FOOD SCIENCE & TECHNOLOGY | RESEARCH ARTICLE

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

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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-

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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, narrow-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 & Bodzarczyk, 2012; Thavarajah et al., 2019) and 30.83%–36.8% on dry weight basis (Acikgoz, 2011; Kahlen, 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.,
| Nutrient       | Talwinder, et al., (2008)¹ (DW) | Ackgoz (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                  | ND                            | 85                            | 81.38                            | NR                             |

Where: FW = Fresh Weight; DW = Dry Weight; NR = Not Reported.
¹Samples collected from local grocery from California, USA
²Kales cv. Karadere 077 grown in Turkey
³Kale genotypes grown in South Carolina, USA
⁴Samples collected from local market of Asba, Delta state, Nigeria.
⁵Kale from Krakow, Poland.
⁶The 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 Bodzianczyk (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 & Bodzianczyk, 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 & Bodzianczyk, 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 (Ray & Chakrabarti, 2003).

A high moisture percentage of 81.38%-82.92% (Sikora & Bodzianczyk, 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

| 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

¹Kale (B. oleracea L. var. acephala Dc.) from six different fields of Trabzon, Turkey.
²Mean of 25 genotypes of kale grown in South Carolina, USA
³Local farms Beltsville, Maryland, USA
⁴Curly Kale (B. oleracea L. var. acephala, 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 sorbitols 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% (Kahlen , 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
| Mineral Type | Manchali et al. (2012)² (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 Bodzianczyk (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                               |
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. oleracea 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 Tohumcular 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). Cystine 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 africanum, 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                       | Arachidonic 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                                         | 179                     |

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

¹Kale (B. oleraceae L. var. acephala Dc.) from Trabzon, Turkey
²The samples were collected from Copenhagen, Denmark
³The 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 (Górsk-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 (Górsk-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 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 & Bodzianczyk, 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

1Kale grown in South Carolina, USA.
2Curly Kale (B. oleracea L. var. acephale, cv. Reflex) from Norwegian University Life Sciences, Norway
3Winterbore kale from University of Tennessee, Knoxville, USA
4Kale (Brassica oleracea) of the common cultivar “Manteiga” from S’ao Paulo, Brazil
5Brassica oleracea L. var. acephala DC cul. “Winterbor” were from USA.
6Kale (Brassica oleracea L. var. acephala) from Krakow, Poland
7Brassica 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). Achikana et al., (2013) have reported that Ficus capensis, Solanum melongena, Mucuna pruriens, Solanum macrocarpon, Solanum nigrum, Moringa oleifera lam, Solanum aethiopicum, Cridoscolus
*A. conifolius* were found to have higher concentrations of vitamin E. Usually the best source of vitamin E are the seeds 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 and the stereo isomers which usually coexist 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 other than 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); Žnidarič 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 Rodríguez-Amaya (2003) and also stated that Violoxanthin 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 violoxanthins.

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 present in the kale are presented in Table 6. The flavonoids content of kale is reported as 661–892 mg 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. Bohorun 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 bloom.
Table 6. Total flavonoid, quercetin, kaempferol, total phenol, hydroxycinnamic acids reported in kale by different researchers

| Constituent                  | Sidsel et al. (2009)\(^1\) (DW) | Susanne et al. (2010)\(^2\) (DW) | Olsen et al. (2009)\(^3\) (FW) | Sikora and Bodzianczyk (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. acephala, 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 gongiloides) from Kashmir, India.

Indonesia. On the contrary, Quercetin in Gnetum africanaum (Afang), Lasianthera africana (Editan) and Gongranema 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), Mungwort (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 & Bodzianczyk, 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 Alahnumba sessilis, Basella alba, Cassia tora, Digera muricata, Ipomoea aquatica, Leucas cephaleotes, 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 (Goboma), Talinum fruticosum (Ademe), Corchorus olitorius (Yevogboma) and Amaranthus spp. (Atomma) 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, pineapples, 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 leaves 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 (Palmitolenoenic 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 (Eicosadienoic acid), 20:3 n-3 (Eicosatrienoic acid), 20:4 n-3 (Eicosatetraenoic 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 (Jondacek, 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 Ernebu 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 Agaire (2011) have reported that Vernonia anydalira (Bitter leaf), Moni esculenta (cassava leaf), Teferia 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 subduced 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 Agaire (2011) has reported that Vernonia anydalira (Bitter leaf), Moni esculenta (Cassava leaf), Teferia 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. Agaire (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 leaves 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 (Nitrate and Nitrates). 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 |
|-------|------------------|----------------------|--------------------------|
| 1     | Short-term intervention with kale extract in macular disease | Randomized controlled clinical trial | Authors concluded that daily kale consumption increased xanthophyll concentrations in plasma and the macular pigment xanthophylls increased significantly by 14.1% and 15.6% after two weeks of intervention respectively. Also, daily kale consumption modified Bilirubin metabolism such that daily kale consumption decreased bilirubin concentrations by 19.6% of total Bilirubin on day 1 and 13.3% on days 8 and 15, respectively. |
| 2     | Kale consumption on macular disease and bile acid metabolism | Randomized crossover study | The results of study revealed that, bile acid binding for kale was significantly higher than for broccoli and mustard greens. The results further revealed that, the health promoting potential of spinach = kale > brussels sprouts > broccoli = mustard greens > capsaicin = green bell peppers = cilantro, as indicated by their bile and binding on dry matter basis. |
| 3     | In vitro binding of bile acids and other dietary components | In vitro binding assay | Concluded that, kale leaves, rated as good dietary sources of natural phenolic antioxidants and other compounds, with high anti-inflammatory properties and anti-carcinogenic effects, can contribute to reduce the risks of coronary artery disease in male subjects with Hyperlipidemia. |
| 4     | Phenolic and carotenoid contents of kale leaves and their antimicrobial properties | HPLC and ELISA | Study concluded that, regular meals supplementation with kale juice can favorably influence serum lipid profile and antioxidant systems, and hence contribute to reduce the risks of coronary artery disease in male subjects with Hyperlipidemia. |
| 5     | Kale Juice on Coronary Artery Disease risk factors in Hypercholesterolemic men | Randomized controlled clinical trial | 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 20 weeks, compared to a 12-week intervention period. |
| S. No | Area of research | Methodology employed | Findings and conclusions | References |
|-------|------------------|----------------------|--------------------------|------------|
| 6     | Kale and papaya supplementation in colitis induced by Trinitrobenzenesulfonic (TNBS) acid in the rat colitis model | Researchers evaluated the effect of dried vegetables as a probiotic 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) |
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-α-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 hydroxy-cinnamic acid derivatives was found after bread preparation. Hence, breads with added fresh kale could enrich health-promoting secondary plant metabolites in baked goods.                                      | Klipsch 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 10⁷ CFU/mL. The viability of the ferments after cold storage in the refrigerator for 4 weeks showed 10³ 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 (56.00 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 nutritional elements. | 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 α 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. paraplanarum G2114, L. brevis R4 13, L. curvatus 154), two as Weissella spp. (W. helenica 152, W. cibaria G4-4), two as Pediococcus spp. (P. pentosaceus KSAN, P. acidilactici 2211), one as Leuconostoc mesenteroides 153 and one as Lactococcus lactis 37BN. | Oguntayoja 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 m²/s. The effect of temperature on diffusivity could be expressed by an Arrhenius type relationship with a high R² of 0.9989. The activation energy of kale was found to be 36.115 kJ/mol. | Mwituha and Olwal (2005) |

(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 Esigubacterium acetylum were isolated and identified from the 5 kGy-irradiated kale juices. The growth of the surviving B. megaterium and E. acetylum 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. | Ro Za 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 puree. 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 processing 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.

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