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Original Paper

Comparative Study of Sensory Attributes of Leafy Green Vegetables Grown Under Organic and Conventional Management

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***Abstract*— This study was carried out to compare the sensory qualities of leafy green vegetables (collard, kale, lettuce and swiss chard) grown under organic and conventional production systems. Four leafy greens were produced on an organically and conventionally managed research farm of Tennessee State University, Nashville, TN in Spring 2019 and 2020. Crops in a conventional field were grown in the open field, whereas in organic field crops were grown in the open and under three different row covers (agribon cloth, insect net and plastic). Row covers in organic systems were used to protect crops from insect damage. Plant samples were collected from all the treatments and evaluated for sensory qualities including color, texture, taste, odor and flavor following two approaches i.e., instrumental and via consumer panel perception. Consumer panel perception results showed minor differences in the sensory qualities between organic and inorganically produced leafy greens. Instrumental methods showed no differences in color parameters of kale, lettuce and swiss chard grown under organic and conventional production systems. In collard, the lightness (L*), b* (yellow-blue axis), brightness (Y) and chroma (C) values were higher in conventional, while hue angle was higher in organic (open). There were no differences in instrumental textural values of organically and conventionally grown leafy greens. Among row covers, the textural value of collard and kale was higher in open relative to row covers. The content of main quality contributors 1-Hexanol was higher in conventionally grown collard compared to organic (open). Aldehyde compound was higher in organically grown kale and trans-hex-2-enyl-acetate (Ester) compound was higher in conventionally grown kale. Monoterpenes were higher in organic lettuce and ketones were higher in conventionally grown lettuce. Overall, there were not many differences in the sensory qualities of leafy greens grown under organic and conventional production systems. Further comparative studies between organic and conventional systems on sensory qualities of leafy greens are needed.**

Keywords*— *color, leafy greens, organic and conventional production, sensory, texture, volatile compounds

I. Introduction

Consumer attitudes towards food have been greatly changed for the last several years, partly due to the increasing health awareness [1]. There is the public belief that organically produced foods are safe for human health due to less or no chemical contaminants than the foods produced by conventional methods [2-4]. Moreover, decisions of purchasing organic food by consumers are predominantly determined by sensory qualities such as appearance, taste, color, texture, flavor and odor [5]. Consumers are attracted to food products that have a good appearance, color, texture, better taste, good flavor and absence of any bad odor. Sensory qualities can be quantified based on consumer perceptions or using the instruments. Consumer perception is one of the important approaches as a qualitative descriptive analysis method to judge products based on their feelings of taste, feel, color, appearance, aroma, flavor and texture. There are reports that the findings on sensory qualities of food products grown organically and conventionally managed systems are mostly inconsistent [3, 6-9].

Leafy greens are highly perishable vegetables whose quality and shelf life are limited by dehydration, which affect quality attributes such as color, texture, and turgidity [10]. The green color is an important quality parameter of leafy green vegetables at the time of purchase and is indicative of freshness [11]. Crispy and crunchy textures are a desirable quality and are particularly important in fruits and vegetables, where consumers associate them with freshness and healthiness [12, 13]. Salad vegetables like lettuce, kale, swiss chard, carrot and celery should be crispy [14].

Because leafy green vegetables are consumed as salads, the flavor is considered an important sensory quality. After harvest, fresh vegetables have a respiratory process, so improper post-harvest handling and storage easily lead to damage and loss of nutritional and sensory value of crops [15]. Similarly, the time between harvest and consumption is longer, implying that there are chances of developing off-flavor in fresh fruits and vegetables [16]. Several volatile compounds are also responsible for the development of flavor and odor. Esters, Aldehydes, alcohols, acids, ketones, pyrazines and terpenes constitute the main groups of volatile compounds of leafy green vegetables. The fresh green odor of green leaves is attributed to the release of C6 - aldehydes and C6 - alcohols and their corresponding esters and leaf alcohol, hexanol. These volatile compounds with a characteristic green odor are associated with the sensory perception of freshness, but in higher concentrations can become off-odor [17]. Several volatile compounds have been reported as contributing to off-odors after harvesting and storage such as alcohols, aldehydes, terpenes, esters and acids [18, 19]. Pyrazines and terpenes (limonene, (+)-cyclosativene, copaene and caryophyllene) are known to contribute to the green aroma and flavor of many vegetables [20]. Furthermore, the type and concentration of volatile compounds in leafy green vegetables vary according to cultivar, season, vegetable parts, development stage of the plant, cultivation methods and postharvest environmental conditions [21].

Most organic vegetable growers use row covers mainly for protecting crops from insect pest damage and increase yield [22]. Besides, this use of row cover on the leafy green has multiple effects on soil and plant physiological parameters, maintaining the quality of crop and reducing the evapotranspiration. Row cover decreases the air movement that protects the plant from break and injury [23] which ultimately helps to preserve the sensory qualities of the crop. In general, sensory attributes of leafy greens in conventional and organic products have been studied, but information on sensory evaluation of leafy greens grown with organic management using different types of row cover is not extensively studied. Therefore, the main objective of the present study was to evaluate the effects of production systems (organic and conventional) on the sensory characteristics; color, texture, sensory tasting of leafy greens and identify the volatile compounds emitted by leafy greens. Additionally, changes in sensory characteristics of leafy greens grown under three different row covers in organic management were evaluated.

II. MATERIALS AND METHODS

A. *Plant materials and treatments*

A field experiment was carried out in organic and conventional fields of Tennessee State University, Nashville, TN. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications in organic and conventional fields. Leafy greens were planted on March 11, 2019. Collard (Brassica oleracea cv. acephala var. champion), Kale (Brassica oleracea cv. sabellica var. red Russian), Lettuce (Lactuca sativa var. coastal star) and Swiss chard (Beta vulgaris var. ford hook giant) were grown in an organic management system under three different row covers: agribon cloth (Ag-19 made from high-quality spun-bonded polypropylene), insect net (0.35 mm mesh size), and plastic film (ultra-clear transparent, Johnny selected seeds Co., ME, USA) and without row cover (Open) as a control in an organic field. Same varieties of four leafy greens were also grown in conventional fields using chemical fertilizer (N-P-K: 8-2-12). The seedlings were raised in a greenhouse in spring 2019 (February-March). One-month-old seedlings were transplanted in the field with a 5 ft. row to row and 1 ft. plant to plant spacing. In the organic field, after transplantation plots were covered with row covers which were supported by wire hoops 2' above ground. Row covers were used only in the organic field. In organic management, crops were grown and maintained with organic management practices as per standards of the National Organic Program regarding fertilization and pest control throughout the growing season. In both fields, no pesticides were applied. At the stage of commercial maturity, plant leaf samples were harvested from both organic and conventional plots and immediately transported to the lab to analyze color, texture and volatile emissions. For the sensory tasting, we repeated the experiment with the same cultivars of leafy greens grown under five different treatments; agribon cloth, insect net, plastic, open and conventional in spring 2020. Leaf samples were harvested at the commercial maturity stage and assessed sensory tasting of leafy greens by a consumer panel in May 2020.

B. *Color Measurement*

The healthy leaves of each crop (collard, kale, lettuce and swiss chard) from each treatment (agribon cloth, insect net, plastic, open and conventional) were selected for assessing the different color parameters. The color parameter was determined using a LabScan XE colorimeter (Hunter Associates Laboratory Inc., Reston, VA, USA). The LabScan XE colorimeter uses 0°/45° optical geometry to measure color. The sampled leaves were placed above the light source of the instrument. Color values (L*, a* and b*) where L* means Lightness (0 for perfect black and 100 for perfect white), a* means red-green axis (+a* is red and -a* is green) and b* means yellow-blue axis (+b* is yellow -b* is blue) and Y- the brightness of leafy greens were reported. The colorimeter was calibrated with standard black and white tiles (X = 80.49, Y = 85.30, Z = 91.20) using an illuminant D65/10° standard observer. Other color terms were also calculated; Hue angle and Chroma. Hue is expressed as an angle, which starts at 0° (+a* [red]), 90° (+b* [yellow]), 180° (−a* [green]), and 270° (−b* [blue]). Chroma is the amount of saturation of color with values of zero being dull and high chroma values are clear and bright. For each color parameter, three samples for each leafy green were averaged to obtain a single color attribute value for analysis.

$$\text{Chroma (C)} = (a^{*2} + b^{*2})^{0.5} \quad (1)$$

$$\text{Hue angle (H°)} = 180 + \arctan(b^*/a^*) \quad (2)$$

C. *Texture Measurement*

Leaf texture was assessed by using a TA-XT2 Texture Analyzer (Stable Micro Systems Ltd. UK). Each leafy greens (collard, kale, lettuce and swiss chard) sample was placed into the Texture Analyzer and clamped at each end and a test was conducted. The leaves of each leafy green sample were cut into a rectangular strip. As the sample was pulled apart, the maximum force applied to shear per unit area of the leaf was recorded in Newton (N). One measurement was taken per leaf and samples were analyzed in triplicate. The texture analyzer was coupled with a computer and maximum peak force (N) was calculated by the associated software, Version 5 to display the results of the test. All tests were performed at a laboratory room temperature.

D. *Volatile Compounds*

The HERCALES GC Flash electronic nose (AlphaMos, Toulouse, France) was used for the determination of volatile compounds of leafy green vegetables. Electronic nose (E-nose) consists of a sampling section, a detector unit containing the array of sensors, and pattern recognition for data recording and processing. Matured leaves of leafy greens from each treatment were harvested and cut into small pieces and 5 g of each sample were kept in a septa-sealed screw cap glass vial. Volatile compounds were identified using specific software AroChemBase. Each analysis was repeated three times and all of the response data were analyzed using AlphaSoft software (Version 3.0.0, Toulouse, France).

E. Sensory Tasting

The sensory taste-testing sessions were conducted at the Tennessee State University (TSU) in Nashville, TN in May 2020 to identify the preferred characteristics and overall qualities of leafy greens grown under different treatments. Four leafy green vegetables; collard, kale, lettuce, and swiss chard random leaves of similar visual characteristics and with no damage were used for evaluation and were harvested with a knife and rinsed with tap water. Then, the leaves were cut into smaller pieces of the same size. The sensory attributes like appearance, texture, aroma, taste and overall quality of the leafy greens were assessed for the sensory quality determination. A total of 40 panelists (from the Department of Agriculture and Environmental Science, Tennessee State University, Nashville, TN) took part in the sensory evaluations using a line scaling method [24]. In this method, panelists were given a scorecard and asked to place an 'x' mark on it to match the intensity of the leafy greens or associated attribute on the line. The left end of the line stands for a low or zero value and the right end for a high or maximum value. The marks were then converted to numerical values by measuring their location on the line with a ruler. The values were between (0-15). The description of leafy greens attributes (Table 1) was provided prior to the tasting session and the panelists were familiar with the product characteristics. Samples were served to the panelists on paper plates and each sample was coded in three-digit numbers to reduce the biases. Panelists were provided with bottled spring water to rinse their mouths between the consumption of each leafy green.

Table 1. Sensory descriptions of leafy greens attributes.

Attributes		LEAFY GREENS ATTRIBUTES
		Definition
Appearance	Overall Green	Aromatic characteristics of plant-based materials. A measurement of the total green characteristics and the degree to which they fit together. Green attributes include one or more of the following: green-unripe, green-peapod, green-grassy/leafy, green-viney and green-fruity. These may be accompanied by musty/earthy, pungent, astringent, bitter, sweet, sour, floral, beany, minty and piney.
	Green-Unripe	A green aromatic associated with unripe or not-fully-developed plant-based materials; characterized by increased sour, astringent and bitter.
	Green-Grassy/Leafy	A green Aromatic associated with newly cut-grass and leafy plants; characterized by sweet and pungent characters.
Texture	Fibrous	Fibrous nature while masticating.
	Glossy	Surface glossiness.
	Crispness	Force required to compress leafy greens until it fractures into small pieces.
	Juiciness	Water released from grated leafy greens while chewing the sample.
	Hardness	The force needed to grind a piece of leafy greens into fine particles by compressing it between the teeth.
Aroma	Citrus	The aromatics associated with commonly known citrus fruits, such as lemons, limes, oranges, could also contain a peely note.
	Woody	Brown, musty aromatics associated with very fibrous plants and bark.
	Musty/Earthy	Humus-like aromatics that may or may not include damp soil, decaying vegetation or cellar-like characteristics.
	Floral	Sweet, light, slightly perfumey impression associated with flowers.
	Metallic	An aromatic and mouthfeel associated with tin cans or aluminum foil.
	Pungent	The sharp aromatics with a physically penetrating sensation in the nose reminiscent of radish and horseradish.
Taste	Sweet, Overall	Aromatics associated with the impression of sweet substances such as fruit or flowers. (Note: This refers to the aromatics of sweetness rather than the sweet taste).
	Sour	The fundamental taste sensation of which citric acid is typical.
	Bitter	A basic taste factor of which caffeine is typical.
	Salty	The fundamental taste factor of which sodium chloride in water is typical.
	Umami	Flat, salty flavor sometimes thought of as brothy naturally occurring in products such as monosodium glutamate.
	Astringent	The drying, puckering sensation on the tongue and other mouth surfaces.

The description of leafy greens attributes (Table 1) was provided prior to the tasting session and the panelists were familiar with the product characteristics. Samples were served to the panelists on paper plates and each sample was coded in three-digit numbers to reduce the biases. Panelists were provided with bottled spring water to rinse their mouths between the consumption of each leafy green.

F. Statistical Analysis

For sensory analysis, data were subjected for one-way analysis of variance (ANOVA) using PROC GLM in SAS 9.4 software (SAS, Inc., Cary, NC) to determine treatment effects on color, texture, volatile compounds and sensory tasting of leafy greens. When the effect was significant, the Fisher's least significant difference (LSD) test was used for comparisons between treatments at a 5% significance level.

III. RESULTS AND DISCUSSIONS

A. Color

Based on ANOVA's results, the color parameters value of collard was significantly influenced by treatments (P<0.05; Table 2). Color parameters; Lightness (L*), b* (yellow-blue axis), Brightness (Y) and Chroma (C) values were significantly higher in conventionally grown collard compared to organic (open) treatment. However, hue angle was significantly lower in conventionally grown collard than organic (open) treatment. There was no difference between row covers and treatment in lightness (L*) value. A negative a* value indicates the prevalence of the green color component than the red color. However, color value (a*) was non-significant among the treatments. All treatments have positive b* values, indicating a larger proportion of yellow color over blue. At the same time, agribon cloth and open were significantly less yellower than plastic and insignificant to insect net. There was no significant difference in comparing row covers and open treatment for Brightness (Y) value. Hue angle was not significantly different with open and row covers whereas a lower value was observed under plastic. Chroma value was significantly higher in plastic treatment (brighter) compared to open and agribon cloth and insignificant effects of an insect net.

Color parameters of kale were measured by LabScan colorimeter and these values were significantly influenced by treatments (*P*<0.05; Table 3). In comparing the conventional and organic (open) treatment, all color values; Lightness (L*), a*, b*, Brightness (Y), Hue angle (°) and Chroma (C) of kale were not significantly different in between them. However, in comparing the row covers with open treatment, L* value was significantly higher under agribon cloth (45.12) compared to open (39.85), which was darker, and had insignificant effects of inset net and plastic were observed. Negative values of a* represent green, where kale grown under agribon cloth showed the higher value indicating greener hue compared to open and insect net, and plastic effects were insignificant. Positive values of b* represent a higher proportion of yellow color over blue. A higher value was observed on crops grown under plastic. Between row covers and open, there were no significant differences. The brightness (Y) value of kale was observed significantly lower on open but there was no significant difference in between the row covers (agribon cloth, insect net and plastic). There was no difference in the hue angle of kale leaves in between the row covers and open treatment. But, chroma value (C) was numerically higher in plastic but there were no significant differences between row covers and open.

Any of the color parameters of lettuce were not significantly different compared to conventional and organic (open) treatment (Table 4). However, color parameter Lightness (L*) was significantly higher on lettuce grown under plastic (51.32) than open (44.07), which means on the open darker color of lettuce leaves, while the effect of agribon cloth and insect net on the lightness of lettuce were insignificant. For a* and b* values, there were no significant effects of row cover on lettuce compared to open. Brightness (Y) of lettuce was observed significantly higher under plastic (19.7) compared to insect net (15.54) and open (13.93), whereas the effect of agribon cloth (16.96) was insignificant. Hue angle and chroma calculated were not statistically different between the row covers and open treatment.

There were no differences in color parameter values of swiss chard between conventional and organic (open) treatment. However, color parameter a* value was significantly different in between the row covers and open treatment (*P*<0.05; Table 5) on swiss chard. Negative a* value means greener which was significantly higher on insect net and plastic in comparison to open and insignificant effects of agribon cloth. There were no significant effects of row covers and open on b* values of swiss chard. Similarly, color parameters; brightness (Y), hue angle (º) and chroma (C) values were insignificant among the row covers and open.

Different aspects of appearance such as leaf color, size, shape and brightness, are the main quality attributes of leafy greens for marketing and for the consumer. Among them, leaf color is an important attribute, associated with consumer acceptability and preference. Vegetables with greener and brighter leaves are preferred by consumers. Visual quality and freshness are thus important for purchase while overall quality is important at consumption [25]. Green color and texture are important attributes for the indication of freshness when purchasing leafy greens [11]. In our study, there were no differences in the instrumental color parameters of organically and conventionally grown leafy greens kale, lettuce and swiss chard. However,, in collard lightness (L*), b* (yellow-blue axis), brightness (Y) and chroma (C) values were higher in conventional, while hue angle was higher in organic. There was no difference between the different organic fertilizers used and control in the evaluation of instrumental colors; L, a* and b * of kale leaves [26]. In another study, the color of the organically grown strawberries was darker, less vivid and redder compared to the conventionally grown [27].

Table 2. Color parameters mean (±SD) for collard grown under different treatments.

	Organic				Conventional
	Agribon cloth	Insect net	Plastic	Open	
L*	41.37±4.73[b]	42.77±1.81[ab]	44.04±2.88[ab]	40.78±4.98[b]	48.42±1.11[a]
a*	-8.14±0.50[a]	-8.61±0.68[a]	-8.99±1.09[a]	-7.93±0.33[a]	-9.02±0.58[a]
b*	12.78±2.44[b]	14.97±1.58[ab]	18.02±4.26[a]	12.91±0.88[b]	19.36±2.60[a]
Brightness (Y)	12.26±2.92[b]	13.03±1.22[b]	13.93±1.94[ab]	11.90±3.08[b]	17.14±0.88[a]
Hue angle (°)	122.84±3.23[a]	119.98±1.98[ab]	116.91±3.34[bc]	121.60±1.62[a]	115.13±1.66[c]
Chroma (C)	15.17±2.33[b]	17.28±1.61[ab]	20.15±4.25[a]	15.15±0.83[b]	21.36±2.59[a]

Different superscript letters in a row are significantly (P<0.05) different. Row covers (Agribon cloth, insect net and plastic) and open belong to organic production systems.

Table 3. Color evaluation of kale. The values are the mean ± standard deviations. Parameters having superscript letters in a row denote the statistically significant difference at P<0.05.

	Organic				Conventional
	Agribon cloth	Insect net	Plastic	Open	
L*	45.12±2.52[a]	42.99±2.42[ab]	42.35±0.94[ab]	39.85±1.44[b]	43.09±2.20[ab]
a*	-9.01±0.35[c]	-8.85±0.45[bc]	-8.20±2.04[bc]	-7.02±0.54[ab]	-5.95±0.82[a]
b*	14.84±1.49[ab]	14.63±1.00[ab]	17.43±5.78[a]	11.48±0.89[ab]	10.41±4.90[b]
Brightness (Y)	14.67±1.81[a]	13.20±1.64[ab]	12.74±0.61[ab]	11.18±0.87[b]	13.25±1.47[ab]
Hue angle (°)	121.35±1.62[a]	121.20±0.61[a]	115.74±2.83[a]	121.47±0.38[a]	121.68±7.67[a]
Chroma (C)	17.36±1.44[ab]	17.10±1.08[ab]	19.27±6.06[a]	13.46±1.04[ab]	12.07±4.66[b]

Row covers (Agribon cloth, insect net and plastic) and open belong to organic production systems.

Table 4. Color parameters Mean (±SD) for lettuce grown under different treatments.

	Organic				Conventional
	Agribon cloth	Insect net	Plastic	Open	
L*	48.19±1.27[ab]	46.34±1.73[ab]	51.32±4.20[a]	44.07±2.31[b]	47.89±3.27[ab]
a*	-11.12±0.79[a]	-10.93±0.30[a]	-11.02±0.63[a]	-10.26±0.73[a]	-10.62±0.61[a]
b*	26.06±3.19[a]	24.78±1.36[a]	26.34±2.09[a]	22.75±1.43[a]	26.57±2.22[a]
Brightness (Y)	16.96±1.01[ab]	15.54±1.29[b]	19.70±3.56[a]	13.93±1.63[b]	16.79±2.59[ab]
Hue angle (°)	113.20±1.07[a]	113.83±0.65[a]	112.73±1.26[a]	114.28±0.24[a]	111.86±2.06[a]
Chroma (C)	28.33±3.24[a]	27.08±1.37[a]	28.55±2.09[a]	24.95±1.60[a]	28.61±2.05[a]

Different superscript letters in a row are significantly different (P<0.05). Row covers (Agribon cloth, insect net and plastic) and open belong to organic production systems.

Table 5. Color properties of swiss chard. The values are the mean ± standard deviations (n=3). Parameters having superscript letters denotes the statistically significant difference at P<0.05.

	Organic				Conventional
	Agribon cloth	Insect net	Plastic	Open	
L*	42.42±4.00[a]	42.29±0.56[a]	42.14±1.59[a]	39.61±4.01[a]	42.37±3.08[a]
a*	-8.80±1.73[ab]	-10.16±0.32[b]	-10.19±0.06[b]	-8.28±0.21[a]	-8.98±0.79[ab]
b*	21.09±4.16[a]	24.57±1.10[a]	23.68±0.91[a]	21.15±0.13[a]	24.08±4.98[a]
Brightness (Y)	12.90±2.54[a]	12.69±0.39[a]	12.61±1.02[a]	11.13±2.29[a]	12.81±1.98[a]
Hue angle (°)	112.66±1.76[a]	112.48±0.48[a]	113.28±0.94[a]	111.38±0.38[a]	110.77±2.54[a]
Chroma (C)	22.86±4.45[a]	26.59±1.13[a]	25.78±0.81[a]	22.71±0.19[a]	25.70±4.93[a]

Row covers (Agribon cloth, insect net and plastic) and open belong to organic production systems.

Table 6. Texture analysis of four leafy greens under different treatments. The shear values (N) are mean ± standard deviations (n=3). Texture parameter having superscript letters in a row denotes the statistically significant difference at P<0.05.

Crop	Organic				Conventional
	Agribon cloth	Insect net	Plastic	Open	
Collard	4.28±1.94^{c}	6.39±1.78^{bc}	7.69±1.26^{ab}	9.28±0.06^{a}	7.20±0.97^{ab}
Kale	5.25±3.61^{ab}	3.95±1.58^{b}	6.90±1.17^{ab}	7.60±1.60^{a}	5.71±0.52^{ab}
Lettuce	7.77±1.66^{a}	6.78±1.67^{ab}	5.94±0.63^{ab}	6.41±0.75^{ab}	5.15±1.80^{b}
Swiss Chard	6.57±2.54^{a}	6.79±2.02^{a}	9.05±0.43^{a}	6.80±0.69^{a}	5.77±3.05^{a}

Row covers (Agribon cloth, insect net and plastic) and open belong to organic production systems.

Table 7. Volatile compounds of Collard grown under different treatments.

Treatments	Name	Surface Percent	Category/ Total Percent	Retention Time (s)	Kovat's Index
Agribon cloth	Trans-hex-2-enyl-acetate	76.59±1.04	Ester 76.59	62.52	1017
	1-Hexanol	8.39±1.69	Alcohol 8.39	50.66	870
	2,5- Dimethyl pyrazine	3.69±0.45	Pyrazine 3.69	55.14	919
	3- Heptanone	2.26±3.09	Ketone 2.26	53.26	896
	SUM	90.93			
Insect Net	Trans-hex-2-enyl-acetate	66.87±6.30	Ester 66.87	62.28	1013
	3- Heptanone	8.63±2.26	Ketone 8.63	53.19	896
	Acetaldehyde	5.92±5.51	Aldehyde 5.92	16.07	442
	1-Hexanol	5.84±0.64	Alcohol 5.84	50.41	867
	2,5- Dimethyl pyrazine	3.07±0.68	Pyrazine 3.07	55.02	918
	SUM	90.33			
Plastic	Trans-hex-2-enyl-acetate	69.82±9.63	Esters 73.13	62.29	1013
	Ethyl Propanoate	3.31±1.49		34.02	714
	3- Heptanone	7.72±9.05	Ketone 7.72	53.22	896
	1-Hexanol	7.11±4.97	Alcohol 7.11	50.55	869
	2,5- Dimethyl pyrazine	2.86±0.53	Pyrazine 2.86	55.11	919
	SUM	90.82			
Open	Trans-hex-2-enyl-acetate	72.69±11.22	Ester 72.69	62.53	1017
	1-Hexanol	8.61±0.43	Alcohol 8.61	50.72	870
	3- Heptanone	6.04±9.96	Ketone 6.04	53.36	897
	2,5- Dimethyl pyrazine	2.87±0.71	Pyrazine 2.87	55.23	921
	SUM	90.21			
Conventional	Trans-hex-2-enyl-acetate	58.94±1.99	Esters 61.89	62.26	1013
	Ethyl propanoate	2.95±1.58		34.1	715
	1-Hexanol	19.27±1.51	Alcohol 19.27	50.65	870
	3- Heptanone	5.54±0.97	Ketone 5.54	53.25	896
	2,5- Dimethyl pyrazine	3.61±0.73	Pyrazine 3.61	55.13	919
	SUM	90.31			

Row covers (Agribon cloth, insect net and plastic) and open belong to organic production systems.

B. *Texture*

The textural value of leafy greens was assessed through the Texture Analyzer Instrument. The instrumental texture values of leafy greens were influenced by treatments (P<0.05; Table 6). There was no difference in the textural value of tested leafy greens between organic (open) and conventional. Among row covers, the textural value of collard was significantly higher in open compared to agribon cloth and insect net, while no effect of plastic row covers. For kale, textual values were higher for open plants than insect net, whereas no effects of agribon cloth and plastic row covers. There was no difference in textural values of lettuce between row cover and open treatment. Similarly, there were no differences in the textural properties of swiss chard grown under different treatments. Textural changes are among the main causes of quality loss for minimally processed vegetables [28]. Vegetables that maintain crispy and crunchy textures are highly desirable quality [29, 30] and consumers associates these textures with freshness and healthiness [12, 13]. The texture evaluation of the lettuce is complex due to the heterogeneity of the photosynthetic and vascular tissues, and inner leaves differ metabolically from the outer leaves [31]. In our study, more force was required to shear the leaves of collard and kale grown on open compared to other row covers. Textural changes are among the main causes of the quality loss of leafy green vegetables. Indeed, the appearance of a soft or sagging product may give rise to consumer rejection prior to consumption. The consumer panels also did not feel any differences in textural quality between the two production systems.

C. *Volatile Compounds*

The Electronic nose is the instrument that is used to identify and detect the information of simple and complex volatile compounds (VCs) of the sample [15]. E-nose is an instrument that offers a rapid and alternative method to detect the aroma of fresh-cut vegetables [32]. The volatile profiles of four leafy greens; collard, kale, lettuce and swiss chard were generated using the e-nose, and more than 90% of the volatile compounds were identified with the Kovats index and Arochembase software.

Collard

The total volatile composition is distributed between esters, alcohol, pyrazine, aldehyde and ketone (Table 7, Fig.1). The major volatile composition was contributed by Trans-hex-2-enyl-acetate (Ester) in treatments; agribon cloth 76.59%, plastic 73.13%, open 72.69%, insect net 66.87% and conventional 61.89%. Most of the volatile compounds of collard were found without any significant differences between organically and conventionally grown collard. Only alcohol compound (1-Hexanol) was found higher on conventionally grown collard (19.27%) compared to organic (open) treatment (8.61%). No volatile compounds of collard were significantly different in between the row cover. The compound acetaldehyde (Aldehyde) was detected only under insect net treatment that means under organic management. It also showed that esters were the major contributor of volatile compounds in collard followed by alcohol, ketone and pyrazine in all treatments.

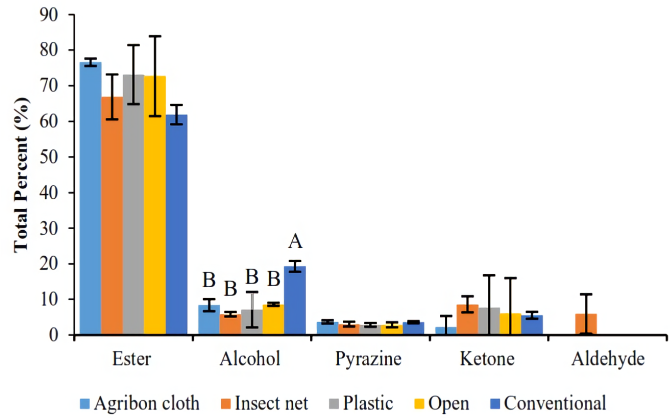

Fig. 1. Comparison of volatile compounds in collard under different treatments. Different letters in a bar are significantly (LSD, P<0.05) different. Row covers (Agribon cloth, insect net and plastic) and open belong to organic production systems.

Kale

The total volatile composition of kale is distributed between esters, alcohols, pyrazines, aldehydes, ketone and acid (Table 8). Major volatile compounds identified in kale were significantly different among the treatments (P<0.05; Fig.2). Ester compound was significantly higher (P<0.05) under conventional treatment (60.24%) compared to other treatments. Alcohol compound was detected higher in conventionally grown kale and open treatment. Nevertheless, in comparison between row covers and open, there was no significant difference between open and agribon cloth whereas alcohol percentage of kale was detected lower in plastic. Aldehydes and pyrazines were significantly lower in conventionally grown kale than in the open. Pyrazine (Acetyl pyrazine) compound was significantly higher under insect net and plastic than the other treatments. Comparing between row covers and open, aldehydes (Benzaldehyde and Heptanal) compound was significantly lower in plastic whereas, under agribon cloth, insect net and open were insignificant. However, ketone (Acetophenone) was found only on conventional (1.04%) and open (1.40%) treatment whereas acid (3-Methyl butanoic acid) was detected only in open (1.63%) treatment.

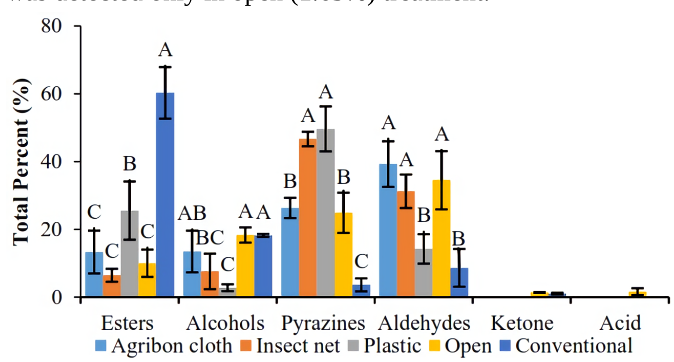

Fig. 2. Comparison of volatile compounds in kale grown under different treatments. Different letters in a bar are significantly (LSD, P<0.05) different. Row covers (Agribon cloth, insect net and plastic) and open belong to organic production systems.

Table 8. Volatile compounds of kale grown under different treatments.

Treatments	Name	Surface Percent	Category/ Total Percent	Retention Time (s)	Kovat's Index
Agribon cloth	Benzaldehyde	32.57±1.61	Aldehydes 39.25	57.88	954
	Heptanal	6.68±5.10		53.51	899
	Acetyl pyrazine	26.31±3.00	Pyrazine 26.31	61.57	1002
	Trans-hex-2-enyl-acetate	9.92±6.14	Esters 13.3	62.47	1016
	Methyl-2-methylbutanoate	3.38±0.33		41.25	777
	2-propanol	7.27±6.54	Alcohols 13.45	18.42	492
	1-Hexanol	6.18±6.56		50.68	870
	SUM	92.31			
Insect Net	Acetyl pyrazine	46.64±2.14	Pyrazine 46.64	61.6	1003
	Benzaldehyde	23.34±5.81	Aldehydes 31.23	57.69	952
	Heptanal	7.89±1.16		53.65	899
	1-Hexanol	7.59±5.25	Alcohol 7.59	50.75	871
	Trans-hex-2-enyl-acetate	6.44±1.92	Ester 6.44	62.33	1014
	SUM	91.9			
Plastic	Acetyl pyrazine	49.63±6.63	Pyrazine 49.63	61.62	1003
	Trans-hex-2-enyl-acetate	21.05±6.27	Esters 25.52	62.24	1013
	Methyl-2-methylbutanoate	4.47±4.20		41.3	778
	Benzaldehyde	8.38±1.89	Aldehydes 14.2	57.61	951
	Heptanal	5.82±2.53		53.45	898
	1-Hexanol	2.77±1.02	Alcohol 2.77	50.69	870
	SUM	92.12			
Open	Benzaldehyde	30.53±8.14	Aldehydes 34.48	57.58	951
	Heptanal	3.95±0.79		53.37	897
	Acetyl pyrazine	24.87±5.93	Pyrazine 24.87	61.34	999
	1-Hexanol	14.18±1.25	Alcohols 18.32	50.77	871
	2-propanol	4.14±1.10		17.76	478
	Methyl-2-methylbutanoate	6.04±2.61	Esters 10.0	40.07	767
	Trans-hex-2-enyl-acetate	3.96±4.30		62.26	1012
	3-methyl butanoic acid	1.63±0.99	Acid 1.63	51.66	886
	Acetophenone	1.40±0.09	Ketone 1.40	65.72	1067
	SUM	90.7			
Conventional	Trans-hex-2-enyl-acetate	58.76±7.59	Esters 60.24	62.19	1012
	Ethyl acrylate	1.48±0.47		32.62	702
	1-Hexanol	18.21±0.43	Alcohol 18.21	50.62	869
	Benzaldehyde	6.23±5.02	Aldehydes 8.64	57.41	948
	Acetaldehyde	1.87±2.19		67.89	1101
	Heptanal	0.54±0.31		53.21	898
	Acetyl pyrazine	2.71±2.07	Pyrazines 3.61	61.14	996
	2,5- Dimethyl pyrazine	0.90±0.17		55.1	919
	Acetophenone	1.04±0.26	Ketone 1.04	65.94	1071
	SUM	91.65			

Row covers (Agribon cloth, insect net and plastic) and open belong to organic production systems.

Table 9. Volatile compounds of Lettuce grown under different treatments.

Treatments	Name	Surface Percent	Category/ Total Percent	Retention Time (s)	Kovat's Index
Agribon cloth	n-Butanol	19.82±2.61	Alcohols 27.86	30.12	674
	1-Hexanol	6.39±0.91		50.47	868
	Methyl eugenol	1.65±0.65		83.15	1404
	Ethyl propanoate	14.72±3.98	Esters 23.39	31.02	684
	Ethyl 3- propanoate	6.02±1.70		68.65	1115
	Ethyl isobutyrate	1.34±0.51		39.57	763
	Methyl 2-methyl butanoate	1.31±0.63		42	784
	Butanal	10.99±0.40	Aldehydes 24.77	21.09	549
	Acetaldehyde	10.50±2.76		16.92	407
	2-4-Heptadienal	2.40±0.85		61.31	998
	2-Methyl propanal	0.88±0.08		19.74	521
	Butanoic acid	4.24±0.38	Acid 4.24	44.97	812
	Limonene	3.83±1.64	Monoterpenes 4.89	65.7	1067
	Alpha-pinene	1.06±0.38		54.73	914
	Acetophenone	3.83±1.64	Ketones 6.02	65.7	1067
	2,3-Pentanedione	2.19±0.73		33.07	706
	Dimethyl trisulfide	0.78±0.11	Sulfur 0.78	59.59	976
	SUM	91.95			
Insect Net	Butanal	13.10±1.18	Aldehydes 33.46	21.68	562
	Acetaldehyde	12.84±0.7		16.9	447
	Furfural	3.20±0.11		44.84	810
	2-Octenal	1.74±0.21		64.55	1049
	Dodecanal	1.69±0.04		83.59	1414
	Benzene Acetaldehyde	0.89±0.04		63.36	1030
	Ethyl propanoate	10.25±1.5	Esters 14.06	30.88	683
	Ethyl 3-propanoate	3.81±1.63		68.53	1113
	n-Butanol	9.40±3.31	Alcohols 25.76	29.97	672
	1-Hexanol	7.40±0.65		50.34	866
	Propylenglycol	4.29±0.40		38.94	757
	Methyl eugenol	1.96±0.16		83.02	1401
	Anisyl alcohol	1.84±0.17		78.46	1302
	2-Propanol	0.87±0.13		19.73	520
	Limonene	4.26±2.50	Monoterpenes 5.09	66	1072
	Myrcene	0.83±0.06		60.52	988
	Butanoic acid	3.20±0.11	Acids 6.39	44.84	810
	Pentanoic acid	1.68±0.53		54.61	913
	3-Methyl butanioc acid	1.51±0.41		51.47	878
	Acetphenone	2.72±0.17	Ketones 4.58	67.03	1088
	2,3-Pentanedione	1.86±0.26		32.62	702
	Trimethyl pyrazine	1.59±0.35	Pyrazine 1.59	61.16	997
	Dimethyl trisulfide	1.02±0.22	Sulfur 1.02	59.43	974
	SUM	91.95			
Plastic	Limonene	19.40±1.21	Monoterpenes 43.77	66.14	1074
	gamma-terpinene	16.69±0.86		67.15	1090
	1-8, cineole	4.18±0.64		63.54	1033
	(-)beta-pinene	1.88±0.19		60.62	990
	Citronellal	1.62±0.52		70.37	1146
	Ethyl-3- propanoate	11.84±0.79	Esters 18.13	68.34	1109
	Ethyl propanoate	3.90±0.21		33.75	712
	Ethyl isobutyrate	2.39±0.10		39.2	759
	Acetaldehyde	8.31±0.82	Aldehydes 16.21	16.9	460
	Butanal	5.62±0.86		21.68	562
	Dodecanal	1.16±0.51		83.71	1417
	2-4-heptadienal	1.12±0.41		61.77	1005

	1- Hexanol	4.54±1.13		50.44	867
	n-Butanol	2.52±0.06	Alcohols 8.6	30	673
	Methyl eugenol	1.54±0.11		83.16	1404
	Butanoic acid	2.47±0.10	Acid 2.47	44.9	811
	Dihydro 2(3H)-Furanone	1.36±0.08	Ketone 1.36	54.75	914
	SUM	90.54			
Open	Acetaldehyde	12.82±1.03	Aldehydes 20.34	16.27	446
	Butanal	7.52±1.52		21.74	563
	Limonene	12.17±2.15	Monoterpenes 26.35	66.07	1073
	Gamma-terpinene	9.79±1.57		67.08	1088
	Citronellal	1.54±0.34		70.24	1144
	1R-alpha-pinene	1.52±0.09		54.71	914
	Myrcene	1.33±0.08		61.28	998
	1-Hexanol	7.34±0.36	Alcohols 20.86	50.48	868
	n-Butanol	7.16±1.60		30.18	675
	Propylenglycol	3.05±0.57		34.6	719
	Methyl eugenol	1.85±0.16		83.11	1403
	3- Heptanol	1.46±0.40		51.65	880
	Ethyl 3- propanoate	7.25±0.79	Esters 14.6	68.56	1113
	Ethyl propanoate	5.95±2.53		31.08	685
	Ethyl isobutyrate	1.40±0.37		39.83	765
	Butanoic acid	3.47±0.45	Acid 3.47	45	812
	2,3-Pentanedione	2.24±0.16	Ketone 2.24	32.81	703
	Acetylpyrazine	2.31±0.69	Pyrazine 2.31	63.46	1032
	SUM	90.17			
Conventional	2-Heptanone	19.92±13.87	Ketones 24.62	51.5	878
	5-Ethyl dihydro2- furanone	1.88±1.49		64.61	1050
	3-Heptanone	1.41±0.40		54.6	912
	Rheosmin	1.41±0.38		88.6	1531
	1-Hexanol	14.25±0.14	Alcohols 21.21	50.44	867
	n-Butanol	6.00±4.02		30	673
	Propylenglycol	0.96±0.15		38.55	754
	Ethyl Propanoate	8.92±5.16	Esters 17.08	34.2	715
	Trans-hex-2-enyl-acetate	5.08±4.00		62.18	1012
	Ethyl 3-propanoate	2.16±1.20		67.1	1089
	Ethyl isobutyrate	0.92±0.07		39.42	761
	Acetaldehyde	5.96±2.50	Aldehydes 17.7	16.95	461
	Butanal	4.60±1.27		21.7	562
	2-Methyl propanal	1.57±0.68		21.1	550
	Dodecanal	1.48±0.34		83.57	1414
	n-nonanal	4.09±1.80		68.63	1115
	Limonene	5.42±3.12	Monoterpene 5.42	66.04	1072
	Butanoic acid	4.59±0.39	Acid 4.59	44.91	811
	SUM	90.62			

Row covers (Agribon cloth, insect net and plastic) and open belong to organic production systems.

Table 10. Volatile compounds of swiss chard grown under different treatments.

Treatments	Name	Surface Percent	Category/ Total Percent	Retention Time (s)	Kovat's Index
Agribon cloth	1-Hexanol	43.10±1.22	Alcohol 43.10	50.66	870
	Trans-hex-2-enyl-acetate	18.61±6.66	Esters 22.89	62.16	1011
	Ethyl propanoate	4.28±1.68		34.76	720
	Limonene	5.18±0.39	Monoterpene 5.18	66.03	1072
	N-nonanal	3.42±2.06	Aldehydes 4.61	68.53	1113
	2-4-heptadienal	1.19±0.31		61.2	997
	Butanoic acid	3.07±1.64	Acids 6.78	44.96	812
	2- methyl propanoic acid	1.94±1.05		42.13	785

	3- methyl butanoic acid	1.77±0.30		51.55	879
	Acetophenone	2.92±0.70		67.03	1088
	Butane-2,3-dione	2.28±1.37	Ketones 6.26	21.77	564
	Dihydro-2-(3H)- furanone	1.06±0.44		54.7	914
	Acetyl pyrazine	1.31±0.32	Pyrazine 1.31	63.44	1031
	SUM	90.13			
Insect Net	1-Hexanol	40.89±3.56	Alcohol 40.89	50.51	868
	Trans-hex-2-enyl acetate	38.29±4.84		62.09	1010
	Ethyl 2- methyl butyrate	2.18±1.17	Esters 42.48	51.43	878
	Ethyl propanoate	0.87±0.43		32.51	701
	Ethyl 3- propanoate	1.14±0.24		68.67	1115
	Butane-2,3-dione	1.89±0.34	Ketones 2.51	21.64	561
	Dihydro-2-(3H)- furanone	0.62±0.29		54.55	912
	Limonene	1.82±0.57	Monoterpene 1.82	65.96	1071
	Butanoic acid	1.12±0.25	Acids 1.99	44.71	809
	2- methyl propanoic acid	0.87±0.12		41.83	783
	Dodecanal	0.91±0.12	Aldehyde 0.91	83.5	1412
	SUM	90.6			
Plastic	1-Hexanol	28.52±11.40	Alcohols 29.79	50.59	869
	Methyl eugenol	1.27±0.41		83.03	1401
	Trans-hex-2-enyl acetate	26.04±16.59		62.17	1012
	Ethyl propanoate	5.74±2.86		34.37	717
	Ethyl-3- propanoate	3.84±0.11	Esters 37.12	68.57	1114
	Butyl butanoate	1.50±0.41		61.2	997
	Limonene	6.67±1.68	Monoterpenes 7.8	66.08	1073
	Citronellal	1.13±0.63		70.25	1144
	Butanoic acid	3.83±1.43		44.85	811
	3-methyl butanoic acid	1.34±0.92	Acids 6.42	51.53	879
	2- methyl propanoic acid	1.25±0.21		42.03	784
	Butane-2,3-dione	2.73±0.98		21.7	562
	5-ethyl-Dihydro-2-(3H)-furanone	2.73±0.37	Ketones 7.87	66.95	1086
	2-Acetyl naphthalene	1.35±0.97		91.5	1601
	Dihydro-2-(3H)- furanone	1.06±0.56		54.67	913
	Acetyl pyrazine	1.61±0.71	Pyrazine 1.61	63.5	1032
	SUM	90.61			
Open	1-Hexanol	27.41±11.35	Alcohols 28.87	50.57	869
	Methyl eugenol	1.46±0.88		83.01	1401
	Limonene	17.48±8.82	Monoterpene 17.48	66.03	1072
	Trans-hex-2-enyl-acetate	16.20±8.07		62.11	1011
	Ethyl propanoate	8.02±4.72		32.59	701
	Ethyl-3- propanoate	3.14±1.95	Esters 29.64	68.21	1107
	Methyl -2- methyl butyrate	0.55±0.45		39.13	759
	Isoamyl acetate	1.73±0.71		51.57	879
	Butane-2,3-dione	3.12±1.84		21.67	562
	2-Acetyl naphthalene	1.40±1.45	Ketones 5.66	91.5	1601
	Dihydro-2-(3H)- furanone	1.14±0.47		54.64	913
	Butanoic acid	2.87±1.50	Acids 4.54	44.86	811
	2- methyl propanoic acid	1.67±0.95		41.98	784
	n-nonanal	2.78±1.68	Aldehydes 3.85	69.29	1126
	2-4-heptadienal	1.07±0.57		61.2	997
	SUM	90.04			
Conventional	1-Hexanol	24.53±5.98	Alcohol 24.53	50.62	869
	Limonene	20.27±1.89	Monoterpene 20.27	66.12	1073
	Trans-hex-2-enyl-acetate	9.87±3.65		62.22	1012
	Pentyl butanoate	7.16±1.03		67.13	1089
	Ethyl 3-Propanoate	4.43±0.48	Esters 27.6	68.35	1110
	Ethyl heptanoate	4.02±1.32		69.25	1123
	Ethyl Propanoate	2.12±0.60		34.54	718
	Acetylpyrazine	5.16±0.95	Pyrazine 5.16	63.5	1032

2-3-pentanedione	4.22±2.65	Ketones 6.73	32.66	702
Butane-2,3-dione	2.51±0.77		21.69	562
Butanoic acid	2.99±1.23	Acids 4.69	44.87	811
2- methyl propanoic acid	1.70±0.43		42	784
2-4 heptadienal	1.44±0.23	Aldehyde 1.44	64.12	1042
SUM	90.42			

Row covers (Agribon cloth, insect net and plastic) and open belong to organic production systems.

Table 11. Mean (±SD) scores from a consumer panel of collard grown under different treatments.

Sensory Attributes		Organic				Conventional
		Agribon cloth	Insect net	Plastic	Open	
Appearance	Overall green	11.32±1.71^{a}	9.73±1.59^{ab}	8.52±2.68^{b}	10.27±2.97^{ab}	9.14±2.85^{ab}
	Green- Unripe	6.16±6.02^{a}	6.06±5.66^{a}	5.48±5.15^{a}	5.75±5.30^{a}	4.29±4.14^{a}
	Green- Grassy/ leafy	2.95±4.14^{a}	2.57±2.99^{a}	4.38±5.03^{a}	4.51±4.84^{a}	5.29±5.60^{a}
Texture	Surface glossiness	9.84±2.28^{a}	6.84±3.64^{b}	9.81±2.82^{a}	7.00±1.77^{b}	9.49±3.71^{ab}
	Hardness	8.04±3.93^{a}	8.13±3.59^{a}	7.55±4.52^{a}	7.46±4.68^{a}	7.34±4.90^{a}
	Fibrous	8.98±3.40^{a}	8.35±3.98^{a}	8.52±2.13^{a}	8.49±3.61^{a}	9.81±3.90^{a}
	Crispness	6.82±4.56^{a}	6.23±4.36^{a}	6.87±5.39^{a}	6.48±4.73^{a}	6.41±5.23^{a}
	Juiciness	6.79±4.46^{a}	7.06±5.26^{a}	7.79±5.34^{a}	6.81±3.75^{a}	8.06±5.27^{a}
Aroma	Citrus	3.91±3.46^{a}	5.09±4.81^{a}	4.94±5.05^{a}	3.29±3.46^{a}	5.02±4.24^{a}
	Woody	2.02±3.63^{a}	2.41±4.43^{a}	1.7±2.96^{a}	1.31±2.16^{a}	2.73±5.10^{a}
	Musty/ Earthy	2.52±4.56^{a}	2.55±4.47^{a}	1.37±2.08^{a}	1.76±3.13^{a}	2.17±3.32^{a}
	Floral	3.21±3.68^{a}	3.89±4.36^{a}	3.61±4.09^{a}	4.10±4.36^{a}	3.45±4.21^{a}
	Metallic	1.55±2.68^{a}	2.00±3.39^{a}	1.54±2.36^{a}	2.17±3.76^{a}	1.73±2.94^{a}
	Pungent	3.35±4.46^{a}	2.26±3.14^{a}	2.71±3.37^{a}	2.24±3.91^{a}	2.82±4.16^{a}
Taste	Sweet	7.18±4.38^{a}	7.14±4.75^{a}	6.26±3.35^{a}	5.62±4.45^{a}	6.03±4.28^{a}
	Sour	1.72±3.05^{a}	0.87±1.39^{a}	1.73±2.82^{a}	1.08±1.63^{a}	1.35±2.11^{a}
	Salty	2.59±3.47^{a}	1.87±2.55^{a}	2.86±4.19^{a}	2.07±2.68^{a}	2.93±4.52^{a}
	Bitter	2.28±3.43^{a}	0.97±1.23^{a}	1.85±2.56^{a}	1.78±2.23^{a}	2.34±3.01^{a}
	Umami	0.19±0.60^{a}	0.26±0.82^{a}	0.29±0.92^{a}	0.16±0.51^{a}	0.22±0.70^{a}
	Astringency	2.27±3.63^{a}	1.25±2.19^{a}	1.73±2.69^{a}	1.48±2.11^{a}	1.84±2.75^{a}
Overall quality		9.23±3.40^{a}	8.10±4.49^{a}	8.26±3.81^{a}	8.07±3.15^{a}	9.04±4.15^{a}

*Different superscript letters in a row are significantly ($P<0.05$) different. Row covers (Agribon cloth, insect net and plastic) and open belong to organic production systems.

Table 12. Mean scores (±SD) from a consumer panel of kale grown under different treatments.

Sensory Attributes		Organic				Conventional
		Agribon cloth	Insect net	Plastic	Open	
Appearance	Overall green	11.01±1.42^{a}	10.74±2.59^{a}	8.33±2.07^{b}	11.62±1.51^{a}	11.12±2.41^{a}
	Green- Unripe	5.83±5.44^{a}	5.24±4.71^{a}	5.46±5.20^{a}	5.20±4.68^{a}	4.81±4.85^{a}
	Green- Grassy/ leafy	6.19±4.93^{a}	5.87±4.45^{a}	5.53±4.16^{a}	7.04±5.32^{a}	6.22±4.89^{a}
Texture	Surface glossiness	8.47±3.23^{a}	9.95±4.36^{a}	7.53±3.28^{a}	8.67±3.52^{a}	9.10±4.34^{a}
	Hardness	8.43±4.53^{a}	8.12±3.76^{a}	9.17±4.54^{a}	8.12±3.26^{a}	8.77±3.90^{a}
	Fibrous	7.98±2.80^{a}	8.58±2.46^{a}	10.01±1.75^{a}	8.53±2.26^{a}	8.54±2.46^{a}
	Crispness	6.67±4.63^{a}	6.16±4.03^{a}	5.74±4.43^{a}	8.28±5.52^{a}	6.98±4.86^{a}
	Juiciness	7.62±3.14^{a}	8.06±3.33^{a}	6.28±2.62^{a}	8.08±3.63^{a}	7.75±3.74^{a}
Aroma	Citrus	5.68±3.53^{a}	5.97±3.78^{a}	4.24±3.02^{a}	5.78±3.98^{a}	5.92±4.29^{a}
	Woody	2.21±2.74^{a}	2.56±3.53^{a}	2.65±3.32^{a}	2.46±3.78^{a}	3.28±4.54^{a}
	Musty/ Earthy	4.64±3.97^{a}	4.12±2.95^{a}	4.15±3.84^{a}	3.34±2.20^{a}	3.17±2.76^{a}
	Floral	7.60±3.50^{a}	6.90±3.78^{a}	6.00±3.10^{a}	7.06±3.32^{a}	6.93±2.78^{a}
	Metallic	1.96±2.48^{a}	2.20±2.70^{a}	2.14±2.96^{a}	1.73±2.40^{a}	2.13±2.69^{a}
	Pungent	4.98±2.91^{a}	5.30±2.95^{a}	5.44±3.94^{a}	5.21±4.12^{a}	6.19±4.17^{a}
Taste	Sweet	7.28±3.51^{a}	8.79±3.28^{a}	6.17±3.13^{a}	7.80±3.28^{a}	6.89±3.00^{a}
	Sour	3.07±3.77^{a}	1.79±1.95^{a}	2.39±2.86^{a}	1.64±1.93^{a}	2.07±2.57^{a}
	Salty	3.56±3.60^{a}	3.34±3.46^{a}	2.78±2.38^{a}	2.95±2.80^{a}	2.85±2.46^{a}
	Bitter	3.41±3.25^{a}	3.39±4.22^{a}	2.88±2.49^{a}	2.94±2.57^{a}	3.93±3.44^{a}
	Umami	2.09±3.09^{a}	2.04±3.04^{a}	1.75±2.41^{a}	1.97±3.20^{a}	2.38±3.56^{a}
	Astringency	5.09±5.45^{a}	4.25±4.74^{a}	3.08±3.71^{a}	3.94±4.75^{a}	2.96±3.76^{a}

Overall Quality	9.22±3.60^{ab}	10.77±1.64^{a}	8.50±3.54^{ab}	9.16±2.61^{ab}	7.65±2.57^{b}

*Different superscript letters in a row are significantly (P<0.05) different. Row covers (Agribon cloth, insect net and plastic) and open belong to organic production systems.

Table 13. Mean scores (±SD) from consumer panel comparing of lettuce grown under different treatments.

Sensory Attributes		Organic				Conventional
		Agribon cloth	Insect net	Plastic	Open	
Appearance	Overall green	7.71±2.70^{c}	10.09±3.25^{ab}	8.33±2.31^{bc}	12.06±1.50^{a}	10.69±2.43^{a}
	Green-Unripe	8.92±4.17^{a}	8.90±4.48^{a}	9.07±3.73^{a}	9.64±4.43^{a}	7.74±3.99^{a}
	Green-Grassy/ leafy	7.60±4.50^{a}	8.01±4.97^{a}	8.00±4.75^{a}	8.17±5.88^{a}	7.27±5.02^{a}
Texture	Surface glossiness	11.04±1.62^{a}	9.37±2.49^{a}	9.92±2.64^{a}	9.38±3.40^{a}	9.27±3.91^{a}
	Hardness	9.51±4.45^{a}	10.33±4.39^{a}	7.53±4.18^{a}	8.10±4.11^{a}	8.47±4.02^{a}
	Fibrous	9.86±3.98^{a}	10.44±2.46^{a}	9.26±2.79^{a}	9.64±1.91^{a}	9.96±2.70^{a}
	Crispness	9.02±4.99^{a}	7.92±4.14^{a}	8.51±4.82^{a}	8.69±4.46^{a}	8.60±3.78^{a}
	Juiciness	8.53±4.53^{a}	9.26±4.05^{a}	8.09±4.40^{a}	7.29±3.93^{a}	8.55±4.61^{a}
Aroma	Citrus	4.81±5.31^{a}	5.52±5.60^{a}	4.90±4.69^{a}	5.06±5.04^{a}	4.39±4.43^{a}
	Woody	2.57±4.54^{a}	2.49±4.92^{a}	2.20±3.84^{a}	2.60±4.75^{a}	2.51±4.24^{a}
	Musty/ Earthy	5.69±6.15^{a}	5.51±5.84^{a}	5.43±5.60^{a}	5.48±5.73^{a}	5.09±5.76^{a}
	Floral	6.01±5.03^{a}	5.90±4.52^{a}	6.02±4.71^{a}	6.62±4.52^{a}	6.71±5.16^{a}
	Metallic	5.49±6.09^{a}	5.24±6.07^{a}	4.98±5.77^{a}	4.05±4.52^{a}	4.92±5.23^{a}
	Pungent	7.71±4.07^{a}	7.13±4.53^{a}	10.17±4.30^{a}	8.30±3.24^{a}	8.44±3.29^{a}
Taste	Sweet	8.64±3.59^{a}	10.06±3.38^{a}	7.85±4.44^{a}	9.39±2.74^{a}	9.51±4.14^{a}
	Sour	3.15±5.69^{a}	3.21±5.39^{a}	4.18±6.21^{a}	3.46±5.53^{a}	2.88±4.76^{a}
	Salty	5.87±5.03^{a}	4.63±4.36^{a}	5.24±5.06^{a}	5.07±4.58^{a}	4.16±4.26^{a}
	Bitter	3.17±3.49^{a}	4.25±5.06^{a}	4.64±5.46^{a}	4.42±4.48^{a}	4.34±4.97^{a}
	Umami	2.96±4.07^{a}	2.76±4.49^{a}	3.82±4.29^{a}	3.72±5.19^{a}	3.05±4.21^{a}
	Astringency	4.32±4.18^{a}	4.21±4.63^{a}	5.53±4.77^{a}	4.93±4.27^{a}	5.16±4.24^{a}
Overall Quality		9.93±2.68^{a}	10.02±2.46^{a}	8.72±3.23^{a}	9.23±1.56^{a}	9.41±3.38^{a}

*Different superscript letters in a row are significantly different at P<0.05. Row covers (Agribon cloth, insect net and plastic) and open belong to organic production systems.

Table 14. Mean scores (±SD) from consumer panel comparing organically and conventionally grown swiss chard.

Sensory Attributes		Organic				Conventional
		Agribon cloth	Insect net	Plastic	Open	
Appearance	Overall green	9.54±2.12^{b}	10.16±1.37^{b}	7.79±2.66^{c}	10.56±1.88^{b}	13.00±0.65^{a}
	Green-Unripe	5.33±4.06^{a}	5.28±4.11^{a}	4.99±2.60^{a}	5.08±3.09^{a}	5.33±4.45^{a}
	Green-Grassy/ leafy	3.88±5.28^{a}	3.01±4.10^{a}	2.73±3.89^{a}	3.61±4.88^{a}	3.38±4.68^{a}
Texture	Surface glossiness	8.86±3.22^{b}	8.91±3.24^{b}	7.74±2.66^{b}	8.79±2.54^{b}	12.57±1.45^{a}
	Hardness	7.91±4.39^{a}	7.78±3.47^{a}	8.14±3.93^{a}	8.82±4.15^{a}	10.54±3.97^{a}
	Fibrous	8.90±3.05^{b}	9.81±2.60^{ab}	8.30±1.46^{b}	9.58±3.72^{ab}	11.36±2.28^{a}
	Crispness	7.09±3.92^{a}	8.95±3.91^{a}	7.23±3.48^{a}	8.60±4.80^{a}	10.12±4.06^{a}
	Juiciness	9.56±3.90^{a}	9.75±4.42^{a}	8.69±4.53^{a}	8.39±3.62^{a}	8.77±4.47^{a}
Aroma	Citrus	1.09±1.33^{a}	1.33±2.09	1.50±2.04^{a}	1.65±2.82^{a}	1.98±2.91^{a}
	Woody	1.43±3.66^{a}	1.61±4.22^{a}	0.94±2.15^{a}	0.75±1.58^{a}	0.70±1.31^{a}
	Musty/ Earthy	1.05±1.86^{a}	1.23±2.50^{a}	1.47±2.95^{a}	1.58±2.99^{a}	1.18±2.25^{a}
	Floral	4.02±4.47^{a}	4.33±4.82^{a}	4.03±4.26^{a}	4.35±5.01^{a}	5.23±5.70^{a}
	Metallic	0.89±2.64^{a}	0.80±2.36^{a}	0.58±1.67^{a}	0.67±1.95^{a}	0.52±0.98^{a}
	Pungent	4.23±4.09^{a}	3.93±3.60^{a}	3.80±3.32^{a}	4.14±3.52^{a}	3.90±3.84^{a}
Taste	Sweet	7.97±4.99^{a}	7.78±5.37^{a}	6.25±4.22^{a}	6.19±4.17^{a}	6.88±4.38^{a}
	Sour	1.52±2.92^{a}	0.98±1.89^{a}	1.72±3.53^{a}	1.42±2.78^{a}	1.20±3.10^{a}
	Salty	1.23±1.78^{a}	1.92±3.86^{a}	0.79±1.36^{a}	1.36±2.41^{a}	1.00±1.77^{a}
	Bitter	2.64±3.85^{a}	2.40±3.47^{a}	3.08±4.42^{a}	1.65±2.40^{a}	1.86±2.92^{a}
	Umami	1.32±2.45^{a}	1.14±2.25^{a}	1.22±2.24^{a}	1.08±1.80^{a}	1.01±1.65^{a}
	Astringency	4.15±3.34^{a}	3.52±2.78^{a}	3.74±2.89^{a}	4.59±3.61^{a}	4.55±3.90^{a}
Overall Quality		8.14±3.62^{ab}	9.12±3.91^{ab}	6.82±3.16^{b}	8.64±3.71^{ab}	10.52±3.83^{a}

*Different superscript letters in a row are significantly (P<0.05) different. Row covers (Agribon cloth, insect net and plastic) and open belong to organic production systems.

Lettuce

Among the different volatile compounds identified in lettuce, most of the compounds were significantly different among the treatments (P<0.05; Table 9). The total volatile composition of lettuce is distributed between alcohols, esters, aldehydes, ketones, monoterpenes, acids, pyrazine and sulfur (Fig.3). In conventionally grown lettuce, most of the volatile compounds were significantly lower in comparison to other treatments. Ketones were significantly higher (24.62%) under conventionally grown lettuce than the other treatments; agribon cloth (6.02%), insect net (4.58%), open (2.24%) and plastic (1.36%). For ester, alcohol and aldehyde compounds, there was no significant difference between conventional and organic (open) treatment. Between row covers and open, the ester compound was significantly higher under agribon cloth than the other treatments. Similarly, alcohol compound percentage was higher under agribon cloth compared to plastic and open treatment. Aldehydes and acids were significantly higher under insect net compared to other treatments; agribon cloth, plastic and open. Under plastic treatment, monoterpenes were higher than the other treatments, but other volatile compounds were lower in plastic row cover. Sulfur and pyrazine compounds were detected only in organically grown lettuce.

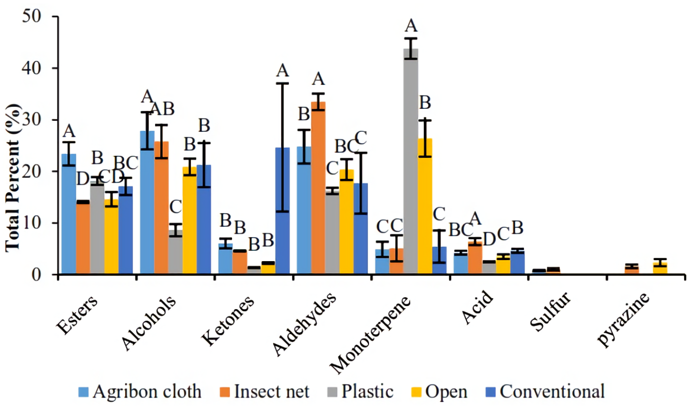

Fig. 3. Comparison of volatile compounds in lettuce grown under different treatments. Different letters in a bar are significantly (LSD, P<0.05) different. Row covers (Agribon cloth, insect net and plastic) and open belong to organic production systems.

Swiss chard

The total volatile composition of swiss chard is distributed between esters, alcohols, monoterpenes, ketones, acids, aldehydes and pyrazine (Fig. 4). Among the different volatile compounds identified in swiss chard, few compounds are significantly different among the treatments (P<0.05; Table 10). Among esters, Trans-hex-2-enyl-acetate compound was dominant, which was higher under insect net relative to agribon cloth and open, whereas plastic row cover has no effect. There was no significant difference in ester, alcohol and monoterpene between organically grown (open) and conventionally grown lettuce. Among row covers, ester compound was significantly higher under insect net than agribon cloth and open but insignificant effect of plastic row cover. Alcohol compound was higher under agribon cloth and insect net compared to open and plastic treatment. Moreover, monoterpene (Limonene) compound percentage was significantly higher under organic (open) treatment. Citronellal (Monoterpene) was only detected in plastic treatment. There was no significant difference in ketones and acid total percentage among the treatments.

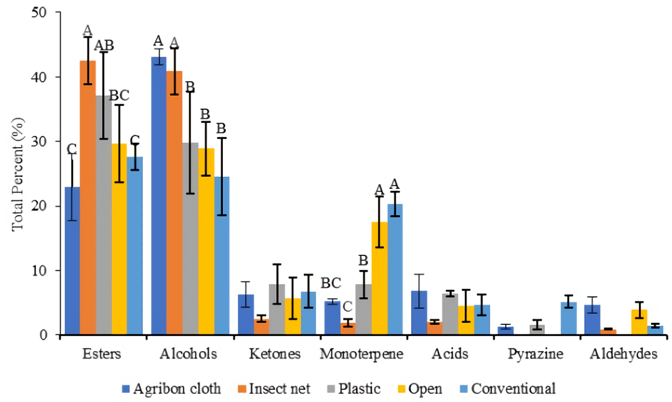

Fig. 4. Comparison of volatile compounds in swiss chard on different treatments. Different letters in a bar are significantly (LSD, P<0.05) different. Row covers (Agribon cloth, insect net and plastic) and open belong to organic production systems.

Esters, Aldehydes, alcohols, acids, ketones, pyrazines and terpenes constituted the main groups of volatile compounds of leafy green vegetables evaluated in this study. Electronic nose (E-nose) has been used to investigate volatile compounds in varieties of food, including wine, juice, dairy products, fruit and vegetables. This device consists of an array of electronic chemical sensors providing a digital fingerprint of the volatiles present in the sample headspace [33]. In our study, collard and kale volatile compounds were mainly dominated by these functional groups; esters, alcohols, ketones, pyrazines and aldehydes. Only alcohol compound (1- Hexanol) percentage was found higher on conventionally grown collard compared to organic (open) treatment and this compound was perceived as pleasant fruity aromas [34]. In collard 2,5- Dimethyl pyrazine was detected in all the treatments, and one study showed that the transition from dimethyl pyrazines to trimethyl pyrazine, in which the odor quality changes from nutty to earthy/roasted flavor [18].

Most of the volatile compounds found in lettuce were previously reported as lettuce volatile emissions: nonanal, dodecanal, limonene, pentanoic acid [19], 1- hexanol, 2-Methylpropanal, 2-Methylpropanol, butanol, butanoic acid, limonene, acetophenone, dimethyl sulfide [35], 2-4 heptadienal, butanal [34]. The most abundant alcohols were n- butanol and 1-hexanol in lettuce in all the treatments. The 1-hexanol compound was perceived as pleasant fruity aromas whereas n- butanol was associated with an adverse rotten odor which had a negative influence on the fragrance of lettuce [34]. In addition, this study also showed that hexanol emission from lettuce was recorded, and it suggested that activities causing tissue damage may generally induce the emissions of hexanol [36]. Among volatiles, aldehydes accounted for the main group of detected volatiles and they are known to contribute to the fresh flavor of many vegetables including lettuce [35]. However, some aldehydes were related to off-odor profiles, such as the compounds butanal and 2- heptenal [34]. This study result showed that butanal and acetaldehyde were more dominant over aldehyde in all the treatments. [37] reported that the concentrations of acetaldehyde and ethanol increased in stressful conditions in salad lettuce. In many plant species, volatile compounds such as monoterpenes are also emitted only in stress conditions [38, 39]. In this study the monoterpene emission rate of the lettuce was dominated by limonene, followed by β-pinene, α-pinene, Myrcene, gamma-terpinene, citronellal and 1-8, cineole. Terpenes have been identified as an important aroma compound and also play an important role in flavor, pollinator attraction and plant defense, even if it is in low concentration [40, 41].

In our study, the most dominant functional groups in swiss chard were esters, alcohol, ketones, monoterpenes and acid. Monoterpene compounds found in swiss chard were previously reported as volatile emissions as Limonene and Citronellol [42], similar to this study. The presence of 1- Hexanol in swiss chard in all the treatments indicates quality contributor [34]. Pyrazines and terpenes are known to contribute to the green flavor of many vegetables [20]. Monoterpenes were found only in lettuce and swiss chard in all the treatments.

D. Sensory tasting

Sensory qualities include product features that are assessed by humans by means of special tests and the organs of taste, smell, touch, sight and hearing. All leafy greens were scored by consumer panels based on the following descriptors: appearance, texture, aroma, taste and overall quality. Among different sensory attributes of collard, overall green and surface glossiness were significantly different ($P<0.05$; Table 11) and other attributes were insignificant among the treatments. Collard's overall green mean score from a consumer panel was higher under agribon cloth (11.32) but insignificant to open (10.27), the lowest value was under plastic (8.52). Surface glossiness mean score was higher under agribon cloth (9.84) and plastic (9.81) compared to open (7.0) and insect net (6.84). The overall green and surface glossiness mean scores were not different between conventional and organic (open). Similarly, other sensory attributes of collard were insignificant among organic (open) and conventional treatment.

Among the different sensory attributes of kale, overall green and overall quality attributes were significantly influenced by treatments ($P<0.05$; Table 12). There was no significant difference in the overall green attribute mean score between agribon cloth (11.01), insect net (10.74) and open (11.62), whereas a significantly lower mean score was found on plastic row cover (8.33). There was no significant difference between row covers and open on overall quality attribute. The overall green and the overall quality mean scores were not significantly different between conventional and organic (open). The other sensory attributes were not influenced by any of the treatments.

The overall green attribute of lettuce mean score was significantly higher ($P<0.05$; Table 13) in organic (open) (12.06) than plastic (8.33) and agribon cloth (7.71), but the insignificant effect of insect net (10.09) row cover. There was no difference in sensory attributes between organic (open) and conventionally produced lettuce. Other sensory attributes of lettuce mean scores were not affected by production systems.

For swiss chard, overall green, surface glossiness, fibrous and overall quality mean scores were influenced by production systems ($P<0.05$; Table 14). Overall green and surface glossiness attribute mean scores were higher in conventional compared to organic (open) swiss chard. Among row covers, there was no difference between agribon cloth, insect net and open whereas the lowest mean score was observed under plastic row covers. For surface glossiness, there was no significant difference between row covers and open. The fibrous and overall quality of swiss chard means scores were not significantly different between conventionally grown and organic (open). Similarly, the sensory attributes; fibrous and overall quality mean scores were not significantly different between the row covers and open. Other sensory attributes were not affected by any of the treatments.

Sensory tasting of leafy greens by consumer panel did not show significant differences between organically and conventionally grown leafy greens. The only exception was in swiss chard where the conventionally produced swiss chard was rated significantly higher scores from consumer panels on overall green and surface glossiness sensory attributes than the organically (open) produced swiss chard. Some studies reported that consumers perceive no difference in the taste of organic food versus conventionally grown produce [43-46]. In contrast, other studies report a better taste for organic produce [47]. Various factors could affect the sensory analysis of organic and conventionally grown produce. Although some researchers also suggest that soil type, crop variety, climate, sampling methods, duration of the experiment and post-harvest practices affects the nutritive and sensory characteristics of foods [9, 48-50]. The quality of the product, particularly that of the leafy vegetables, improved under row covers. In the present study, also some row covers performed better in some sensory attributes. Overall green sensory attributes of collard and kale under agribon cloth performed better. Additionally, consumer panels rated a higher score for surface glossiness of collard under agribon cloth and plastic row covers. In a previous consumer study on Chinese cabbage, the texture of the leaves became tender, leaves were pale green in color, as preferred by consumers as well as the quality was also improved by the use of row covers [51]. This suggests that covering the plants with row covers reduced the radiation and prevented scorching or wilting of leaves [51]

IV. CONCLUSION

All differences in the sensory qualities between the two production systems generally were very small. It can be concluded that organic and conventional production systems do not create major sensory differences in the leafy greens vegetables evaluated. Further studies are needed to confirm and investigate the consumer preference towards organic products growing under different row covers. In addition, it is advisable to increase panel size in order to get more specific consumer results when comparing organic versus conventional fruits and vegetables.

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