mg/100 g of Kaempferol. In general, kale has good concentration of the Kaempferol as compared to other vegetables.

Phenolic compounds are not nutrients but, the dietary intake provides health-protective effects (Cheynier, 2012). They can be divided into phenolic acids, flavonoids, tannins, coumarins, lignans, quinones, stilbens, and curcuminoids (Agati et al., 2012). Phenolic compounds are reported to have health benefits including, antibacterial, anti-inflammatory and anti-mutagenic activities (Chandrasekara & Josheph Kumar, 2016). Kale is reported for 201.67–1167 mg/100 g of total phenolic content (Murtaza et al., 2006; Olsen et al., 2009; Sidsel et al., 2009; Sikora & Bodziarczyk, 2012; Susanne et al., 2010). Johari and Khong (2019) have reported that the total phenolic content of *Pereskia bleo* as 252.0–408.2 mg/100 g. Aryal et al. (2019) have reported the total phenolic content of wild vegetables from Western Nepal such as *Alternanthera sessilis, Basella alba, Cassia tora, Digera muricata, Ipomoea aquatica, Leucas cephalotes, Portulaca oleracea* and *Solanum nigrum* to be 770.6–2926.5 mg/100 g. Hossain et al. (2017) have reported that green amaranth, water spinach leaf and Indian spinach leaf had a total phenolic content of 93.33, 92.14 and 91.95 mg GAE/100 g, respectively. Obeng et al. (2019) have reported that, *Solanum macrocaron* (Gboma), *Talinum fruticosum* (Ademe), *Corchorus olitorius* (Yevogboma) and *Amaranthus spp.* (Atormaa) have a total phenolic content of 0.014–0.982 mg/100 g by the fresh weight. Research reports have clearly identified the quantitative and qualitative differences of polyphenols in fruits, vegetables and GLVs. These differences can be attributed to the method of extraction, processing and growing conditions and varietal differences.

Hydroxycinnamic acids are the natural phenyl propenoic acid compounds which are the metabolic products of cinnamic acid with 3–6 carbon backbone (Johari & Khong, 2019). Hydroxycinnamic acids are very important sources for antioxidants and possess the role in the stability of flavor, color and nutritional bioavailability of foods (Wilson et al., 2017). Very little research is done on Hydroxycinnamic acids concentration in the kale. Olsen et al. (2009) have reported that kale has 204 mg of Hydroxycinnamic acids per 100 g kale. Dietary sources of Hydroxycinnamic acids include apples, blueberries, cereals, cherries, cinnamon, coffee, ginger, grapes, lettuce, olives, oranges, pears, pine-apples, plums, potatoes, prunes, spinach, strawberries, sunflower seeds, turmeric and herbs like basal, marjoram, oregano, rosemary, sage and thyme (El-Seedi et al., 2012). Compared to fruits and vegetables, kale has less concentration of this phenolic acid. Some of the plant sources like tea showed huge amount of the Hydroxycinnamic acids but kale has these acids similar to other GLVs like spinach.

Glucosinolates are the plant secondary metabolite characteristics of the Cruciferae family. Glucosinolate containing plants include mustard, wasabi, cabbage, swede, rapeseed, kale, turnip are the source for food and feed for humans and animals (Cartea et al., 2011). Kale is reported to have 41 µmol/g by dry weight (Velasco et al., 2007) which is comparable with other brassica vegetables. Recent studies have reported a positive nature of glucosinolates, which include regulation of inflammation, stress, antioxidant activities and antimicrobial properties (Melrose, 2019). A comprehensive analysis of glucosinolates among broccoli, brussels sprouts, cabbage, cauliflower and kale has reported that, Brassicaceae vegetables contained wider glucosinolates among the other vegetables (Carlson et al., 1987). Broccoli contains glucoraphanin as the primary glucosinolate whereas brussels sprouts, cabbage, cauliflower and kale have higher levels of sinigrin and progoitrin with very little amounts of glucoraphanin (Jeffery & Stewart, 2004).

8. Fatty acids in kale

Ayaz et al. (2006) have reported different types of fatty acids in kale by dry weight basis and presented in Table 4. Usually, the fat content in kale is reported as 11.8% on dry weight basis (Kahlon, Chiu and Chapman, 2008) and 0.26–0.74% by fresh weight basis (Emebu & Anyika, 2011; Manchali et al., 2012; Sikora & Bodziarczyk, 2012). Among the reported results, the unsaturated fatty acids are higher than the saturated fatty acids. As reported by Ayaz et al. (2006), the total saturated fats are 30.0 µg/g whereas, the total unsaturated fats are 129 µg/g of kale. Among the saturated fatty acids kale is reported to have C14:0 (Myristic acid), C15:0 (Pentadecylic acid), C16:0 (Palmitic acid), C18:0 (Stearic acid), C20:0 (Arachidic acid), C22:0 (Behenic acid), C24:0 (Lignoceric acid). Among all these saturated fatty acids, C16:0 is reported as 18.7 µg/g whereas other fatty acids such as C14:0, C15:0, C18:0, C20:0, C22:0, C24:0 are reported to have 0.70, 0.33, 5.92, 0.72, 0.71 µg/g, respectively (Ayaz et al., 2006).

Saturated fatty acids are reported as the reason for elevated lipid levels in human blood and considered as non-essential because they can synthesize in human body (Clifton & Keogh, 2017). All saturated fatty acids from 8 to 16 carbon atoms are responsible to raise the serum LDL cholesterol levels when they are consumed through human diet (Forouhi et al., 2018). However, stearic acid does not raise the serum LDL cholesterol levels due to rapid conversion into oleic acid in the body (Denke & Grundy, 1991). Kale is reported to have low composition of the saturated fatty acids compared to some of the GLVs (Adeyeye et al., 2018).

Total unsaturated fatty acids reported in dry kale leafs as 129 µg/g (Ayaz et al., 2006). Among the total unsaturated fatty acids, kale is reported to have 14:1 (Myristoleic acid), 16:1 (Sapienic acid), 16:3 (Palmitolinolenic acid), 18:1 n-9 (Oleic Acid), 18:1 n-7 (Vaccenic Acid), 18:2 n-6 (linoleic acid), 18:3 n-3 (α-linolenic Acid), 20:1 n-9 (Eicosenoic acid), 20:2 n-6 (Ecosadienoic acid), 20:3 n-3 (Eicosatienoic acid), 20:4 n-3 (Eicosatetaenoic acid), 20:5 n-3 (Heneicosapentaenoic acid), 22:1 n-9 (Erucic acid). Among all, 18:3 n-3 is reported to be 85.3 µg/g (Ayaz et al., 2006).

Kale is reported to have ω-3, 6, 7 and 9 fatty acids in good concentrations (Ayaz et al., 2006). Unsaturated and poly unsaturated fatty acids (PUFA) are reported to have numerous benefits like preventing Coronary Heart Diseases (CHD) and deaths related to CHD (Mozaffarian et al., 2010). Among different fatty acids, linoleic acid is reported for overall health benefits (Jandacek, 2017). Researchers have reported that, ω-3, 6, fatty acids are very important to patients surviving from myocardial, cardiovascular disease (Dunbar et al., 2014) and anti-inflammatory effects, positive effect on obesity, improved endothelial function, reduced blood pressure, lowered triglycerides in blood (Patterson et al., 2012), for alteration of chemotherapeutic drugs toxicity, protection from skin and oral cancers (M. Johnson et al., 2019).

Calder (2015) has reported that, n-3 PUFA are very important in immunomodulatory and anti-inflammatory properties. Consumption of fatty acids help in prevention of many inflammatory related diseases like diabetes (Lee et al., 2014) and cardiovascular disease (Phang et al., 2013). Simopoulos (2004) has reported that Purslane, Spinach, Butter crunch Lettuce, Red Leaf Lettuce, Mustard are good source for omega fatty acids which contain more PUFA fatty acids compared to that of kale. M. Johnson et al. (2013), (2018), 2019) had reported that the GLVs serve as a major dietary reservoir of the essential PUFAs and the consumption of GLVs determines the liver fatty acid composition. Uddin et al. (2014) have reported that, kale has low sources of omega-3 fatty acids which are similar to broccoli.

9. Anti-nutritional factors in kale

Oxalic acid and its salts are present in number of plant based foods that have an adverse effect on mineral bioavailability of Calcium and other minerals (Bhandari & Kawabata, 2004). Tea, rhubarb, spinach and beet are reported for high oxalate-containing foods (Noonan, 1999). Kale was reported as the rich source of oxalates. Erdogan and Onar (2011) have reported that the oxalate content as 297 mg/100 g by fresh weight and 2302 mg/100 g by dry weight of kale. These contents are less compared to the oxalates in Chard and Spinach. The oxalate content (0.08 mg/100 g) reported by Emebu and Anyika (2011) is very much lower than reported by Erdogan and Onar (2011). This difference can be attributed to variations in the method of analysis, the species and agro-geological conditions. P Agbaire (2011) have reported that *Vernomia anydalira* (Bitter leaf), *Moni esculenta* (cassava leaf), *Teiferia occidentalis* (Ugu leaf), *Talinum triangulare* (water leaf), *Amaranthus spinosus* (Green vegetable) has 0.076–0.106 mg/100 g of oxalates by dry weight base. Kale is a rich source of Calcium and oxalate content is very important consideration for bio-availability of Calcium. Noonan (1999) has reported that processing methods like soaking and heat processing of high oxalate food samples have reduced the oxalate content.

Nitrates in kale is reported to be 201.6 mg/100 g by fresh weight basis and 1563 mg/100 g by dry weight basis of kale (Erdogan & Onar, 2011). It is noted that the nitrate content of kale is higher than in spinach and lower than in chard. Nitrate in kale is 11.1 and 85.7 mg/100 g by fresh and dry weight basis, respectively (Erdogan & Onar, 2011). Compared to spinach and chard kale is reported to have more concentration of Nitrate. Dennis and Wilson (2003) have reported that, nitrate content in the samples of kale from USA was reported as 178.0 mg/kg. Nitrate is a usual component of plants which is found due to microbiological attack. Nitrate in the soil is utilized by plant as nitrogen in protein synthesis. Photosynthesis is a key for protein synthesis in plant, however, photosynthesis is decreased as the light levels fall and this situation leads to nitrate accumulation in cell fluids (Keeton, 2011). The nitrate concentrations in vegetables grown under subdued light are reported to be higher than that is grown under bright light. Overall, nitrate content in plant is determined by genotype and growing conditions (Anjana & Iqbal, 2007).

Erdogan and Onar (2011) have reported that kale has phytate content as 0.12 mg/100 g and tannin as 0.15 mg/100 g of the kale grown from the Nigeria. P Agbaire (2011) has reported that *Vernomia anydalira* (Bitter leaf), *Moni esculenta* (Cassava leaf), *Teiferia occidentalis* (Ugu leaf), *Talinum triangulare* (Water leaf), *Amaranthus spinosus* (Green vegetable) have 0.58–0.811 mg/100 g of phytate, while kale is reported to have least concentration of the phytate than the above leafy vegetables. P.O. Agbaire (2012) has analyzed the anti-nutritional factors in GLVs and reported that the phytate is in the range of 0.412–1.3 mg/100 g which is higher than that of kale. The tannin content reported by P.O. Agbaire (2012) is 0.004–0.026 mg/100 g in different GLVs which is lower than the phytate content in kale (Erdogan & Onar, 2011).

Phytate has anti-nutritional activities in human body by strong chelation of calcium, iron and zinc to form insoluble complexes and contributes to the deficiency of iron and zinc (Lopez et al., 2002). On the other hand, phytate has a positive nutritional role as an antioxidant and anti-cancer agent (Kumar et al., 2010). Phytate is reported to be contributing 60 to 80% of total phosphorus in cereals, legumes, nuts and oilseeds. The lower concentrations of phytate are found in roots, tubers, fruits and berries (Reddy, 2001).

10. Studies reported on the health benefits of the kale

Consumers considering kale consumption provide better health, to confirm this, researchers reported limited *in vitro* and *in vivo* studies, and they are summarized in Table 7. Only few researchers established kales positive role in management of macular disease, bilirubin metabolism, protective role in coronary artery disease, Anti-inflammatory activity, Antigenotoxic ability, Gastro intestinal protective activity, inhibition of the carcinogenic compounds formation, positive to gut microbes, anti-microbial nature against specific microorganisms. However, there are clear gaps and researchers can work on different aspects related to the health and pharmacological activities of the kale.

11. Studies reported on the value-added products from the kale

Kale is widely consuming as part of the diet, but very limited studies were reported on the value-added products and they are summarized in Table 8. The products reported from the kale are incorporation of kale in bread, fresh kale juice sterilized with radiation, fermented kale juice by spontaneous and induced fermentations (*L. plantarum* BFE 5092 and *L. fermentum* BFE 6620), beverages with addition of apple juice, kale purée, dried kale leafs and kale leaves chlorophyll microcapsules. Even though kale is a famous GLV, conversion of the kale to different value-added products are not studied well. Still there is a huge scope for development of value-added products from kale.

12. Conclusions

Kale is one of the oldest GLVs in the world, known for its best source of fiber in dry conditions and also for providing good concentration of prebiotic carbohydrates while it has been the poor source of fat, energy and carbohydrates. Kale is a better source of potassium and calcium. The bioavailability of the calcium in kale is very high which is better than milk. The amino acid composition of kale is balanced and contains more unsaturated fatty acid than the saturated. Kale is also a good source of vitamin A and β-carotenes and also for flavonoids like, Quercetin, kaempferol. In addition, kale has good concentrations of the phenolic compounds hydroxycinnamic acids. With better mineral compositions, kale contains high concentration of oxalates which is a major anti-nutritional component. Kale also has glucosinolates along with tannins, phytates and nitrogen compounds (Nitrates and Nitrites). In case of the health benefits, limited studies only reported *in vitro* and *in vivo* studies and established that kales potential role in management of macular disease, bilirubin metabolism, protective role in coronary artery disease, Anti-inflammatory activity, Antigenotoxic ability, gastro protective activity, inhibition of the carcinogenic compounds formation, positive to gut microbes, anti-microbial against specific microorganisms. Kale is usually consumed as a salad crop similar to other green leafy vegetable with minimal processing. However, the value-added products and research on product developments from the kale leaf is not reported well, except for its drying and preparation of juice. However, the role of kale in health promotion also investigated in narrow. It can be concluded that kale is a potential leafy vegetable for dietary recommendations for all age groups and it have very good potential for food and health based products.

In future line of work researchers can intensively work on kale utilization in different foods and kale based value-added food products for wider age groups consumers. Scholars can also carry research on isolation of bio-active components from kale and their effective utilization in nutrition. In addition, researchers can also work to determine kale role in nutrition, health and pharcological

Table 7. Reported research studies on the health benefits of kale leaf, juice and extracts in humans by different authors

S. No	Area of research	Methodology employed	Findings and conclusions	References
1	Short-term intervention with an kale extract in macular disease	A randomized, double-blind, placebo-controlled, parallel trial conducted to determine the influence of a short-term intervention of oleaginous extract of kale on plasma xanthophyll concentrations and the optical density of the macular pigment xanthophylls in 20 patients conducted for 10-weeks.	The concentrations of the xanthophylls in plasma and the the macular pigment xanthophylls increased significantly by the kale consumption within 4 weeks of intervention.	Arnold et al. (2013)
2	Kale consumption on cytochrome activity and bilirubin metabolism	Randomized crossover study was conducted to determine the effect of kale consumption on Cytochrome P4501A2 (CYP1A2, CYP2A6, XO) and N-acetyltransferase (NAT2) activity was determined by urinary caffeine metabolite ratios, UGT1A1 (Uridine di-phosphate glucuronosyl transferase1 A1) activity by serum bilirubin concentrations and GSTA (Glutathione S-transferase alpha) protein and GST (Glutathione S-transferase) activity in blood by ELISA.	Authors concluded that, daily kale consumption increased CYP1A2 activity as determined by caffeine metabolite ratios by 16.4% and 15.2% after one and two weeks of feeding, respectively. Also, daily kale consumption modified Bilirubin metabolism such that serum conjugated Bilirubin decreased from 19.4% of total Bilirubin on day 1 to 14.3% and 9.5% on days 8 and 15, respectively.	Charron et al. (2020)
3	*In vitro* binding of bile acids by kale and other vegetables	The *in vitro* binding of bile acids by kale in comparison with other brassica vegetables was determined using a mixture of bile acids secreted in human bile at a duodenal physiological pH of 6.3.	The results of study revealed that, Bile acid binding for spinach, kale and brussels sprouts was significantly higher than for broccoli and mustard greens. These results point to the health promoting potential of spinach = kale = brussels sprouts > broccoli = mustard greens > cabbage = green bell peppers = collards, as indicated by their bile acid binding on dry matter basis.	Kahlon et al. (2007)
4	Phenolic acid contents of kale extracts and their antioxidant and antibacterial activities	Nine phenolic acids were identified and quantified by HPLC–MS in leaves and their antimicrobial properties are determined against different micro organisms.	Concluded that, kale leaves rated as good dietary sources of natural phenolic antioxidants and other compounds with high or moderate antimicrobial activity. The plant extracts of kale showed anti bacterial effect on Gram-positive (*S. aureus, E. faecalis, B. subtilis*), Gram-negative (*M. catarrhalis*) bacteria,and the two yeast-like fungi (C. *tropicali and C. albicans*),	Ayaz, et al., (2008)
5	Kale Juice on Coronary Artery Disease risk factors in Hypercholesterolemic men	Evaluated the effect kale juice supplementation on coronary artery disease risk factors among 32 hyper-cholesterolemic men. The subjects consumed 150 mL of kale juice per day for a 12-week intervention period.	Study concluded that, regular meals supplementation with kale juice can favorably influence serum lipid profiles and antioxidant systems, and hence contribute to reduce the risks of coronary artery disease in male subjects with Hyperlipidemia.	SooYeon S. Y. Kim et al. (2008)

(*Continued*)

Table 7. (*Continued*)

S. No	Area of research	Methodology employed	Findings and conclusions	References
6	Kale and papaya supplementation in colitis induced by Tri-nitrobenzenesulfonic (TNBS) acid in the rat	Researchers evaluated the effect of dried vegetables as a prebiotic and intestinal anti-inflammatory in the rat colitis model. Rats received, orally, 500 mg/kg of rat weight of three treatments of dried vegetables: papaya, kale and the mixture of both vegetables (60% of kale plus 40% of papaya). After two weeks of feeding the evaluation was done to determine anti-inflammatory activity.	Administration of the mixture was able to modulate the bacterial flora in healthy rats, as well as in rats with colitis induced by TNBS. In addition mixture of kale and papaya showed intestinal anti-inflammatory effect in the colitic rats.	Lima et al. (2010)
7	Kale on Genotoxic and Anti-genotoxic potential in Different Cells of Mice	The researchers were performed this study using the comet assay, on leukocytes, liver, brain, bone marrow and testicular cells,and using the micronucleus test (MN) in bone marrow cells. In this study, eight groups of albino Swiss mice were used, control (C), positive control (doxorubicin 80 mg/kg (DXR)) and six experimental groups, which received 500, 1000 and 2000 mg/kg of kale extract alone while a further three groups received the same doses plus DXR (80 mg/kg).	The results demonstrated that none of the tested doses of kale extract showed genotoxic effects by the comet assay, or clastogenic effects by the MN test. In addition, all cells evaluated, the three tested doses of the kale extract promoted inhibition of DNA damage induced by DXR. Finally, concluded that, kale leaf extract showed no genotoxic or clastogenic effects in different cells of mice. However, it showed a significant decrease in DNA damage induced by doxorubicin.	Gonçalves et al. (2012)
8	Gastroprotective activity of hydroalcoholic extract of kale leaves	Antiulcer assays were performed using the protocol of ulcer induced by ethanol/HCl, and non-steroidal anti-inflammatory drugs (NSAIDs). Parameters of gastric secretion were determined by the pylorus ligation model and mucus in gastric contents. In the study used Wistar rat's female (250–350 g) and Swiss mice male (25–35 g) were supplemented with food and groups of six, in standard cages. The kale extract administered by the oral route at 25, 50 and 100 mg/kg.	Study showed a significant increase in gastric pH and mucus production in the groups treated with kale when compared with the control group. The results of the present study showed that hydroalcoholic extract of kale displays antiulcer activity, as demonstrated by the significant inhibition of ulcer formation induced using different models.	Lemos et al. (2011)
9	Kale juice supplementation up-regulates HSP70 and suppresses cognitive decline in a mouse model of accelerated senescence	In this study researchers investigated the ability of kale juice dietary supplementation to delay cognitive decline in the senescence-accelerated mouse prone 8 (SAMP8) mouse. SAMP8 mice were fed a diet containing 0.8% (W/W) of kale for 16 weeks, and cognitive performance was examined using the Morris water maze.	Kale juice administration improved spatial and leaning memory as well as suppressed levels of serum 8-hydroxy-2′-deoxyguanosine and brain malondialdehyde with respect to the control group. This study concluded that dietary kale supplementation can suppress cognitive decline and age-related oxidative damage through the activation of HSP70 in SAMP8 mice.	Kushimoto et al. (2018)

(*Continued*)

https://doi.org/10.1080/23311932.2020.1811048

Table 7. (*Continued*)

S. No	Area of research	Methodology employed	Findings and conclusions	References
10	Inhibitory effect of whole strawberries, garlic juice or Kale Juice on endogenous formation of N-nitrosodimethylamine (NDMA) in Humans	*In vitro* and *in vivo* experiments were performed on inhibition of nitrosation by strawberry, garlic and kale extracts. They studied the formation of the carcinogen NDMA in humans after administration of nitrate (400 mg/day) in combination with an amine-rich diet and its possible inhibition by administration of whole strawberries (300 g), garlic juice (200 g: 75 g garlic juice in drinking water), or kale juice (200 g) in 27 males and 13 females (ten healthy volunteers in each group) of age 24±3 years.	Authors were reported that nitrate intake resulted in a significant increase in mean salivary nitrate and nitrite concentrations. Also, nitrate excretion in urine during the experimental day was significantly increased compared with the control days. When whole strawberries, garlic juice, or kale juice was provided immediately after an amine-rich diet with a nitrate, NDMA excretion was decreased by 70, 71 and 44%, respectively, compared with NDMA excretion after ingestion of an amine-rich diet with a nitrate. These results suggest that consumption of whole strawberries, garlic juice, or kale juice can reduce endogenous NDMA formation.	Chung et al. (2002)
11	Functionality and bioavailability of kaempferol- glucoside in kale by its glucosidase activity by gut microbes	Researchers studied the effects of the probiotic *Lactobacillus paracasei* A221 on the functionality and bioavailability of kaempferol-3-o-sophroside (KP3S), a kaempferol-glucoside contained in kale, were investigated *in vitro* and *in vivo*.	Authors were reported that, using an intestinal barrier model, treatment with *Lactobacillus paracasei* A221 significantly improved the effects of kale extract on the barrier integrity in *in vitro*. Kaempferol (KP), but not KP3S, clearly induced similar effects, suggesting that KP contributes to the functional improvement of the kale extract by *Lactobacillus paracasei* A221. Pharmacokinetics analyses revealed that the co-administration of *Lactobacillus paracasei* A221 and KP3S significantly enhanced the amount of deconjugated KP in murine plasma samples at 3 h post-administration. Finally, the oral administration of KP clearly ameliorated various pathologies, including skin thinning, fatty liver and anemia.	Shimojo et al. (2018)

Table 8. Various food products from kale reported by different authors

#	Product	Objective/Method	Findings of the Results	References
1	Bread	The impact of kale leaves on bread making was assessed.	This study revealed that baking of non-processed kale in bread induced relatively low losses of flavonoids, but high losses of glucosinolates break down products, carotenoids and chlorophylls. Additionally, in kale an increase in hydroxycinnamic acid derivatives was found after bread preparation. Hence, breads with added fresh kale could enrich health-promoting secondary plant metabolites in baked goods.	Klopsch et al. (2019)
2	Fermented kale juice	Fermented kale juices was prepared using four types of *Lactobacilli*	The study findings reported as after 48 h of fermentation time, viable cell counts of all ferments reached an above 10^9 CFU/mL. The viability of the ferments after cold storage in the refrigerator for 4 weeks showed 10^8 CFU/mL in all ferments. Among four types of fermented kale juices, the ferment of *Lactobacillus acidophilus* IFO 3025 indicated a good nutritional composition, including neutral sugar (909. 76 µg/mL), reducing sugar (564.00 µg/mL). Authors were concluded that probiotic kale juices produced useful for the prevention of chronic diseases and are suggested as healthy probiotic fermented beverages with high essential nutrients.	Seong Yeong Kim (2017)
3	Fermentation of African kale by L. *plantarum* BFE 5092 and L. *fermentum* BFE 6620 starters	*Lactobacillus plantarum* BFE 5092 and *Lactobacillus fermentum* BFE 6620 starter strains were investigated for their application in fermentation of African kale.	The strains utilized simple sugars in the kale to quickly reduce the pH from pH 6.0 to pH 3.6 within 24 h. The strains continued to produce both D and L-lactic acid up to 144 h, reaching a maximum concentration of 4.0 g/L. Although vitamins C, B1 and B2 decreased during the fermentation, the final level of vitamin C in the product was an appreciable concentration of 35 mg/100 g and shelf life also extended. Researchers concluded that, controlled fermentation of kale offers a promising avenue to prevent spoilage and improve the shelf life and safety.	Wafula et al. (2015)
4	Kale Juice spontaneous fermentation by Lactic acid bacteria	This study report on spontaneous fermentation of curly kale and characteristics of autochthonous Lactic acid bacteria in kale juice production.	Kale fermentation is the new possibility of the technological use of kale. Ten different species of bacteria species were isolated from three phases of kale fermentation. Among them, four species were identified as Lactobacillus spp. (L. plantarum *332*, L. paraplantarum G2114, L. brevis R413, L. curvatus 154), two as Weissella spp. (W. hellenica 152, W. cibaria G44), two as Pediococcus spp. (P. pentosaceus 45AN, P. acidilactici 2211), one as Leuconostoc mesenteroides 153 and one as Lactococcus lactis 37BN.	Oguntoyinbo et al. (2016)
5	Drying of kale in convective hot air dryer	Authors studied the effect of air temperature and sample thickness (10, 20, 40 and 50 mm) on the drying kinetics of kale using a convective air-dryer at a fixed airflow rate of 1 m/s and drying air temperatures of 30, 40, 50 and 60 °C.	The drying rate increased with drying air temperature but decreased with layer thickness. The effective diffusivity for 10 mm thick layers was found to increase with the drying air temperature and ranged between 14.9 and 55.9 × 10^{-10} m^2/s. The effect of temperature on diffusivity could be expressed by an Arrhenius type relationship with a high R^2 of 0.9989. The activation energy of kale was found to be 36.115 kJ/mol.	Mwithiga and Olwal (2005)

(*Continued*)

Table 8. (*Continued*)

#	Product	Objective/Method	Findings of the Results	References
6	Fresh kale juice treated with gamma irradiation	Researchers evaluated gamma radiation treatment on shelf life of natural kale juice. The total aerobic bacteria in fresh kale juice, prepared by a general kitchen process and the bacteria survived in the juice in spite of gamma irradiation treatment was determined.	Two typical radiation-resistant bacteria, *Bacillus megaterium* and *Exiguobacterium acetylicum* were isolated and identified from the 5 kGy-irradiated kale juices. The growth of the surviving *B. megaterium* and *E. acetylicum* in the 3–5 kGy-irradiated kale juice retarded and/or decreased significantly during a 3 day post-irradiation storage period. This study suggested that 3–5 kGy of gamma irradiation may be effective for prolonging the shelf-life of natural kale juice from a microbiological point of view.	D. Kim et al. (2007)
7	Fresh Ashitaba and kale juice treatment with gamma irradiation	In this study, examined the effects of irradiation on the microbiological, chemical and sensory properties of ashitaba and kale juices for industrial application and possible shelf-life extension.	Irradiation of 5 kGy induced higher than 2 decimal reductions in the microbial level, which was consistently maintained during storage for 7 days under refrigerated conditions. Total content of ascorbic acid in vegetable juice decreased upon irradiation in a dose-dependent manner, in contrast, flavonoids did not change, whereas that of polyphenols increased upon irradiation. This study recommended irradiation sterilizing fresh vegetable juice.	Jo et al. (2012)
8	Beverages based on apple Juice with addition of frozen and freeze-dried kale leaves	Authors were determined the polyphenols, glucosinolates and ascorbic acid content including antioxidant activity of beverages on the base of apple juice with addition of frozen and freeze-dried kale leaves.	Upon enrichment with frozen (13%) and freeze-dried curly kale (3%), the naturally cloudy apple juice showed an increase in phenolic compounds by 2.7 and 3.3-times, accordingly. The antioxidant activity of beverages with the addition of curly kale ranged from 6.6 to 9.4 μmol Trolox/mL. Prepared beverages were characterized glucosinolates content at 117.6–167.6 mg/L and ascorbic acid content at 4.1–31.9 mg/L. Sensory acceptability of prepared juice reported high acceptability.	Ró Ża et al. (2017)
9	Whey protein isolate-kale leaves chlorophyll (WPI-CH) microcapsules	The authors were reported whey protein isolate-kale leaves chlorophyll (WPI-CH) microcapsules were prepared by spray drying. Effect of inlet air drying temperatures on the physicochemical properties and antioxidant activity of WPI-CH microcapsules were investigated	The moisture content of WPI-CH (20% addition) microcapsule was decreased by 21.1% with the inlet air drying temperature increased from 120 to 180 °C. The encapsulation efficiency and solubility of chlorophyll were enhanced by 3.78% and 7.79%, respectively. Furthermore, DPPH scavenging capacity of WPI-CH microcapsules under different addition of chlorophyll were increased from 42.9% to 74.3%, 52.7%–82.7% and 71.8%–85.3%, respectively. This method concluded as promising to preserve chlorophyll with WPI.	Zhang et al. (2019)
10	Kale purée: Thermal processing impact on process intensity and storage on quality	The authors were focused on investigating quality changes of thermally processed kale purée. Low, medium and high processing intensities (carried out at 70, 90 and 128 °C) were used.	The physicochemical properties, consumer acceptability of the puree is largely dependent on the treatment intensity. The high intensity treatments resulted in the least favorable quality characteristics (distinct brown color, chlorophyll and vitamin C destruction as well as a phase separation after storage). Enzymes were inactivated with increasing thermal load. Form this study concluded that, intermediate thermal process intensity seems the best choice to create a high quality kale product that is reasonably quality stable under refrigerated conditions.	Wibowo et al. (2019)

properties. Research should conduct on the loss of nutrient in kale by different preservation, processing or cooking methods.

Acknowledgements
The authors are grateful to the Dean, Faculty of Chemical and Food Engineering, at Bahir Dar Institute of Technology, Bahir Dar University, Bahir Dar, Ethiopia for constant encouragement in publishing this review article. We are always kind to Professor Nageshwer Rao for helping in proof reading and editing of this article.

Author details
Neela Satheesh[1]
E-mail: neela.micro2005@gmail.com
ORCID ID: http://orcid.org/0000-0002-6474-2594
Solomon Workneh Fanta[1]
ORCID ID: http://orcid.org/0000-0002-0244-1104
[1] Bahir Dar University, Bahir Dar, Ethiopia.

Disclosure statement
The authors declare no conflict of interest.

Funding
The authors received no direct funding for this research.

Ethical statement
This article does not involve any human or animal testing

Citation information
Cite this article as: Kale: Review on nutritional composition, bio-active compounds, anti-nutritional factors, health beneficial properties and value-added products, Neela Satheesh & Solomon Workneh Fanta, *Cogent Food & Agriculture* (2020), 6: 1811048.

References

Achikanu, C. E., Eze-Steven, P. E., U de, C. M., & Ugwuokolie, O. C. (2013). Determination of the vitamin and mineral composition of common leafy vegetables in south eastern Nigeria. *International Journal Current Microbiology Applications Science*, *2*(11), 347–353. https://www.ijcmas.com/vol-2-11/C.E.Achikanu,%20et%20al.pdf

Acikgoz, F. E. (2011). Mineral, vitamin C and crude protein contents in kale (Brassica oleraceae var. acephala) at different harvesting stages. *Africa Journal Biotechnology*, *10*(7), 17170–17174. https://doi.org/10.5897/AJB11.2830

Adefegha, S. A., & Oboh, G. (2011). Enhancement of total phenolics and antioxidant properties of some tropical green leafy vegetables by steam cooking. *Journal of Food Processing and Preservation*, *35*(5), 615–622. https://doi.org/10.1111/j.1745-4549.2010.00509.x

Adeyeye, A., Ayodele, O. D., Akinnuoye, G. A., & Sulaiman, W. (2018). Proximate composition and fatty acid profiles of two edible leafy vegetables in nigeria. *America Journal Food Nutrition Health*, *3*(2), 51–55. http://article.aascit.org/file/pdf/8290019.pdf

Agati, G., Azzarello, E., Pollastri, S., & Tattini, M. (2012). Flavonoids as antioxidants in plants: Location and functional significance. *Plant Science*, *196*(1), 67–76. https://doi.org/10.1016/j.plantsci.2012.07.014

Agbaire, P. (2011). Nutritional and anti-nutritional levels of some local vegetables(Vernomia anydalira, Manihot esculenta, Teiferia occidentalis, Talinum triangulare, Amaranthus spinosus) from Delta State, Nigeria. *Journal Applications Science Environment Management*, *15*(4), 625–628. https://www.ajol.info/index.php/jasem/article/view/88615

Agbaire, P. O. (2012). Nutritional and antinutritional levels of some local vegetables from Delta State, Nigeria. *African JournalFood*, *Sci.6*(1), 8–11. https://doi.org/10.5897/ajfs111.175

Agte, V. V., Tarwadi, K. V., Mengale, S., & Chiplonkar, S. A. (2000). Potential of traditionally cooked green leafy vegetables as natural sources for supplementation of eight micronutrients in vegetarian diets. *Journal of Food Composition and Analysis*, *13*(6), 885–891. https://doi.org/10.1006/jfca.2000.0942

Aly, N., El-Gendy, K., Mahmoud, F., & El-Sebae, A. K. (2010). Protective effect of vitamin C against chlorpyrifos oxidative stress in male mice. *Pesticide Biochemistry and Physiology*, *97*(1), 7–12. https://doi.org/10.1016/j.pestbp.2009.11.007

Andarwulan, N., Batari, R., Sandrasari, D. A., Bolling, B., & Wijaya, H. (2010). Flavonoid content and antioxidant activity of vegetables from Indonesia. *Food Chemistry*, *121*(4), 1231–1235. https://doi.org/10.1016/j.foodchem.2010.01.033

Anjana, S. U., & Iqbal, M. (2007). Nitrate accumulation in plants, factors affecting the process, and human health implications-A review. *Agronomy for Sustainable Development*, *27*(1), 45–57. https://doi.org/10.1051/agro

Anonymous. (1998). *Dietary reference intakes: A risk assessment model for establishing upper intake levels for nutrients*. Food and Nutritional Board, National Academies Press.

Anonymous. (2010). Scientific opinion on dietary reference values for carbohydrates and dietary fibre. *EFSA. Journal*, *8*(3), 1462–1539. https://doi.org/10.2903/j.efsa.2010.1462

Anonymous. (2011). Scientific opinion on the substantiation of health claims related to the sugar replacers xylitol, sorbitol, mannitol, maltitol, lactitol, isomalt, erythritol, D-tagatose, isomaltulose, sucralose and polydextrose and maintenance of tooth mineralisation, an. *EFSA Journal*, *9*(4), 2076–2101. https://doi.org/10.2903/j.efsa.2011.2076

Arnold, C., Jentsch, S., Dawczynski, J., & Böhm, V. (2013). Age-related macular degeneration: Effects of a short-term intervention with an oleaginous kale extract-a pilot study. *Nutrition*, *29*(11–12), 1412–1417. https://doi.org/10.1016/j.nut.2013.05.012

Arowora, K. A., Ezeonu, C. S., Imo, C., & Nkaa, C. G. (2017). Protein levels and amino acids composition in some leaf vegetables sold at wukari in taraba state, Nigeria. *International Journal Biology Science Applications*, 4(2), 19–24. https://pdfs.semanticscholar.org/5618/6cf3cc4489d4997027a35b1f088f2ea807fe.pdf

Aryal, S., Baniya, M. K., Danekhu, K., Kunwar, P., Gurung, R., & Koirala, N. (2019). Total phenolic content, flavonoid content and antioxidant potential of wild vegetables from western Nepal. *Plants*, *8*(4), 96–107. https://doi.org/10.3390/plants8040096

Ayaz, F. A., Glew, R. H., Millson, M., Huang, H. S., Chuang, L. T., Sanz, C., & Haryirhoglu-Ayaz, S. (2006). Nutrient contents of kale [brassica oleraceae l. var. acephala dc.]. *Food Chemistry*, *96*(4), 572–579. https://doi.org/10.1016/j.foodchem.2005.03.011

Ayaz, F. A., Hayırlıoglu-Ayaz, S., Alpay-Karaoglu, S., Grúz, J., Valentová, K., Ulrichová, J., Strnad, M. (2008). Phenolic acid contents of kale (Brassica oleraceae L. var. acephala DC.) extracts and their antioxidant and antibacterial activities. Food Chemistry, 109(1), 19-25. https://doi.org/10.1016/j.Food Chemistry.2007 2007 107.07 1.003 doi:10.1016/j.foodchem.2007.07.003

Bahorun, T., Luximon-Ramma, A., Crozier, A., & Aruoma, O. I. (2004). Total phenol, flavonoid, proanthocyanidin and vitamin C levels and antioxidant activities of Mauritian vegetables. *Journal of the Science of Food and Agriculture*, *84*(12), 1553–1561. https://doi.org/10.1002/jsfa.1820

Barrett, D. M., Beaulieu, J. C., & Shewfelt, R. (2010). Color, flavor, texture, and nutritional quality of fresh-cut fruits and vegetables: Desirable levels, instrumental and sensory measurement, and the effects of processing. *Critical Reviews in Food Science and Nutrition*, *50*(5), 369–389. https://doi.org/10.1080/10408391003626322

Batista-Silva, W., Nascimento, V. L., Medeiros, D. B., Nunes-Nesi, A., Ribeiro, D. M., Zsögön, A., & Araújo, W. L. (2018). Modifications in organic acid profiles during fruit development and ripening: Correlation or causation? *Frontiers Plant Science*, *9*(1), 1–20. https://doi.org/10.3389/fpls.2018.01689

Bazzano, L. A., Green, T., Harrison, T. N., & Reynolds, K. (2013). Dietary approaches to prevent hypertension. *Current Hypertension Reports*, *15*(6), 694–702. https://doi.org/10.1007/s11906-013-0390-z

Bhandari, M. R., & Kawabata, J. (2004). Assessment of antinutritional factors and bioavailability of calcium and zinc in wild yam (Dioscorea spp.) tubers of Nepal. *Food Chemistry*, *85*(2), 281–287. https://doi.org/10.1016/j.foodchem.2003.07.006

Bhattacharjee, S., Dasgupta, P., Paul, A. R., Ghosal, S., Padhi, K. K., & Pandey, L. P. (1998). Mineral element composition of spinach. *Journal of the Science of Food and Agriculture*, *77*(4), 456–458. https://doi.org/10.1002/(SICI)1097-0010(199808)77:4<456::AID-JSFA55>3.0.CO;2-M

Bhattacharya, P. T., Misra, S. R., & Hussain, M. (2016). Nutritional aspects of essential trace elements in oral health and disease: An extensive review. *Scientifica*, *2016*, 1–12. Article ID5464373. https://doi.org/10.1155/2016/5464373

Biehler, E., Alkerwi, A., Hoffmann, L., Krause, E., Guillaume, M., Lair, M. L., & Bohn, T. (2012). Contribution of violaxanthin, neoxanthin, phytoene and phytofluene to total carotenoid intake: Assessment in Luxembourg. *Journal of Food Composition and Analysis*, *25*(1), 56–65. https://doi.org/10.1016/j.jfca.2011.07.005

Binia, A., Jaeger, J., Hu, Y., Singh, A., & Zimmermann, D. (2015). Daily potassium intake and sodium-to-potassium ratio in the reduction of blood pressure: A meta-analysis of randomized controlled trials. *Journal of Hypertension*, *33*(8), 1509–1520. https://doi.org/10.1097/HJH.0000000000000611

Booth Sarah, L., Guylaine, L. F., John, A. W., & Guylaine, L. F. (1993). Vitamin K1 (Phylloquinone) content of foods: A provisional table. *Journal of Food Composition and Analysis*, *6*(2), 109–120. https://doi.org/10.1006/jfca.1993.1014

Bryan, L. 2020. How avocados and kale became so popular. BBC Work Life. 5 January. https://www.bbc.com/worklife/article/20190304-how-avocados-and-kale-became-so-popular.

Calder, P. C. (2015). Marine omega-3 fatty acids and inflammatory processes: Effects, mechanisms and clinical relevance. *Biochemistry Biophysics Acta*, *1851*(4), 469–484. https://doi.org/10.1016/j.bbalip.2014.08.010

Calderón-Montaño, J. M., Burgos-Morón, E., Pérez-Guerrero, C., & López-Lázaro, M. (2011). A review on the dietary flavonoid kaempferol. *Mini-Reviews in Medicinal Chemistry*, *11*(4), 298–344. https://doi.org/10.2174/138955711795305335

Calvo, M. M. (2005). Lutein: A valuable ingredient of fruit and vegetables. *Critical Reviews in Food Science and Nutrition*, *45*(7–8), 671–696. https://doi.org/10.1080/10408690590957034

Cao, G., Sofic, E., & Prior, R. L. (1997). Antioxidant and prooxidant behavior of flavonoids: Structure-activity relationships. *Free Radical Biology and Medicine*, *22*(5), 749–760. https://doi.org/10.1016/S0891-5849(96)00351-6

Carlson, D., Daxenbichler, M., Vanetten, C., Kwolek, W., & Williams, P.(1987). Glucosinolates in crucifer vegetables : Broccoli, brussels sprouts, cauliflower, collards, kale, mustard greens, and kohlrabi. *Journal American Socity Horticultural Science*, *112*(1), 173–178. https://naldc.nal.usda.gov/download/23901/PDF

Cartea, M. E., Francisco, M., Soengas, P., & Velasco, P. (2011). Phenolic compounds in Brassica vegetables. *Molecules*, *16*(1), 251–280. https://doi.org/10.3390/molecules16010251

Catak, J., & Yaman, M. (2019). Determination of nicotinic acid and nicotinamide forms of Vitamin B3 (Niacin) in fruits and vegetables by HPLC using postcolumn derivatization system. *Pakistan Journal of Nutrition*, *18*(6), 563–570. https://doi.org/10.3923/pjn.2019.563.570

Catani, M. V., Savini, I., Rossi, A., Melino, G., & Avigliano, L. (2005). Biological role of vitamin C in keratinocytes. *Nutrition Reviews*, *63*(3), 81–90. https://doi.org/10.1301/nr.2005.mar.000-000

Cerdó, T., García-Santos, J. A., Bermúdez, M. G., & Campoy, C. (2019). The role of probiotics and prebiotics in the prevention and treatment of obesity. *Nutrients*, *11*(3), 1–31. https://doi.org/10.3390/nu11030635

Chandrasekara, A., & Josheph Kumar, T. (2016). Roots and tuber crops as functional foods: A review on phytochemical constituents and their potential health benefits. *International Journal of Food Science*, *2016*, 1–15. Article ID3631647. https://doi.org/10.1155/2016/3631647

Charron, C. S., Novotny, J. A., Jeffery, E. H., Kramer, M., Ross, S. A., & Seifried, H. E. (2020). Consumption of baby kale increased cytochrome P450 1A2 (CYP1A2) activity and influenced bilirubin metabolism in a randomized clinical trial. *Journal of Functional Foods*, *64*(8), 103624. https://doi.org/10.1016/j.jff.2019.103624

Cheynier, V. (2012). Phenolic compounds: From plants to foods. *Phytochemistry Reviews*, *11*(2–3), 153–177. https://doi.org/10.1007/s11101-012-9242-8

Chinyere, G. C., & Obasi, N. A. (2011). Changes in the amino acids contents of selected leafy vegetables subjected to different processing treatments. *African Journal Biochemistry Research*, *5*(6), 182–187. http://www.academicjournals.org/app/webroot/article/article1380186785_Chinyere%20and%20Obasi.pdf

Chiplonkar, S. A., Tarwadi, K. V., Kavedia, R. B., Mengale, S. S., Paknikar, K. M., & Agte, V. V. (1999). Fortification of vegetarian diets for increasing bioavailable iron density using green leafy vegetables. *Food Research International*, *32*(3), 169–174. https://doi.org/10.1016/S0963-9969(99)00070-8

Choo, Y. M., Yapa, S. C., Ooi, C. K., Ma, A. N., Goh, S. H., & Ong, S. H. (1996). Recovered oil from palm-pressed fiber: A good source of natural carotenoids, vitamin E, and sterols. *Journal of the American Oil Chemists' Society*, *73*(5), 599–602. https://doi.org/10.1007/BF02518114

Chung, M. J., Lee, S. H., & Sung, N. J. (2002). Inhibitory effect of whole strawberries, garlic juice or kale juice on endogenous formation of N-nitrosodimethylamine in humans. *Cancer Letters*, *182*(1), 1–10. https://doi.org/10.1016/S0304-3835(02)00076-9

Cleary, B. V. M. (2003). Dietary fibre analysis. *Proceedings of the Nutrition Society*, *62*(1), 3–9. https://doi.org/10.1079/pns2002204

Clifton, P. M., & Keogh, J. B. (2017). A systematic review of the effect of dietary saturated and polyunsaturated fat on heart disease. *Nutrition, Metabolism and Cardiovascular Diseases*, *27*(12), 1060–1080. https://doi.org/10.1016/j.numecd.2017.10.010

Coleman, J. (2015). *Threonine: Food sources, functions and health benefits*. Nova Science, Hauppauge.

Connie, M. W., & Aren, L. P. (1994). Dietary calcium: Adequacy of a vegetarian diet. *The American Journal of Clinical Nutrition*, *59*(5), 1238S–1241S. https://doi.org/10.1136/bmj.2.6095.1105-a

Davani-Davari, D., Negahdaripour, M., Karimzadeh, I., Seifan, M., Mohkam, M., Masoumi, S. J., Berenjian, A., & Ghasemi, Y. (2019). Prebiotics: Definition, types, sources, mechanisms, and clinical applications. *Foods*, *8*(3), 1–27. https://doi.org/10.3390/foods8030092

De Azevedo, C. H., & Rodriguez-Amaya, D. B. (2005). Carotenoid composition of kale as influenced by maturity, season and minimal processing. *Journal of the Science of Food and Agriculture*, *85*(4), 591–597. https://doi.org/10.1002/jsfa.1993

De Sá, M. C., & Rodriguez-Amaya, D. B. (2003). Carotenoid composition of cooked green vegetables from restaurants. *Food Chemistry*, *83*(4), 595–600. https://doi.org/10.1016/S0308-8146(03)00227-9

Denke, M. A., & Grundy, S. M. (1991). Effects of fats high in stearic acid on lipid and lipoprotein concentrations in men. *The American Journal of Clinical Nutrition*, *54*(6), 1036–1040. https://doi.org/10.1093/ajcn/54.6.1036

Dennis, M. J., & Wilson, L. A. (2003). Nitrates and nitrites. In C. Benjamin (Ed.), *Encyclopedia of Food Sciences and Nutrition,2 ed* (pp. 4136–4141). Academic Press.

Di Noia, J. (2014). Defining powerhouse fruits and vegetables: A nutrient density approach. *Preventing Chronic Disease*, *11*(6), 3–7. https://doi.org/10.5888/pcd11.130390

Doleman, J. F., Grisar, K., Van Liedekerke, L., Saha, S., Roe, M., Tapp, H. S., & Mithen, R. F. (2017). The contribution of alliaceous and cruciferous vegetables to dietary sulphur intake. *Food Chemistry*, *234*(1), 38–45. https://doi.org/10.1016/j.foodchem.2017.04.098

Dunbar, B. S., Bosire, R. V., & Deckelbaum, R. J. (2014). Omega-3 and omega-6 fatty acids in human and animal health: An African perspective. *Molecular and Cellular Endocrinology*, *398*(1–2), 69–77. https://doi.org/10.1016/j.mce.2014.10.009

Edelman, M., & Colt, M. (2016). Nutrient value of leaf vs. seed. *Frontiers in Chemistry*, 4(1), 2–6. https://doi.org/10.3389/fchem.2016.00032

Ejtahed, H. S., Angoorani, P., Soroush, A. R., Mortazavian, A. M., Larijanid, B., Atlasi, R., & Hasani-Ranjbara, S. (2019). Probiotics supplementation for the obesity management; A systematic review of animal studies and clinical trials. *Journal of Functional Foods*, *52*, 228–242. https://doi.org/10.1007/s00223-017-0339-3

El Khoury, D., Cuda, C., Luhovyy, B. L., & Anderson, G. H. (2012). Beta glucan: Health benefits in obesity and metabolic syndrome. *Journal Nutrition Methods*, *2012*. Article ID851362. https://doi.org/10.1155/2012/851362

El-Seedi, H. R., El-Said, A. M. A., Khalifa, S. A. M., Goransson, U., Bohlin, L., Borg-Karlson, A. K., & Verpoorte, R. (2012). Biosynthesis, natural sources, dietary intake, pharmacokinetic properties, and biological activities of hydroxycinnamic acids. *Journal of Agricultural and Food Chemistry*, *60*(44), 10877–10895. https://doi.org/10.1021/jf301807g

Emebu, P., & Anyika, J. (2011). Proximate and mineral composition of kale (brassica oleracea) grown in Delta State, Nigeria. . *Pakistan Journal of Nutrition*, *10*(2), 190–194. https://doi.org/10.3923/pjn.2011.190.194

Eppendorfer, W. H., & Bille, S. W. (1996). Free and total amino acid composition of edible parts of beans, kale, spinach, cauliflower and potatoes as influenced by nitrogen fertilisation and phosphorus and potassium deficiency. *Journal of the Science of Food and Agriculture*, *71*(4), 449–458. https://doi.org/10.1002/(SICI)1097-0010(199608)71:4<449::AID-JSFA601>3.0.CO;2-N

Erdogan, B. Y., & Onar, A. N. (2011). Determination of nitrates, nitrites and oxalates in kale and sultana pea by capillary electrophoresis. *Journal of Animal and Veterinary Advances*, *10*(15), 2051–2057. https://doi.org/10.3923/javaa.2011.2051.2057

Fadigas, J. C., Dos Santos, A. M., de Jesus, R. M., Lima, D. C., Fragoso, W. D., David, J. M., & Ferreira, S. L. (2010). Use of multivariate analysis techniques for the characterization of analytical results for the determination of the mineral composition of kale? *Micro Chemistry Journal*, *96*(2), 352–356. https://doi.org/10.1016/j.microc.2010.06.0060

Fahey, J. W. (2003). Brassica. In C. Benjamin (Ed.), *Encyclopedia of Food Sciences and Nutrition, 2nd ed* (pp. 606–615). Academic Press.

Fischer Walker, C. L., Ezzati, M., & Black, R. E. (2009). Global and regional child mortality and burden of disease attributable to zinc deficiency. *European Journal of Clinical Nutrition*, *63*(5), 591–597. https://doi.org/10.1038/ejcn.2008.9

Flores, P., Hellín, P., & Fenoll, J. (2012). Determination of organic acids in fruits and vegetables by liquid chromatography with tandem-mass spectrometry. *Food Chemistry*, *132*(2), 1049–1054. https://doi.org/10.1016/j.foodchem.2011.10.064

Forouhi, N. G., Krauss, R. M., Taubes, G., & Willett, W. (2018). Dietary fat and cardiometabolic health: Evidence, controversies, and consensus for guidance. *The Bmj*, *361*(K2139), 1–8. https://doi.org/10.1136/bmj.k2139

Gonçalves, Á. L. M., Lemos, M., Niero, R., De Andrade, S. F., & Maistro, E. L. (2012). Evaluation of the genotoxic and antigenotoxic potential of Brassica oleracea L. var. acephala D.C. in different cells of mice. *Journal of Ethnopharmacology*, *143*(2), 740–745. https://doi.org/10.1016/j.jep.2012.07.044

Gopalan, C., Sastri, B. V. R., & Balasubramanian, S. C. (1989). *Nutritive value of Indian foods*. National Institute of Nutrition, Indian Council of Medical Research.

Górska-Warsewicz, H., Laskowski, W., Kulykovets, O., Kudlińska-Chylak, A., Czeczotko, M., & Rejman, K. (2018). Food products as sources of protein and amino acids-The case of Poland. *Nutrients*, *10*(12), 1977–1997. https://doi.org/10.3390/nu10121977

Grembecka, M. (2015). Sugar alcohols—their role in the modern world of sweeteners: A review. *European Food Research and Technology*, *241*(1), 1–14. https://doi.org/10.1007/s00217-015-2437-7

Gupta, K., & Rana, M. K. (2003). Salad crops, leaf-types. In C. Benjamin (Ed.), *Encyclopedia of Food Sciences and Nutrition,2nded* (pp. 5060–5073). Academic Press.

Gupta, R. K., Gangoliya, S. S., & Singh, N. K. (2013). Reduction of phytic acid and enhancement of bioavailable micronutrients in food grains. *Journal of Food Science and Technology*, *52*(2), 676–684. https://doi.org/10.1007/s13197-013-0978-y

Gupta, S., Gowri, B. S., Lakshmi, A. J., & Prakash, J. (2013). Retention of nutrients in green leafy vegetables on dehydration. *Journal of Food Science and Technology*, *50*(5), 918–925. https://doi.org/10.1007/s13197-011-0407-z

Hagen, S. F., Borge, G. I. A., Solhaug, K. A., & Bengtsson, G. B. (2009). Effect of cold storage and harvest date on bioactive compounds in curly kale [Brassicaoleracea L. var. acephala]. *Postharvest Biology and Technology*, *51*(1), 36–42. https://doi.org/10.1016/j.postharvbio.2008.04.001

Hasan, M. N., Akhtaruzzaman, M., & Sultan, M. Z. (2013). Estimation of Vitamins B-complex (B2, B3, B5 and B6) of some leafy vegetables indigenous to bangladesh by HPLC Method. *Journal Analysis Science Methods Institute*, *3*(3), 24–29. https://doi.org/10.4236/jasmi.2013.33a004

Hassan, F. A., Ismail, A., Hamid, A. A., Azlan, A., & Al-Sheraji, S. H. (2011). Characterisation of fibre-rich powder and antioxidant capacity of Mangifera pajang K. fruit peels. *Food Chemistry*, *126*(1), 283–288. https://doi.org/10.1016/j.foodchem.2010.11.019

Hayes, C. (2001). The effect of non-cariogenic sweeteners on the prevention of dental caries: A review of the evidence. *Journal of Dental Education*, *65*(10), 1106–1109. https://doi.org/10.1002/j.0022-0337.2001.65.10.tb03457.x

Heaney, R. P., Weaver, C. M., Hinders, S., Martin, B., & Packard, P. T. (1993). Absorbability of calcium from brassica vegetables: Broccoli, Bok Choy, and Kale. *Journal of Food Science*, *58*(6), 1378–1380. https://doi.org/10.1111/j.1365-2621.1993.tb06187.x

Holden, J. M., Eldridge, A. L., Beecher, G. R., Marilyn Buzzard, I., Bhagwat, S., Davis, C. S., Douglass, L. W., Gebhardt, S., Haytowitz, D., & Schakel, S. (1999). Carotenoid content of U.S. foods: An update of the database. *Journal of Food Composition and Analysis*, *12*(3), 169–196. https://doi.org/10.1006/jfca.1999.082

Hossain, A., Khatun, M. A., Islam, M., & Huque, R. (2017). Enhancement of antioxidant quality of green leafy vegetables upon different cooking method. *Preventive Nutrition and Food Science*, *22*(3), 216–222. https://doi.org/10.3746/pnf.2017.22.3.216

Howard, G. M., Nguyen, T. V., Harris, M., Kelly, P. J., & Eisman, J. A. (1998). Genetic and environmental contributions to the association between quantitative ultrasound and bone mineral density measurements: A twin study. *Journal of Bone and Mineral Research*, *13*(8), 1318–1327. https://doi.org/10.1359/jbmr.1998.13.8.1318

Hunt, J. R. (2003). Bioavailability of iron, zinc, and other trace minerals from vegetarian diets. *The American Journal of Clinical Nutrition*, *78*(3), 633S–639S. https://doi.org/10.1093/ajcn/78.3.633s

Jaishankar, M., Tseten, T., Anbalagan, N., Mathew, B. B., & Beeregowda, K. N. (2014). Toxicity, mechanism and health effects of some heavy metals. *Interdisciplinary Toxicology*, *7*(2), 60–72. https://doi.org/10.2478/intox-2014-0009

Jandacek, R. J. (2017). Linoleic acid: A autritional quandary. *Healthcare*, *5*(2), 25–33. https://doi.org/10.3390/healthcare5020025

Jeffery, E. H., & Stewart, K. E. (2004). Upregulation of quinone reductase by glucosinolate hydrolysis products from dietary broccoli. *Methods. Enzymology*, *382*(2), 457–469. https:// doi.org/10.1016/S0076-6879(04)82025-1

Jo, C., Ahn, D. U., & Lee, K. H. (2012). Effect of gamma irradiation on microbiological, chemical, and sensory properties of fresh ashitaba and kale juices. *Radiation Physics and Chemistry*, *81*(8), 1076–1078. https://doi.org/10.1016/j.radphyschem.2011.11.065

Johari, M. A., & Khong, H. Y. (2019). Total phenolic content and antioxidant and antibacterial activities of pereskia bleo. *Advances in Pharmacological Sciences*, *2019*, 1–4. Article ID7428593. https://doi.org/10.1155/2019/7428593.

Johnson, M., McElhenney, W. H., & Egnin, M. (2019). Influence of green leafy vegetables in diets with an elevated ω-6: ω-3 fatty acid ratio on rat blood pressure, plasma lipids, antioxidant status and markers of inflammation. *Nutrients*, *11*(2), 1–14. https://doi.org/10.3390/nu11020301

Johnson, M., Pace, R. D., Dawkins, N. L., & Willian, K. R. (2013). Diets containing traditional and novel green leafy vegetables improve liver fatty acid profiles of spontaneously hypertensive rats. *Lipids Health Disease*, *12*(1), 1–7. https://doi.org/10.1186/1476-511X-12-168

Johnson, M., Pace, R. D., & Mc Elhenney, W. H. (2018). Green leafy vegetables in diets with a 25:1 omega-6/omega-3 fatty acid ratio modify the erythrocyte fatty acid profile of spontaneously hypertensive rats. *Lipids Health Disease*, *17*(1), 1–7. https://doi.org/10.1186/s12944-018-0723-7

Joy, E. J. M., Ander, E. L., Young, S. D., Black, C. R., Watts, M. J., Chilimba, A. D. C., Broadley, M. R., Siyame, E. W. P., Kalimbira, A. A., Hurst, R., Fairweather-Tait, S. J., Stein, A. J., Gibson, R. S., White, P. J., & Broadley, M. R. (2014). Dietary mineral supplies in Africa. . *Physiologia Plantarum*, *151*(3), 208–229. https://doi.org/10.1111/ppl.12144

Kader, A. A. (2008). Flavor quality of fruits and vegetables. Journal of the Science of Food and Agriculture, 881, 1863–1868. https://doi.org/10.1002/jsfa.3293 11 doi:10.1002/jsfa.v88:11

Kahlon, T. S., Chapman, M. H., & Smith, G. E. (2007). In vitro binding of bile acids by spinach, kale, brussels sprouts, broccoli, mustard greens, green bell pepper, cabbage and collards. *Food Chemistry*, *100*(4), 1531–1536. https://doi.org/10.1016/j.foodchem.2005.12.020

Kahlon, T. S., Chiu, M. C. M., & Chapman, M. H. (2008). Steam cooking significantly improved in vitro bile acid binding of collard greens, kale, mustard greens, broccoli, green bell pepper, and cabbage. *Nutrition Research*, *28*(6), 351–357. https://doi.org/10.1016/j.nutres.2008.03.007

Kawatra, A., Singh, G., & Sehgal, S. (2001). Nutriton composition of selected green leafy vegetables, herbs and carrots. *Plant Foods for Human Nutrition*, *56*(4), 359–365. https://doi.org/1011873119620

Kayashima, T., & Katayama, T. (2002). Oxalic acid is available as a natural antioxidant in some systems. *Biochimica Et Biophysica Acta (BBA) - General Subjects*, *1573*(1), 1–3. https://doi.org/10.1016/S0304-4165(02)00338-0

Keeton, J. T. (2011). History of nitrite and nitrate in Food. In N. S. Bryan & J. Loscalzo (Eds.), *Nitrite and nitrate in human health and disease* (pp. 69–84). Humana Press.

Kim, D., Song, H., Lim, S., Yun, H., & Chung, J. (2007). Effects of gamma irradiation on the radiation-resistant bacteria and polyphenol oxidase activity in fresh kale juice. *Radiation Physics and Chemistry*, *76*(7), 1213–1217. https://doi.org/10.1016/j.radphyschem.2006.12.003

Kim, S. Y. (2017). Production of fermented kale juices with lactobacillus strains and nutritional composition. *Preventive Nutrition and Food Science*, *22*(3), 231–236. https://doi.org/10.3746/pnf.2017.22.3.231

Kim, S. Y., Yooun, S., Kwon, S. M., Ke, S. P., & Lee-Kim, Y. C. (2008). Kale juice improves coronary artery disease risk factors in hypercholesterolemic men. *Biomedical and Environmental Sciences*, *21*(1), 91–97. https://doi.org/10.1016/S0895-3988(08)60012-4

Kim, Y. A., Keogh, J. B., & Clifton, P. M. (2017). Probiotics, prebiotics, synbiotics and insulin sensitivity. *Nutrition*

Research Reviews, *31*(1), 35–51. https://doi.org/10.1017/S095442241700018X

Klopsch, R., Baldermann, S., Hanschen, F. S., Voss, A., Rohn, S., Schreiner, M., & Neugart, S. (2019). Brassica-enriched wheat bread: Unraveling the impact of ontogeny and breadmaking on bioactive secondary plant metabolites of pak choi and kale. *Food Chemistry*, *295*(5), 412–422. https://doi.org/10.1016/j.foodchem.2019.05.113

Kruger, J., Mongwaketse, T., Fabe, M., Hoeven, M., & Smuts, C. (2015). Potential contribution of African green leafy vegetables and maize porridge composite meals to iron and zinc nutrition. *Nutrition*, *31*(9), 117–1123. https://doi.org/10.1016/j.nut.2015.04.010

Kubmarawa, D., Andenyang, I. F. H., & Magomya, A. M. (2009). Proximate composition and amino acid profile of two non-conventional leafy vegetables [Hibiscus cannabinus and Haematostaphis barteri]. *African Journal Food Science*, *3*(9), 233–236. https://academicjournals.org/journal/AJFS/article-full-text-pdf/3E45C4020448

Kumar, V., Sinha, A. K., Makkar, H. P. S., & Becker, K. (2010). Dietary roles of phytate and phytase in human nutrition: A review. *Food Chemistry*, *120*(4), 945–959. https://doi.org/10.1016/j.foodchem.2009.11.052

Kushimoto, S., Uchibori, Y., Yanai, S., Makabe, H., Nakamura, S., & Katayama, S. (2018). Kale supplementation up-regulates HSP70 and suppresses cognitive decline in a mouse model of accelerated senescence. *Journal of Functional Foods*, *44*(6), 292–298. https://doi.org/10.1016/j.jff.2018.03.011

Lako, J., Trenerry, V. C., Wahlqvist, M., Wattanapenpaiboon, N., Sotheeswaran, S., & Premier, R. (2007). Phytochemical flavonols, carotenoids and the antioxidant properties of a wide selection of Fijian fruit, vegetables and other readily available foods. *Food Chemistry*, *101*(4), 1727–1741. https://doi.org/10.1016/j.foodchem.2006.01.031

Lannitti, T., & Palmieri, B. (2010). Therapeutical use of probiotic formulations in clinical practice. *Clinical Nutrition*, *29*(6), 701–725. https://doi.org/10.1016/j.clnu.2010.05.004

Lee, J. (2015). Sorbitol, Rubus fruit, and misconception. *Food Chemistry*, *166*(4), 616–622. https://doi.org/10.1016/j.foodchem.2014.06.073

Lee, T. C., Ivester, P., Hester, A. G., Sergeant, S., Case, L. D., Morgan, T., Kouba, E. O., & Chilton, F. H. (2014). The impact of polyunsaturated fatty acid-based dietary supplements on disease biomarkers in a metabolic syndrome/diabetes population. *Lipids Health. Disease*, *13*(1), 196–208. https://doi.org/10.1186/1476-511X-13-196

Lee, Y. K., & Mazmanian, S. K. (2010). Has the microbiota played a critical role in the evolution of the adaptive immune system? *Science*, *330*(6012), 1768–1773. https://doi.org/10.1126/science.1195568

Lefsrud, M., Kopsell, D., Wenzel, A., & Sheehan, J. (2007). Changes in kale (Brassica oleracea L. var. acephala) carotenoid and chlorophyll pigment concentrations during leaf ontogeny. *Science Horticultural*, *112*(2), 136–141. https://doi.org/10.1016/j.scienta.2006.12.026

Lefsrud, M. G., Kopsell, D. A., Kopsell, D. E., & Curran-Celentano, J. (2005). Air temperature affects biomass and carotenoid pigment accumulation in kale and spinach grown in a controlled environment. *HortScience*, *40*(7), 2026–2030. https://doi.org/10.21273/hortsci.40.7.2026

Lemos, M., Santin, J. R., Júnior, L. C. K., Niero, R., & De, S. F. (2011). Gastroprotective activity of hydroalcoholic extract obtained from the leaves of Brassica oleracea var. acephala DC in different animal models. *Journal of Ethnopharmacology*, *138*(2), 503–507. https://doi.org/10.1016/j.jep.2011.09.046

Leonard., P. 2019. Growing and using cabbage and kale. Department of Plant and Soil Science, University of vermont extension, Summer News Article, 20 May2019, Burlington, VT, USA. https://pss.uvm.edu/ppp/articles/kale.html.

Li, Y., Yao, J., Han, C., Yang, J., Chaudhry, M. T., Wang, S., Liu, H., & Yin, Y. (2016). Quercetin, inflammation and immunity. *Nutrients*, *8*(3), 1–14. https://doi.org/10.3390/nu8030167

Lima, C., Albuquerque, D., Comalada, M., Camuesco, D., Luiz-ferreira, A., Nieto, A., & Ga, J. (2010). Effect of kale and papaya supplementation in colitis induced by trinitrobenzenesulfonic acid in the rat. *E-SPEN, Eur. e-Journal Clinical Nutrition and Methods*, *5*(5), 111–116. https://doi.org/10.1016/j.eclnm.2009.12.002

Lin, L. Z., & Harnly, J. M. (2009). Identification of the phenolic components of collard greens, kale, and Chinese broccoli. *Journal of Agricultural and Food Chemistry*, *57*(16), 7401–7408. https://doi.org/10.1021/jf901121v

Lisiewska, Z., Kmiecik, W., & Korus, A. (2008). The amino acid composition of kale (Brassica oleracea L. var. acephala), fresh and after culinary and technological processing. *Food Chemistry*, *108*(2), 642–648. https://doi.org/10.1016/j.foodchem.2007.11.030

Lopez, H. W., Leenhardt, F., Coudray, C., & Remesy, C. (2002). Minerals and phytic acid interactions: Is it a real problem for human nutrition? *International Journal of Food Science and Technology*, *37*(7), 727–739. https://doi.org/10.1046/j.1365-2621.2002.00618.x

Mäkinen, K. K. (2016). Gastrointestinal disturbances associated with the consumption of sugar alcohols with special consideration of xylitol: Scientific review and instructions for dentists and other health-care professionals. *International Journal of Dentistry*, *2016*, 1–16. Article ID5967907. https://doi.org/10.1155/2016/5967907

Manchali, S., Chidambara Murthy, K. N., & Patil, B. S. (2012). Crucial facts about health benefits of popular cruciferous vegetables. *Journal of Functional Foods*, *4*(1), 94–106. https://doi.org/10.1016/j.jff.2011.08.004

Manisha, G., Soumya, C., & Indrani, D. (2012). Studies on interaction between stevioside, liquid sorbitol, hydrocolloids and emulsifiers for replacement of sugar in cakes. *Food Hydrocolloids*, *29*(2), 363–373. https://doi.org/10.1016/j.foodhyd.2012.04.011

Marinova, D., Ribarova, F., & Atanassova, M. (2005). Total phenolics and total flavonoids in Bulgarian fruits and vegetables. *Journal University Chemistry Technology Methods*, *40*(3), 255–260. https://www.scienceopen.com/document?vid=8b15cef4-bb0a-41fe-b93b-789ac9246917

Mayland, C. R., Bennett, M. I., & Allan, K. (2005). Vitamin C deficiency in cancer patients. *Palliative Medicine*, *19*(1), 17–20. https://doi.org/10.1191/0269216305pm970oa

Megan, W. 2020. What are the health benefits of kale? Med. News Today. 5 January. https://www.medicalnewstoday.com/articles/270435.php.

Melrose, J. (2019). The glucosinolates: A sulphur glucoside family of mustard anti-tumour and antimicrobial phytochemicals of potential therapeutic application. *Biomedicines*, *7*(3), 62–77. https://doi.org/10.3390/biomedicines7030062

Mozaffarian, D., Micha, R., Wallace, S., & Katan, M. B. (2010). Effects on coronary heart disease of increasing polyunsaturated fat in place of saturated fat: A systematic review and meta-analysis of randomized controlled trials. *PLoS Medicine*, *7*(3), e1000252. https://doi.org/10.1371/journal.pmed.1000252

Mu, X., Wang, P., Du, J., Gao, Y. G., Zhang, J., & Liu, J.-H. (2018). Comparison of fruit organic acids and metabolism-related gene expression between Cerasus humilis (Bge.) Sok and Cerasus glandulosa (Thunb.) Lois. *PLoS One*, *13*(4), e0196537. https://doi.org/10.1371/journal.pone.0196537

Murtaza, I., Beigh, G. M., Shah, T. A., Hussain, A., Khan, A. A., & Kaur, C. (2006). Antioxidant activity and total phenolic content of kale genotypes grown in kashmir valley. *Journal of Plant Biochemistry and Biotechnology*, *14*(2), 215–217. https://doi.org/10.1007/BF03263250

Mwithiga, G., & Olwal, J. O. (2005). The drying kinetics of kale (Brassica oleracea) in a convective hot air dryer. *Journal of Food Engineering*, *71*(4), 343–378. https://doi.org/10.1016/j.jfoodeng.2004.10.041

Nakamura, Y. K., & Omaye, S. T. (2012). Metabolic diseases and pro- and prebiotics: Mechanistic insights. *Nutrition Methods*, *9*(1), 1–9. https://doi.org/10.1186/1743-7075-9-60

Navarro-Alarcon, M., & Cabrera-Vique, C. (2000). Selenium in food and the human body: A review. *Science of the Total Environment*, *400*(1–3), 115–141. https://doi.org/10.1016/j.scitotenv.2008.06.024

Noonan, S. C. (1999). Oxalate content of foods and its effect on humans. *Asia Pacific Journal of Clinical Nutrition*, *8*(1), 64–74. https://doi.org/10.1046/j.1440-6047.1999.00038.x

Novotny, J. A., Harrison, D. J., Pawlosky, R., Flanagan, V. P., Harrison, E. H., & Kurilich, A. C. (2010). β-carotene conversion to vitamin A decreases as the dietary dose increases in humans. *The Journal of Nutrition*, *140*(5), 915–918. https://doi.org/10.3945/jn.109.116947

Ntuli, N. R. (2019). Nutrient content of scarcely known wild leafy vegetables from northern KwaZulu-Natal, South Africa. *South African Journal of Botany*, *127*(1), 19–24. https://doi.org/10.1016/j.sajb.2019.08.033

Nwanna, E. E., Oyeleye, S. I., Ogunsuyi, O. B., Oboh, G., Boligon, A. A., & Athayde, M. L. (2016). In vitro neuroprotective properties of some commonly consumed green leafy vegetables in Southern Nigeria. *Nutrition and Food Society Journal*, *2*(1), 19–24. https://doi.org/10.1016/j.nfs.2015.12.002

Obeng, E., Kpodo, F. M., Tettey, C. O., Essuman, E. K., & Adzinyo, O. A. (2019). Antioxidant, total phenols and proximate constituents of four tropical leafy vegetables. *Science Africa*, *7*(1), e00227. https://doi.org/10.1016/j.sciaf.2019.e00227

Oguntoyinbo, F. A., Cho, G. S., Trierweiler, B., Kabisch, J., Rösch, N., Neve, H., Franz, C. M. A. P., Frommherz, L., Nielsen, D. S., Krych, L., & Franz, C. M. A. P. (2016). Fermentation of African kale (Brassica carinata) using L. plantarum BFE 5092 and L. fermentum BFE 6620 starter strains. . *International Journal of Food Microbiology*, *238*(1), 103–112. https://doi.org/10.1016/j.ijfoodmicro.2016.08.030

Olsen, H., Aaby, K., & Borge, G. I. (2009). Characterization and quantification of flavonoids and hydroxycinnamic acids in curly kale (brassica oleracea l. convar. acephala var.sabellica) by HPLC-DAD-ESI-MSn. *Journal of Agricultural and Food Chemistry*, *57*(7), 2816–2825. https://doi.org/10.1021/jf803693t

Palego, L., Betti, L., Rossi, A., & Giannaccini, G. (2016). Tryptophan biochemistry: Structural, nutritional, metabolic, and medical aspects in humans. *Journal of Amino Acids*, *2016*, 1–13. Article ID8952520. https://doi.org/10.1155/2016/8952520

Pandey, M., Abidi, A. B., Singh, S., & Singh, R. P. (2006). Nutritional evaluation of leafy vegetable Paratha. *Journal of Human Ecology*, *19*(2), 155–156. https://doi.org/10.1080/09709274.2006.11905871

Patterson, E., Wall, R., Fitzgerald, G. F., Ross, R. P., & Stanton, C. (2012). Health implications ofhigh dietaryomega-6 polyunsaturated fattyacids. *Journal Nutrition Methods*, *2012*. Article ID539426. https://doi.org/10.1155/2012/539426

Perera, C. O., & Yen, G. M. (2007). Functional properties of carotenoids in human health. *International Journal of Food Properties*, *10*(2), 201–230. https://doi.org/10.1080/10942910601045271

Phang, M., Lincz, L. F., & Garg, M. L. (2013). Eicosapentaenoic and docosahexaenoic acid supplementations reduce platelet aggregation and hemostatic markers differentially in men and women. *The Journal of Nutrition*, *143*(4), 457–463. https://doi.org/10.3945/jn.112.171249

Phillips, G. O., & Cui, S. W. (2011). An introduction: Evolution and finalisation of the regulatory definition of dietary fibre. *Food Hydrocolloids*, *25*(2), 139–143. https://doi.org/10.1016/j.foodhyd.2010.04.011

Phuke, R. M., Anuradha, K., Radhika, K., Jabeen, F., Anuradha, G., Ramesh, T., Hariprasanna, K., Mehtre, S. P., Deshpande, S. P., Anil, G., Das, R. R., Rathore, A., Hasha, T., Reddy, B. V. S., & Kumar, A. A. (2017). Genetic variability, genotype × environment interaction, correlation, and GGE biplot analysis for grain iron and zinc concentration and other agronomic traits in RIL population of Sorghum (Sorghum bicolor L. Moench). *Frontiers Plant Science*, *8*(3), 1–13. https://doi.org/10.3389/fpls.2017.00712

Piste, P. (2013). Cystine–Master antioxidant. *International Journal Pharmacy Chemistry Biology Science*, *3*(1), 143–149. http://www.ijpcbs.com/files/volume3-1-2013/18.pdf

Pool-Zobel, B. L. (2005). Inulin-type fructans and reduction in colon cancer risk: Review of experimental and human data. *British Journal of Nutrition*, *93*(S1), S73–S90. https://doi.org/10.1079/bjn20041349

Raiola, A., Errico, A., Petruk, G., Monti, D. M., Barone, A., & Rigano, M. M. (2018). Bioactive compounds in brassicaceae vegetables with a role in the prevention of chronic diseases. *Molecules*, *23*(1), 1–10. https://doi.org/10.3390/molecules23010015

Raju, M., Varakumar, S., Lakshminarayana, R., Krishnakantha, T. P., & Baskaran, V. (2007). Carotenoid composition and vitamin A activity of medicinally important green leafy vegetables. *Food Chemistry*, *101*(4), 1598–1605. https://doi.org/10.1016/j.foodchem.2006.04.015

Reddy, R. (2001). Occurrence, distribution, content, and dietary intake of phytate. In R. Reddy & S. K. Sathe (Eds.), *Food phytates* (pp. 1–28). CRC Press.

Ró Ża, B. M., Elżbieta, R. M., & Marecik, R. (2017). Characterization of phenolics, glucosinolates and antioxidant activity of beverages based on apple juice with addition of frozen and freeze-dried curly kale leaves [Brassica oleracea L. var. acephala L.]. *Food Chemistry*, *230*(1), 271–280. https://doi.org/10.1016/j.foodchem.2017.03.047

Roy, S. K., & Chakrabarti, A. K. (2003). Vegetables of temperate climates, commercial and dietary importance. In C. Benjamin (Ed.), *Encyclopedia of food sciences and nutrition* (pp. 5925–5932). Academic Press.

Scantlebury, M. T., & Rgibson, G. (2004). Prebiotics. *Best Practice & Research Clinical Gastroenterology*, *18*(2), 287–298. https://doi.org/10.1016/j.bpg.2003.10.008

Schrauzer, G. N. (2002). Lithium: Occurrence, dietary intakes, nutritional essentiality. *Journal of the*

American College of Nutrition, *21*(1), 14–21. https://doi.org/10.1080/07315724.2002.10719188

Sheetal, G., Jyothi Lakshmi, A., Manjunath, M. N., & Jamuna, J. P. (2005). Analysis of nutrient and anti-nutrient content of underutilized green leafy vegetables. *Food Science Technology*, *38*(4), 339–345. https://doi.org/10.1016/j.lwt.2004.06.012

Shegokar, R., & Mitri, K. (2012). Carotenoid lutein: A promising candidate for pharmaceutical and nutraceutical applications. *Journal of Dietary Supplements*, *9*(3), 183–210. https://doi.org/10.3109/19390211.2012.708716

Shimojo, Y., Ozawa, Y., Toda, T., Igami, K., & Shimizu, T. (2018). Probiotic Lactobacillus paracasei A221 improves the functionality and bioavailability of kaempferol-glucoside in kale by its glucosidase activity. *Scientific Reports*, *8*(1), 1–8. https://doi.org/10.1038/s41598-018-27532-9

Sidsel, F. H., Borge, G. I. A., Solhaug, K. A., & Bengtsson, G. B. (2009). Effect of cold storage and harvest date on bioactive compounds in curly kale [Brassica oleracea L.var. acephala]. *Postharvest Biology and Technology*, *51*(1), 36–42. https://doi.org/10.1016/j.postharvbio.2008.04.001

Sikora, E., & Bodziarczyk, I. (2012). Composition and antioxidant activity of kale (Brassica oleracea L. var. acephala) raw and cooked. *Acta scientiarum Polonorum. Technologia Alimentaria*, *11*(3), 239–248. https://pubmed.ncbi.nlm.nih.gov/22744944/

Simopoulos, A. P. (2004). Omega-3 fatty acids and antioxidants in edible wild plants. *Biology Research*, *37* (2), 263–277. https://doi.org/10.4067/S0716-97602004000200013

Squires, E. J., Julian, R. J., & Squires, E. J. (1994). Cobalt-induced polycythaemia causing right ventricular hypertrophy and ascites in meat-type chickens. *Avian Pathology*, *23*(1), 91–104. https://doi.org/10.1080/03079459408418977

Stahl, W., & Sies, H. (2004). Antioxidant activity of carotenoids. *Molecular Aspects of Medicine*, *24*(6), 345–351. https://doi.org/10.1016/s0098-2997(03)00030-x

Subhasree, B., Baskar, R., Laxmi Keerthana, R., Lijina Susan, R., & Rajasekaran, P. (2009). Evaluation of antioxidant potential in selected green leafy vegetables. *Food Chemistry*, *115*(4), 1213–1220. https://doi.org/10.1016/j.foodchem.2009.01.029

Sultana, B., & Anwar, F. (2008). Flavonols (kaempeferol, quercetin, myricetin) contents of selected fruits, vegetables and medicinal plants. *Food Chemistry*, *108*(3), 879–884. https://doi.org/10.1016/j.foodchem.2007.11.053

Susan Hedayati, S., Minhajuddin, A. T., Ijaz, A., Moe, O. W., Elsayed, E. F., Reilly, R. F., & Huang, C. L. (2012). Association of urinary sodium/potassium ratio with blood pressure: Sex and racial differences. *Clinical Journal of the American Society of Nephrology*, *7*(2), 315–322. https://doi.org/10.2215/CJN.02060311

Susanne, S., Michaela, Z., Monika, S., Sascha, R., Angelika, K., & Krumbein, A. (2010). Genotypic and climatic influences on the concentration and composition of flavonoids in kale [Brassica oleracea var. sabellica]. *Food Chemistry*, *119*(4), 1293–1299. https://doi.org/10.1016/j.foodchem.2009.09.004

Takeiti, C. Y., Antonio, G. C., Motta, E. M. P., Collares-Queiroz, F. P., & Park, K. J. (2009). Nutritive evaluation of a non-conventional leafy vegetable [Pereskia aculeata Miller]. *International Journal of Food Sciences and Nutrition*, *60*(1), 148–160. https://doi.org/10.1080/09637480802534509

Thavarajah, D., Siva, N., Johnson, N., Mc Gee, R., & Thavarajah, P. (2019). Effect of cover crops on the yield and nutrient concentration of organic kale [Brassica oleracea L. var. acephala]. *Scientific Reports*, *9*(1), 1–8. https://doi.org/10.1038/s41598-019-46847-9

Thavarajah, D., Thavarajah, P., Abare, A., Basnagala, S., Lacher, C., Smith, P., & Combs, G. F. (2016). Mineral micronutrient and prebiotic carbohydrate profiles of USA-grown kale [Brassica oleracea L. var. acephala]. *Journal of Food Composition and Analysis*, *52*(1), 9–15. https://doi.org/10.1016/j.jfca.2016.07.003

Traylor, D. A., Gorissen, S. H. M., & Phillips, S. M. (2018). Perspective: Protein requirements and optimal intakes in aging: Arewe ready to recommend more than the recommended daily allowance? *Advances in Nutrition*, *9* (3), 171–182. https://doi.org/10.1093/advances/nmy003

Trumbo, P., Yates, A. A., Schlicker, S., & Poos, M. (2001). Dietary reference intakes: Vitamin A, vitamin K, arsenic, boron, chromium, copper, iodine, iron, manganese, molybdenum, nickel, silicon, vanadium, and zinc. *Journal of the American Dietetic Association*, *101*(3), 294–302. https://doi.org/10.1016/S0002-8223(01)00078-5

Tucker, K. L., Hannan, M. T., Chen, H., Cupples, L. A., Wilson, P. W. F., & Kiel, D. P. (1999). Potassium, magnesium, and fruit and vegetable intakes are associated with greater bone mineral density in elderly men and women. *The American Journal of Clinical Nutrition*, *69*(4), 727–736. https://doi.org/10.1093/ajcn/69.4.727

Uddin, M. K., Juraimi, A. S., Hossain, M. S., Nahar, M. A. U., Ali, M. E., & Rahman, M. M. (2014). Purslane weed (portulaca oleracea): A prospective plant source of nutrition, omega-3 fatty acid, and antioxidant attributes. *The Scientific World Journal*, *2014*, 1–6. Article ID951019. https://doi.org/10.1155/2014/951019

Uriu-Adams, J. Y., & Keen, C. L. (2005). Copper, oxidative stress, and human health. *Molecular Aspects of Medicine*, *26*(4–5), 268–298. https://doi.org/10.1016/j.mam.2005.07.015

Uusiku, N. P., Oelofse, A., Duodu, K. G., Bester, M. J., & Faber, M. (2010). Nutritional value of leafy vegetables of sub-Saharan Africa and their potential contribution to human health: A review. *Journal of Food Composition and Analysis*, *23*(6), 499–509. https://doi.org/10.1016/j.jfca.2010.05.002

Velasco, P., Cartea, M. E., González, C., Vilar, M., & Ordás, A. (2007). Factors affecting the glucosinolate content of Kale [Brassica oleracea acephala Group]. *Journal of Agricultural and Food Chemistry*, *55*(3), 955–962. https://doi.org/10.1021/jf0624897

Wafula, E. N., Franz, C. M. A. P., Rohn, S., Huch, M., Mathara, J. M., Trierweiler, B., & Becker, B. (2015). Fermentation of African leafy vegetables to lower post-harvest losses, maintain quality and increase product safety. *African Journal Horticultural Science*, *9*(6), 1–13. http://www.hakenya.net/ajhs/index.php/ajhs/article/view/151/116

Wang, C. Y. (1998). Heat treatment affects postharvest quality of kale and collard, but not of Brussels sprouts. *Horticultural Science*, *9*(1), 133–134. https://doi.org/10.21273/HORTTECH.9.1.133C

Whisner, C. M., & Castillo, L. F. (2018). Prebiotics, bone and mineral metabolism. *Calcified Tissue International*, *102*(4), 443–479. https://doi.org/10.1007/s00223-017-0339-3

Wibowo, S., Afuape, A. L., De, S., Bernaert, M., Droogenbroeck, B., Van, Grauwet, T., & Hendrickx, M. (2019). Thermal processing of kale purée: The impact of process intensity and storage on different quality related aspects. *Innovative Food Science & Emerging Technologies*, *58*(1), 102213. https://doi.org/10.1016/j.ifset.2019.102213

William, B. F., Edwards, D. G., Jurkovitz, C. T., & Weintraub, W. S. (2015). Dietary sodium and health: More than just blood pressure. *Journal of the American College of Cardiology*, *65*(10), 1042–1050. https://doi.org/10.1016/j.jacc.2014.12.039

Wilson, D. W., Nash, P., Singh, B. H., Griffiths, K., Singh, R., De Meester, F., Horiuchi, R., & Takahashi, T. (2017). The role of food antioxidants, benefits of functional foods, and influence of feeding habits on the health of the older person: An overview. *Antioxidants*, *6*(4), 1–20. https://doi.org/10.3390/antiox6040081

Yamada, K. (2013). Cobalt: Its role in health and disease. In D. S. Avila, R. L. Puntel, & M. Aschner (Eds.), *Interrelations between essential metal ions and human diseases* (pp. 295–320). Springer.

Yoon, Y. E., Kuppusamy, S., Kim, S. Y., Kim, J. H., & Lee, Y. B. (2016). Free amino acid composition of Korean Spinach (Spinacia oleracea) cultivars as influenced by different harvesting time. *Korean Journal of Environmental Agriculture*, *35*(2), 104–110. https://doi.org/10.5338/kjea.2016.35.2.21

Zhang, Z. H., Peng, H., Ma, H., & Zeng, X. A. (2019). Effect of inlet air drying temperatures on the physico-chemical properties and antioxidant activity of whey protein isolate-kale leaves chlorophyll (WPI-CH) microcapsules. *Journal of Food Engineering*, *245*(8), 149–156. https://doi.org/10.1016/j.jfoodeng.2018.10.011

Žnidarčič, D., Ban, D., & Šircelj, H. (2011). Carotenoid and chlorophyll composition of commonly consumed leafy vegetables in Mediterranean countries. *Food Chemistry*, *129*(3), 1164–1168. https://doi.org/10.1016/j.foodchem.2011.05.097