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Full Length Research Paper

Mineral, vitamin C and crude protein contents in kale (*Brassica oleraceae* var. *acephala*) at different harvesting stages

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This study compares mineral, vitamin C and crude protein contents at different harvesting stages in kale (*Brassica oleraceae* var. *acephala*). Three different harvest periods as first harvest stage (at the rosette stage), second harvest stage (at the budding stage) and third harvest stage (at the flowering/blooming stage) were utilized in the study. The results of the study presented the highest values as follows: Third harvesting stage for vitamin C with 109.43 mg 100 g^{-1}; first stage for crude protein value of 35.00%; first harvesting stage for nitrogen (N) and iron (Fe) with 5.60% and 15.31 mg 100 g^{-1}, respectively; and second harvesting stage for phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), manganese (Mn), cupper (Cu), and zinc (Zn) as 0.57, 4.62, 2.67, 0.38%, and 15.63, 0.20, 2.12 mg 100 g^{-1} respectively. In conclusion, kale is a relatively good source of abundant antioxidants with its vitamin C, crude protein and mineral contents. The study propounds that kale can be consumed as a choice of fundamental nutrients selections and it would be worth considering the harvesting stage of maturity.

Key words: Kale (*Brassica oleracea* var. *acephala*), harvesting stage, vitamin C, crude protein, mineral content.

INTRODUCTION

Cabbage, as a highly rated leafy vegetables and a marvelous food item, is grown for its enlarged, edible, terminal buds; and is also preferably eaten almost everywhere in the world (Tirasoglu et al., 2005). Kale *(Brassica oleracea* var. *acephala*) is one of the oldest forms of the cabbage family. It has origins in the eastern Mediterranean. Kale is used as a food crop since 2000 BC. It is reported that Theophrastus labeled a savoy form of kale in 350 BC. This green vegetable was made known around the world by travellers and immigrants (Nieuwhof, 1969; Balkaya and Yanmaz, 2005). Farmers generally allocate the tenderer leaves for human consumption and elder ones for forage. Traditional and native varieties are grown in small plots through seed production of their own (Balkaya et al., 2003).

The function of diet in human health attracts increasing attention in recent years. Numerous studies have indicated that a high intake of plant products results in a reduced risk of a number of chronic diseases and cancer (Podsedek, 2007; Gosslau and Chen, 2004; Gundgaard et al., 2003; Hashimoto et al., 2002; Kris-Etherton et al., 2002; Law and Morris, 1998; Temple, 2000). The consumption of *Brassica* vegetables remains related to human health and reduces the risk of certain cancers and cardiovascular diseases (Francisco et al., 2010; Sies and Stahl, 1995; Traka and Mithen, 2009; Verhoeven, et al., 1997). Crucifers are rich in antioxidants, that is, vitamin E (tocopherol), vitamin C, and carotenoids (Cao et al., 1996). They significantly are the richest source of the phytochemical glucosinolate in the human diet (Fahey et al., 2001). According to Podsedek (2007), the contribution of *Brassica* vegetables to health can be correlated to their antioxidant capacity. Due to their extremely high content and capacity, phenolic compounds with vitamin C are the major antioxidants of *Brassica* vegetables.

The high nutritional value of kale derives from its intense chemical composition (Rosa and Heaney, 1996).

It is particularly rich in vitamins, minerals, dietary fiber and antioxidant compounds (Lisiewska et al., 2008; Kurilich et al., 1999). Furthermore, nitrogen compounds, in which amino acids predominate forms about one third of the dry matter in kale. Deepa et al. (2007) reported that the antioxidant level in raw plant materials in which the main antioxidant is vitamin C, depends on factors such as variety, degree of maturity, and weather conditions during the growth period. Maturity is one of the key factors that ascertain the compositional quality of fruits and vegetables (Lee and Kader, 2000). The higher amount of ascorbic acid presents in fully ripe maturity stage and its content increases progressively in the advance stages of maturity (Maorun et al., 2009). For dietary and nutritional aims, changes in the antioxidant and related compounds have great importance during growth and maturation (Deepa et al., 2007).

The aim of this study was to determine and compare mineral, vitamin C, and crude protein contents in kale at different harvesting stages. To suggest the most appropriate stage of maturity in mineral, vitamin C, and crude protein content for consumers that prefer fresh vegetables is also among the goals of the study.

MATERIALS AND METHODS

The experiment was conducted during successive crop seasons as autumn – winter, in an UV consisting of PE unheated greenhouse in Corlu, Turkey (41°11' N, 27°49' E) in 2010 to 2011. The experiment was carried out according to random blocks experimental design with four replicates. Kales seeds, cv. Karadere 077 (Istanbul Tohumculuk co.), were sown in September growing period in multi-celled trays filled with peat (Klasmann-Deilmann, potground H, Germany). Seedlings were transplanted to greenhouse soil at the 2 to 3 true leaf stage with the 25 × 25 cm distances between the rows and in the rows, respectively and with border plant on their sides. Cultural program followed is given as follows: Sowing time: 7 September; Germination time: 17 September; First true leaf out: 27 September; planting seedlings (formed 3 to 4 leaves): 18 October; First harvest stage (at the rosette stage): 22 February (18 weeks from planting to harvest. The plants were approximately 15 to 25 cm in height with older leaves at the base and younger leaves developing in the center at this stage); Second harvest stage (at the budding stage): 14 March (21 weeks from planting to harvest. Flower buds were present on the panicle at this stage); Third harvest stage (at the flowering/blooming stage): 22 March (22 weeks from planting to harvest. The buds of the plant began to open as the plant continued to grow and develop new buds at this stage).

This cultural program has similar characteristics to the one used by Miller-Cebert, et al. (2009a). Harvest covers cutting the whole plants and removing unmarketable leaves with yellowing leaves are usually at the plant base (Korus, 2010a). Table 1 gives the chemical characteristics of the soil which is used in the experiment and Table 2 represents the climate data in unheated greenhouse during the experiments. As a conclusion of the experiment, the following characteristics were studied: Ascorbic acid (vitamin C) in samples (mg 100 g^{-1}), crude protein (%) and mineral contents; nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), manganese (Mn), cupper (Cu), iron (Fe) and zinc (Zn)) (%,mg 100 g^{-1}). Collected samples were washed with distilled water and dried in a ventilated oven at 65°C for mineral content. Ascorbic acid content of samples was estimated with titrimetric method (Anonymous, 1983).

The samples were analyzed based on nitrogen analysis utilizing the Kjeldahl system according to the Association of Official Analytical Chemists International (AOAC) for crude protein content. The crude protein was calculated using a nitrogen conversion factor of 6.25 (AOAC, 1990). Nitrogen content of the samples was determined by Kjeldahl system (Gerhadt, KB/20S) and P, K, Ca, Mg, Mn, Cu, Fe and Zn content were determined by ICP-OES spectrophotometer (Perkin Elmer, 2100DV) (Kacar, 1972). During the experiment, neither fertilization nor pesticide application of any kind was carried out. Moreover, pests and disease incidences were not observed. Weeding activity was performed when needed in the growing periods. All data were analyzed statistically using SPSS software program (v.16.0 for Windows OS) and the differences between practices were assessed and compared by LSD test.

RESULTS AND DISCUSSION

Vitamin C

98.30 mg 100 g^{-1} of vitamin C content was found for first harvest stage, 105.21 mg 100 g^{-1} for second harvest stage and 109.43 mg 100 g^{-1} for third harvest stage (Table 3). Lee and Kader, (2000) reported that maturity is among the major factors that define the compositional quality of fruits and vegetables. According to the results of Korus (2010b), vitamin C levels in the kale leaves ranged from 77 to 133 mg 100 g^{-1} and they depend on the year of research, variety, and degree of plant maturity as well. Singh et al. (2007) stated that vitamin C content ranged from 9.66 to 52.9 mg 100 g^{-1} and that the harvesting stage of the samples might be another important source of variation. Podsedek (2007) gave that climatic conditions might also alter vitamin C level.

According to Maorun et al. (2009), ascorbic acid content varied significantly during maturation and showed a growing trend as maturity advances. In this study, vitamin C reached to its peak value at the third harvesting stage in which maturity is also at the highest level. Clarifying well the low levels of vitamin C content in first harvesting stage; Lee and Kader, (2000), Harris (1975) and Weston and Barth (1997) had a general agreement that the lower the light intensity, the lower the content of L-ascorbic acid (or vitamin C) in plant tissues.

Crude protein

35.00% of crude protein content was found for the first stage, 30.62% for the second and 26.87% for third harvesting stage (Table 3). Higher crude protein concentration in the plants might be a result of N accumulation in the young tissues which receive soluble forms of nitrogen transported from elder leaves as well (Salisbury and Ross, 1992). It can be explained by the higher protein content in the first harvesting stage.

Fresh kale leaves (or young plant) can be a good source of amino acids. Nitrogen compounds, in which

Table1. Chemical characteristics of the soil (0 to 20 cm).

Parameter	Value	Unit
pH	7.26	%
EC	0.17	%
$CaCO_3$	1.24	%
Organic Matter	5.62	%
Total N	0.28	%
Available Ca	0.54	%
Available P	167.46	ppm
Available K	265.47	ppm
Available Mg	713.67	ppm
Available Mn	6.98	ppm
Available Cu	1.51	ppm
Available Fe	6.03	ppm
Available Zn	5.23	ppm

Table 2. Average climate data in unheated greenhouse during the months of the experiment.

Month	Average temperature (°C)	Maximum temperature (°C)	Minimum temperature (°C)	Average humidity (%)
September	8.7	19.1	7.6	85
October	8.9	18.6	7.8	87
November	9.1	19.0	4.9	86
December	8.2	17.1	3.9	90
January	9.9	18.2	4.1	89
February	10.0	21.0	4.0	87
March	10.0	22.1	4.1	90

amino acids predominate, form about one third of the dry matter in kale (Lisiewska et al., 2008). It is therefore convenient with the first harvesting stage. Miller-Cebert et al. (2009b) reported that canola leaves at pre-bolting stage have significantly higher protein content (23.69%) compared to those of the rosette and blooming growth stages as 20.52 and 22.27%. Depending on the genotypic characteristics, this study similarly offers that crude protein contents are higher at the first harvesting stage.

Mineral content

N, P, K, Ca, Mg, Mn, Cu, Fe, and Zn contents for different harvesting stages in kale are given in Table 4. N content was found as 5.60% for the first harvesting stage; 4.90% for the second and 4.30% for the third. P content was 0.48% for the first, 0.57% for the second, and 0.51% for the third harvesting stage. K content was determined as 3.58% for the first harvesting stage, 4.62% for the second, and 4.30% for the third stage. Ca content was 2.60% for the first, 2.67% for the second, and 2.57% for the third stage. Mg content was found 0.36% for the first, 0.38% for the second harvesting stage and 0.35% for the third harvesting stage. Mn content was 13.71 mg 100 g^{-1} at the first harvesting, 15.63 mg 100 g^{-1} at the second, and 14.97 mg 100 g^{-1} at the third harvesting stage; Cu content was 0.18 mg 100 g^{-1} for the first harvesting stage, 0.20 mg 100 g^{-1} for the second, and 0.17 mg 100 g^{-1} for the third harvesting stage. Fe content was found 15.31 mg 100 g^{-1} for the first, 11.21 mg 100 g^{-1} for the second, and 10.07 mg 100 g^{-1} for the third stage. Zn content was determined as 2.04 mg 100 g^{-1} for the first, 2.12 mg 100 g^{-1} for the second, and 2.10 mg 100 g^{-1} for third harvesting stage. Thus, N and Fe contents were higher at the first harvesting stage; however, P, K, Ca, Mg, Mn, Cu and Zn were higher in the second stage than other harvesting stages. These analyzed elements are essential activators for enzyme-catalyzing reactions (Ayaz et al., 2006).

Nitrogen is necessary for protein production in the plant, for the proper growth of leaves, and for many other critical functions (such as photosynthesis) performed. Phosphorus is essential for plant growth and it is also vital for early attainment of growth. Phosphorus has roles in photosynthesis, respiration, energy storage and transfer, cell division, cell enlargement and several

Table 3. Fresh weight, dry matter weight, vitamin C and protein content in kale for different harvesting stages.

Harvesting stage	Fresh weight (g)	Dry matter weight (g)	Vitamin C (mg 100^{-1} g)	Crude protein (%)
First harvest	245.18	46.02	98.30^{b}	35.00^{a}
Second harvest	270.26	56.80	105.21^{ab}	30.62^{b}
Third harvest	290.81	65.23	109.43^{a}	26.87^{c}
Mean	268.75	56.01	104.31	30.83
$LSD_{0.05}$	10.79	2.25	10.01	2.98

Table 4. Mineral content in kale for different harvesting stages.

Harvesting stage	N (%)	mg 100 g^{-1}							
		P	K	Ca	Mg	Mn	Cu	Fe	Zn
First harvest	5.60^{a}	0.48^{b}	3.58^{b}	2.60^{ab}	0.36^{b}	13.71^{b}	0.18^{b}	15.31^{a}	2.04^{b}
Second harvest	4.90^{b}	0.57^{a}	4.62^{a}	2.67^{a}	0.38^{a}	15.63^{a}	0.20^{a}	11.21^{b}	2.12^{a}
Third harvest	4.30^{b}	0.51^{ab}	4.30^{ab}	2.57^{b}	0.35^{b}	14.97^{ab}	0.17^{b}	10.07^{c}	2.10^{ab}
Mean	3.60	0.52	4.16	2.61	0.36	14.77	0.18	12.19	2.08
$LSD_{0.05}$	0.24	0.04	1.34	0.45	0.02	7.63	0.04	0.80	0.37

other processes in the plant (Tirasoglu et al., 2005). Potassium is an indispensible nutrient with its significant role in the synthesis of amino acids and proteins (Malik and Srivastava, 1982). Potassium has a key role in stomatal functioning and helps the plant use water more efficiently by promoting turgidity to maintain internal pressure of the plant (Tırasoglu et al., 2005). Ca and Mg have significant roles in photosynthesis, carbohydrate metabolism, nucleic acids, and binding agents of cell walls (Russel, 1973). Magnesium is also an essential constituent of chlorophyll (Tirasoglu et al., 2005). Mn plays a structural role in the chloroplast membrane system. It may be responsible for color, taste, and smell. It is also a cofactor for fatty acids, DNA and RNA synthesis (Gibbs, 1978). Fe and Cu may exist as Fe and Cu proteins. Iron is a vital constituent of plant (Tirasoglu et al., 2005). Iron is also a crucial activator for enzyme–catalyzing reactions involving chlorophyll synthesis and for ferrodoxin nitrate reductase (Bowling, 1976). Zn is an important micronutrient. It is associated with a number of enzymes; especially those for synthesis of ribonucleic acids (Oser, 1979).

Salisbury and Ross (1992) stated that N accumulation exists in young tissue which also receives soluble forms of nitrogen transported from older leaves. In this study, it is found at the highest concentration in the first harvesting stage where the leaves were still younger. Miller-Cebert et al. (2009a) found highest P at the budding stage as 0.42 g 100 g^{-1}. It is convenient with this study, since that value was determined as 0.39 g 100 g^{-1} in kale. In the leaves of kale, K sufficiency ranges from 2.00 to 4.00% (Mills and Jones, 1996). K was determined as 4.62% for the second harvesting stage in this study. Miller-Cebert et al. (2009a) stated that the levels of K in canola increased with growth. Therefore, it was highest at the blooming stage with 2.05 g 100 g^{-1} and it is coherent with the results of this study in which that value was found as 1.72 g 100 g^{-1} for kale. Clarkson (1984) reported that calcium translocation depends on transpiration. High temperatures could increase transpiration and increase Ca transport to the leaves in kale and collards. This study, however, found Ca higher as 2.67% for the second harvesting stage than other stages. The temperature increased in the second stage than the first and that might result in increased transpiration.

Kopsell et al. (2004) found that high temperatures could increase Mg uptake and accumulation. Moreover, magnesium accumulation in the leaves of kale and collards was positively correlated with Ca accumulation. A similar positive correlation was also determined in this study between Ca and Mg; and the values of the second harvesting stage were 2.67 and 0.38%, respectively. It is coherent with the results of this study that Miller-Cebert et al. (2009a) found the levels of Mn in canola increased during growth and it was peak at the blooming stage with 16.40 mg 100 g^{-1}. In addition, that value was found 18.40 mg 100 g^{-1} in kale. Miller-Cebert et al. (2009a) indicated that Cu presented the least variation from rosette to blooming stages. As in this study, budding stage gave the highest Cu value (0.30 mg 100 g^{-1}). That value was 0.19 mg 100 g^{-1} in kale and it is also coherent to this study. Furthermore, the same author stated the highest Zn for canola as 3.00 mg 100 g^{-1} at the budding stage. That value for kale was given as 3.62 mg 100 g^{-1}. It is also coherent with this study that Miller-Cebert et al. (2009a) found the highest Fe in canola for rosette stage or the first harvesting stage as 24.77 mg 100 g^{-1}.

Finally, it can be said that kale is a relatively good source of abundant antioxidants with its vitamin C, crude protein and mineral contents. The study therefore

popounds that kale can be consumed as a good choice within fundamental nutrients alternatives and it would be worth considering the harvesting stage for kale.

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