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Quality Evaluation of Honeydew Melon: Effects of Ethylene Treatment
(Under the Direction of ROBERT L. SHEWFELT)

Exogenous ethylene used to determine if the quality of honeydew melons as delivered to the consumer could be enhanced. External color of melons turned more yellow and less green, the respiratory climacteric was induced, and the total volatile concentration increased sharply after treatment with 1000 ppm ethylene. Thirty-three volatile compounds were identified by gas chromatography/mass spectrometry. Significant odor active compounds included 2-methyl-methylbutanoate, 2-methyl-ethyl butanoate 3-methylbutyl acetate, (Z) 6-nonenal, and nonanal. Volatile compounds most closely related to enhanced ripening were 2-methyl methylbutanoate, ethyl butanoate, 2-methylethyl butanoate, pentyl acetate, benzyl acetate, and (Z) 6-nonen-ol (R^2=0.43).

Descriptive analysis demonstrated that ethylene treatment increased the intensity of fruitiness and decreased crispiness. The melons with low maturity did not respond to the ethylene treatment. Total soluble solids, volatile concentration, internal color L* and the external b* were the best indicators of melon maturity. The results suggest that ethylene treatment can improve the quality of honeydew melons but only within a small range maturity.

INDEX WORDS: Honeydew Melon, Quality, Ethylene treatment, Descriptive analysis, Volatile analysis, Total soluble solid (TSS).

QUALITY EVALUATION OF HONEYDEW MELON: EFFECTS OF ETHYLENE TREATMENT

by

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To my grandpa and grandma

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INTRODUCTION

Cucumis melo is a polymorphic species that has been divided them into seven different cultivars. Two cultivars have important commercial significance in U.S.: the C. *melo* var. Reticulatus Naud (cantaloupe or muskmelon) and C. *melo* var. Inodorus Naud (the winter melon).

Unlike netted muskmelons, honeydew melons belong to the winter melon group and do not form an abscission zone on the vine until reaching the commercially overripe stage. Thus it is difficult to determine optimal harvest timing. Formation of volatile aromatic compounds can be induced by postharvest ethylene treatment, but the fruit must have sufficient sugar reserves at harvest.

This thesis describes a systematic approach to measure the quality of honeydew melons and the effect of ethylene treatment. Both instrumental analysis and sensory evaluation were used in this research to determine quality. A regression equation was developed to relate the total soluble solid contents (TSS) to production of specific volatile compounds.

This thesis is divided into five parts. The first chapter is the review of literature relevant to this study. The instrumental analysis of honeydew melon physicochemical characteristics and the effects of ethylene treatment are discussed in chapter 2. A linear regression model relating total soluble solid contents and volatile compounds is presented in chapter 3, the correlation coefficients among all quality-related physicochemical factors were also been discussed. The fourth chapter discusses the effect of ethylene treatment on sensory attributes of honeydew melons and the interrelationship of

instrumental readings with sensory analysis. Significant findings of the study are summarized in chapter 5.

Chapters 2 to 4 are prepared in the form of manuscripts prepared for submission to scientific journals. The formats of these sections are in accordance with guidelines set forth by respective journals.

CHAPTER 1

REWIEW OF LITERATURE

Cucumis melo is a polymorphic species that has been divided into seven different cultivars: C. *melo* var. Canteloupensis Naud, C. *melo* var. Conomon Mak, C. *melo* var. Chito Naud, C. *melo* var. Dudaim, C. *melo* var. Flexuosus Naud, C. *melo* var. Reticulatus Naud, and C. *melo* var. Inodorus Naud. (Whitaker and Davis et al., 1962). The latter two cultivars have important commercial significance in U.S. The C. *melo* var. Reticulatus Naud (cantaloupe or muskmelon) and C. *melo* var. Inodorus Naud (the winter melon).

What is commercially called cantaloupe but more appropriately named netted muskmelon belongs to C. *melo* var. Reticulatus Naud group, it has netted, warty or scaly surfaces; the flesh is usually orange but sometimes green and emits characteristic melon flavor or musty flavor; with fruits dehiscent at maturity. (McCreight et al, 1993)

"The honeydew muskmelon is an old cultivar of high quality with distinctive appearance and flavor and unique horticultural and physiological characteristics." (Pratt et. al., 1977) Honeydew melon belongs to the *Cucumis melo L.* Inodorus group that includes green or white-fleshed casaba, dark green, wrinkled rind and pink flesh crenshaw, orange-fleshed Persian, juan canary, and santa claus melons (Hall, 1992). Honeydew melon has a smooth surface, with flesh that is usually white or green and lacking in a musky odor; usually has longer storage life than muskmelon with no abscission zone formed in the vine at maturity (McCreight et al, 1993)

According to USDA Agricultural Statistics Board, honeydew melon consumption in the U.S. doubled from about 1.0 pound per person during the early 1970's to about 1.8 pound per person during the early 1990's. This increased consumption is attributed to

greater melon availability by importing the honeydew melons from Mexico and Central America during the off-season (winter and spring) in the United States.

The normal season of honeydew melons ranges from May through September. According to the census of agriculture in 1992, California, Arizona, and Texas's production in the United States accounted for 98 percent of honeydew melon. The important climacteric factors for honeydew production are warm temperature, low relative humidity and a long, frost free season with abundant sunshine; which accounts for these three states leading in honeydew melon production.

Melons ripened on the plant have superior eating qualities and flavor than those harvested before reaching the fully ripe stage (Wyllie et al., 1995). Unlike cantaloupe, honeydew melon does not form a well-developed abscission zone until the melon becomes commercially overripe (Pratt et. al., 1977). Thus it is hard to decide the suitable harvest timing. There are three classes of commercial maturity:
(http://www.vric.ucdavis.edu):

"1= Mature, Unripe:

> Ground color white with greenish accents, no characteristic aroma, peel fuzzy/hairly and not waxy. California Grade Standards establish a minimum legal harvest index of 10% soluble solid (10 % Brix)

2= Mature, Ripening:

> Ground color white with slightly discernible green tint, slightly waxy peel, blossom-end firm and unyielding, no or slight aroma. Preferred commercial maturity class.

3= Ripe:

Ground color creamy white with yellow accents, clearly waxy peel, characteristic aroma noticeable, blossom-end yields slightly to press."

Melons are an excellent source of vitamin C; they also provide potassium, iron and dietary fiber. In addition, cantaloupe is an excellent source of beta-carotene. Table 1.1 provides a comparison of selected melon cultivars.

Table 1.1: Composition of various melon cultivars

	Cantaloupe	Casaba	Honeydew	Watermelon
Refuse (g)	45	45	45	50
Water (g)	90	92	87	90
Protein (g)	1.0	0.6	0.9	0.6
Fat (g)	0.1	0.1	0.1	0.1
Total sugar (g)	7.0	6.2	10.1	9.0
Other carbohydrate (g)	0.2	0.1	0.2	0.1
Vitamin A, I. U.	4200	Tr.	500	300
Thiamine (mg)	0.06	0.06	0.06	0.08
Riboflavin (mg)	0.02	0.02	0.02	0.02
Niacin (mg)	0.9	0.4	0.6	0.2
Vitamin C (mg)	45	19	32	6
Minerals-Ca (mg)	10	5	6	5
Fe (mg)	0.4	0.4	0.2	0.2
Mg (mg)	17	8	10	11
P (mg)	39	7	14	9
K (mg)	330	210	330	130
Na (mg)	20	12	20	5
Calories	27-36	26	41	31-40

From Howard et al. (1962), values are for 100g fresh weight of edible portion

Quality

"Quality is a human construct comprising many properties or characteristics" (Abbott et al., 1999). For research purposes, instrumental analysis is preferred to sensory evaluation since the instrumental measurements are more precise, more reliable, and can generate a common language among researchers, consumers and the industry (Abbott et al., 1999). To be useful, the quality-related attributes need to be reliably quantified. The perception of quality by consumer is based on appearance, color, texture, flavor (Shewfelt et al., 1990). Essentially, appearance is related to electromagnetic properties, texture to mechanical properties, and flavor (taste and aroma) to chemical properties (Abbott et al., 1999). Limitations in the use of instrumental analysis to accurately predict consumer response require the comparison of instrumental data to that collected from consumer testing.

Appearance is usually the first quality attribute perceived by consumers while purchasing. Several methods are used to determine the color, such as objective visual determination, or use of colorometers, spectrometers and spectrophotometers. The most frequently used color system is the CIE L*a*b* color system. L* indicates lightness and the scale is from white=100 to black=0. The a* and b* coordinates together can indicate the directions of color with a* the red-green axis and b* the yellow blue axis. The origin is achromatic. Hue is relating to the color name, (e.g. orange, yellow, green) the location around the circumference and saturation (chroma) is the distance from the origin (relating to the intensity of the color)(Minolta 1994). Fluorescence measurements can be used to detect the surface damage of product with significant amount of chlorophyll (Butler et al.,

1963), while X-ray techniques can be used to measure the interior quality of produce (Nylund et al., 1950).

Texture is also an indicator of produce quality. During the fruit ripening process, the softening reaction is mainly due to the cell wall degradation and the hydrolysis of the pectic component. Several techniques can be used to determine the texture of the product, such as the penetrometer (Jackman et al., 1990) as well as sonic and ultrasonic vibration (Farabee et al., 1991).

The aroma and sweetness of melons are also the important factors in overall quality and consumer acceptability (Yamaguchi et al., 1977,Shalit et al., 2000). The techniques used for sweetness are total soluble solids contents determined by refractomer, or near-infrared (NIR) imaging (Dull, et al., 1989 and 1992, Sugiyama et al., 1999, and Greensill et al., 2001). The basic principal for NIR is to utilize tilting-interference-filter technology for wavelength scanning and a silicon detector with preamplifer for sensing radiation that has passed the fruit flesh. It can be used as a non-destructive measurement to ensure the consumer at least a minimum level of sweetness in agricultural products with thin skin (Dull et al., 1992).

Gas chromatography is widely used in volatile compound analysis. Several techniques can be used to collect the volatile compounds from the fruit, such as gas chromatographic (GC) headspace sampling, solvent extraction, vacuum and steam distillation, supercritical fluid extraction (SFE), and solid-phase microextraction (SPME). Different volatile collection methods may results in different aroma profiles. GC analysis can be coupled with mass spectrometry to form a GC-MS system. The mass spectrometer serves as the GC detector with high sensitivity. The mass spectrum of each

molecule detected is stored in the system's computer and the mass spectrum corresponding to a given GC peak can be read out by matching the spectrum with the compounds in the computer database.

The gas chromatography-olfactometry is used to identify the odor impact compound in the collected volatile sample and quantify the odor activity of the volatile compounds. The basic principal of GCO is inhalation of the GC effluent to determine which components have specific odor characteristics. The volatile compounds are separated in the capillary column and connected to a non-destructive thermal conductivity detector (TCD) with the outlet to a sniff port.

Physicochemical attributes in melon:

Carbohydrate:

Sweetness may be the most important factor determining quality of melon fruits (Yamaguchi et al., 1977). Research indicates that sugar accumulation during the development of melon has strong correlation with subjective fruit quality in a wide range of cultivars (Lester et al., 1992; Burger et al., 2000). Hughes et al. (1983) quantified the major carbohydrates: fructose, glucose, sucrose, riffinose and stachyose in whole muskmelon plants finding that the stachyose is the predominant sugar in the leaves but absent in the fruit. In contrast, glucose and fructose are the major sugars in fruit but only contribute to little amount of total sugar concentration in the leaf.

Sucrose, glucose and fructose are the three major contributors to the total sugar content in the ripe melon fruit (Burger et al., 2000). During the fruit development stage, there is a large increase in sucrose relative to glucose and fructose, with a decline in acid

invertase activity and an increase in sucrose phosphate synthase (Pratt et al., 1971 and Schaffer et al., 1986, and Lingle et al., 1987).

Melons do not have starch reserve in the fruit (Pratt et al., 1971), thus the accumulation of sugar depends on the supply of photoassimilates from the leaf during the ripening (Hubbard et al., 1990). A reduction of leaf area can result in the low sucrose accumulation in the fruit. The sucrose in melon accumulates when Sucrose phosphate synthase (SPS) activity is higher than soluble acid invertase during fruit ripening (Hubbard et al., 1989). Lester (2001) suggests that an increase in sugar accumulation in melon could be achieved via genetic manipulation or by selection of the cultivar with high SPS activity throughout melon maturation.

Cohen et al. (1986) reported that levels of fructose and glucose decreased with an increase in storage time and temperature, however, no change was detected in soluble solids content or in sucrose concentration.

Respiration and ethylene production:

Ethylene is a plant hormone, which has effect on the growth, development and the storage life. The effects of ethylene on quality of fresh fruits and vegetables have been reviewed by Saltveit (1999). Those effects include the stimulation of fruit ripening respiration, abscission, senescence, cholorophyll destruction yellowing, and seed germination.

During development, the honeydew melon rapidly produces trace amount of ethylene, but the ethylene concentration increases sharply about 10 days before the onset

of ripening, and the concentration reaches about 3 ppm within the tissue prior to the start of the climacteric rise in respiration (Pratt et al, 1968).

Measurement of the respiratory rate and ethylene concentration provides an indicator of the initiation of ripening. The rise in respiratory rate may also be due to the more energy by plant tissue during the early (synthetic) stages of ripening (Pratt et al., 1968).

Pigments:

Chlorophyll is the major pigment in many plants, masking other fruit pigments such as caroteinoids. "Fruit skin color results from a dynamic process involving continual changes in pigment composition taking place through growth, maturity, and storage."(Hutchings, 1999) During ripening, chlorophyll disappears in plant tissue as chloroplasts are converted to chromoplasts, thus revealing yellow or red pigments present in fruit. In netted muskmelons, the orange flesh color is an important quality characteristic. Reid et al. (1977) indicated that the chlorophyll contents in the cantaloupe decreases steadily throughout the development of the fruit. During the ripening process, the gradual rise in carotenoid content accompanies chlorophyll degradation.

Volatile Compounds:

Melon is a fragrant fruit, emitting the characteristic aroma during ripening, with the aroma is often used as an indicator of quality by the consumer. The aroma of fruit is ordinarily composed of complex mixtures of volatile compounds present in the headspace (Ohliff et al., 1978). Shalit et al. (2000) emphasized the importance of aroma in melons in

their overall quality and consumer acceptability. The key volatile contributors to characteristic aroma of melons include alcohols, aldehydes, and large quantities of esters (Kemp et al., 1972 and 1973; Yabumoto et al., 1977 and 1978; Buttery et al., 1982, and Wyllie et al., 1990). While the peculiar aroma of melons cannot be related to any single compound, the melon or fruity notes are provided by the interaction of many individual volatile compounds (Shalit et al., 2001).

Flavor research on melon volatiles has focused on identification of the volatile compounds in melon fruit and the biosynthesis pathway of volatiles (Motomura et al., 1994, Ueda et al., 1997,Shalit et al., 2001, Wyllie et al., 1995). The concentration of volatile compounds has been quantified by gas chromatography with compound identification by mass spectrometry. Several major volatile compounds collecting method has been used, such as steam or vacuum distillation (Horvat et al., 1987, Kemp et al., 1971,1972, and 1973, Wyllie et al., 1992 and 1995), headspace volatile collection using absorbent (Buttery et al., 1982, Bauchot et al., 1998) solid phase microextraction (SPME)(Fallik et al., 2001; Beaulieu et al., 2001) or directly insert a syringe into melon cavity to obtain a gas sample (Yabumoto et al., 1978). One of the difficulties in flavor research is that different volatile collecting techniques result in different aroma profiles due to the difference in specificity between the volatile compounds and the absorbent or extraction solvent.

When comparing the volatile compounds of honeydew melons with those commonly found in many other fruits, Buttery et al. (1982) indicated that (Z)-6-nonenyl acetate, (Z)-3-nonenyl acetate, and (Z, Z)-3,6-nonadienyl acetate are unique to the

honeydew melon (*Cucumis melo* Inodorus Naud.). They also reported that (Z)-6-nonenyl acetate has a pleasant honeydew melon like aroma and is reasonably potent.

Melon cultivars differ in many physical and chemical characteristics. The formation of volatile aldehyde is through the degradation of fatty acid, while the alcohols are from the dehydrogenation of aldehydes catalyzed by alcohol dehydrogenase (Tressl et al., 1973). Volatile ester compounds are important aroma contributors of melon fruit (*Cucumis melo* L.). They are formed through the esterification of carboxylic acid and alcohols. The reaction is catalyzed by alcohol acetyltransferase and CoA ester is used s the acyl donor (Ueda et al., 1997 and Shalit et al., 2001).

The relationship between the free amino acids and the formation of aroma volatiles in melon fruit is reviewed by Wyllie et al. (1995)**.** They indicated that the radiotracer works in melon (Yabumoto et al., 1977 and 1978) showed amino acids could be converted into branched-chain alcohols and esters. For example: Leucine can be converted into esters that contain 3-methylbutyl structure, isoleucine to 2-methylbutyl structure (Buttery et al., 1982). Valine could be the precursor of esters that contain 2-methylpropyl structure. Alanine can supply both ethyl group and acyl group due to its structure (Wyllie et al., 1995). The structure of several sulfur containing volatile compounds suggested they might derive from methionine (Wyllie et al., 1992, Yang et al., 1984). Wyllie et al. (1995) reported that amino acid showed considerable increases in concentration coincide with ripening process and the generation of volatiles in *Cucumis melo* cv Makdimon fruit.

To determine the odor active compounds, gas chromatography-olfactorymetry (GCO) technique need to be used. By using aroma extraction dilution assay (AEDA), the odor activity value (OAV) could be identified. The definition of OAV is “the concentration/threshold where the threshold is the lowest concentration detectable by humans in the sample" (Mayol et al., 2001).

Using AEDA, Schieberle et al. (1990) concluded that the most important aroma contributors in muskmelon (*Cucumis melo*) are methyl 2-methylbutanoate, (Z)-3 hexanal, (E)-2 hexanal, ethyl 2-methylpropanoate. In order to evaluate the relative sensory significance of sulfur compounds and esters to the overall melon aroma, Wyllie et al. (1992) used AEDA to evaluate the melon (*Cucumis melo*) volatile compounds. They found that 3-(methylthio) propanal, S-methyl thiobutanoate, and dimethyltetrasufide convey a musky overtone to the classical fruity aroma associated with3- (methythio) propyl acetate, ethyl 2-methylpropanoate, ethyl 2-methyl butanoate and methyl 2-methylbutanoate.

The storage condition also can affect the netted muskmelon (*Cucumis melo* Reticulatus Naud.) volatile production. Kemp et al. (1973) found that C_9 alcohols increased about 10 fold after freezing while 2-nonenal increased approximately 20 fold. The increases in some esters of C_{18} unsaturated fatty acids were also observed.

The attachment of fruit to its parent plant may be a factor that affects the fruit volatile production. Bliss and Pratt (1979) found that volatile production in netted muskmelons was inhibited by the attachment to parent plant, while there is no evidence for inhibition of honeydew volatile generation by parent plant. They also found that

ethylene could trigger an earlier production of volatile esters (ethyl acetate) in preclimacteric fruits.

Firmness:

The texture of melon is a critical factor limiting its storage life (Simandjuntk et al., 1996). During ripening, softening of the tissue occurs in the fruit. This loss of flesh firmness during muskmelon fruit ripening is related to modifications of pectic and hemicellulosic polysaccharides, and a net loss of non-cellulosic neutral sugars (McCollum et al., 1989). The decrease in the non-cellulosic neutral sugars (rhamnose, arabinose, mannose, and galactose) suggested that both pectins and hemicellulose are modified and solublized during the ripening process. (Simandjuntak et al., 1996).

Fils-Lycaon et al. (1991) classified the glycosidases of melon mesocarp into three groups based on changes in specific activity: Decrease during ripening (α-D-galactosidase, α-D-mannosidase and α-L-arabinofuranosidase), increase toward the end of ripening and overripening(β-D-galactosidase, β-D-glucosidase and α-L-arabinopyranosidase), and remain constant during ripening(β-D-xylosidase).

Lester and Stein (1993) described changes in texture during the melon maturation process in turns of the biochemical changes affecting the lipid matrix of plasma membrane as they influence fruit membrane permeability during maturation and postharvest storage of muskmelon fruit. In this explanation the change of hypodermal mesoscarp tissue membrane results in the softening of fruit, presumably by a loss of turgor pressure. During the storage of mature melons, membrane electrolyte leakage has high correlation with the postharvest senescence (Lester et al., 1988).

Postharvest handling:

Fungal rot is the major factor leading to the short storage life of melon fruits. A well-studied control for these organisms has been the use of hot water treatment (57°C) alone or in combination with fungicides to minimize fungal growth on the fruit surface (Carter et al., 1981, Mayberry et al., 1992, and Wade et al., 1983).

Desiccation is another factor limiting melon quality. Mayberry et al. (1992) reported that using hot water treatment along with wrapping the melon with polyethylene wraps can maintain the melon quality at least 28 days of storage at 3 ºC. Wrapped fruit provide a moisture saturated environment conducive to fungal growth, thus the control of decay organism becomes more important. Lester (1989) compared three treatments: gamma irradiation, hot water (57 °C) treatment and the fungicide imazalil (1000 ppm) with or without shrink-film wrap. Gamma irradiation injured the physical quality of melons and was ineffective in controlling the fungal growth. Although the imazalil treatment with shrink-wrap prolonged the storage period for 60 days, imazalil has not been registered by the United States Food and Drug Administration for commercial use on muskmelon. Thus Lester concluded that hot water treatment along with shrink-film wrap is most effective way to maintain physical quality and controlling fungal growth. Lingle et al. (1987) conducted a research in order to know the effect of heat treatment and polyethylene wrap on sugar metabolism. Although the polyethylene wrap helps to maintain the appearance of melon fruit, it cannot prevent a small loss of sucrose in mesocarp tissue between 12 and 18 days at 4°C storage.

Lester and Grusak (USDA 1999) found that dipping the honeydew melon into amino acid-calcium chelate solution with at least 80 mM calcium can extend the storage life of the melons grown in the green house. Dipping the melon in calcium solution not only can prolong melon's market life but also increase the calcium levels in the honeydew melons.

Ethylene treatment:

Harvested melons can be treated with ethylene, usually 18-24 hours, to provide uniform ripening. Ethylene concentrations in the range of 40 to 1000 ppm have proved effective experimentally (McGlasson et al., 1963, Bianco et al., 1977, Pratt et al., 1977, and Bliss et al., 1979). The response to ethylene differs due to tissue temperature, the physiological age of the fruit, duration of treatment and concentration applied (Pratt 1961, McGlasson et al., 1964, Pratt et al.1968, Bianco et al., 1977, Pratt et al., 1977, and Bliss et al. 1979,). The immature fruits fail to ripen even though the ethylene has been applied.

While ethylene has been used to ripen physiologically mature honeydew melon, an immature melon will not respond to ethylene treatment and develop characteristic sensory quality. The limiting factor appears to be the lack of sugar production in ethylene related fruit due to the lack of starch reserves for conversion into sugar. Therefore, there is no significant change in total sugar content after ethylene treatment (Pratt et al., 1977).

The application of high concentration of exogenous ethylene on harvested melons accelerated the production of organic volatiles but did not significantly affect their final concentrations (Bliss et al., 1979). Once normal ripening begins; endogenous ethylene

should be sufficient to induce the production of volatile esters. Harvestable maturity of honeydew melon is attained at 35-37 days after anthesis and the self-ripening stage was reached 47 days after anthesis (Pratt et al., 1977). Generally speaking, melons are harvested at the harvestable maturity stage, thus the ethylene treatment can contribute to uniform ripening. This thesis is designed to determine the effects of ethylene on harvested honeydew melons and to determine if ethylene treatment can enhance the quality of honeydew melons in the supermarket.

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CHAPTER 2

INSTRUMENTAL ANALYSIS OF HONEYDEW MELON (*Cucumis melo* L. Inodorus Naud.) QUALITY CHACTERISTICS: A COMPARISON WITH AND WITHOUT ETHYLENE TREATMENT

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ABSTRACT

Ethylene treatment was used to determine if the quality of honeydew melons could be enhanced. External color, respiratory rate and exogenous ethylene concentration of honeydew melons were monitored during the experiment. Honeydew melon volatile compounds were collected by Tenax trapping, identified by gas chromatography-mass spectrometry and quantified by gas chromatography. Thirty-three volatile compounds were identified with two compounds containing a sulfur functional group. Gas Chromatography-Olfactometry was used to determine the odor impact compounds of honeydew melon volatiles. Five volatile compounds were identified as odor active compounds. Ethylene treatment produced significant effects in the color, respiratory rate, ethylene concentration and total volatile concentration of the melons before they self-ripened. External color turned more yellow and less green, the respiratory climacteric was shown, and the total volatile concentration increased sharply.

INTRODUCTION

The effects of ethylene on quality of fresh fruits and vegetables have been thoroughly reviewed by Saltveit (1999). Generally speaking, ethylene has numerous effects on the growth, development and shelf life of many fruits, vegetables and ornamental crops at the µl/l level (Bianco et al., 1977 and Bliss et al., 1979); it can enhance the flavor and the taste of the fruit by stimulating the ripening (Pratt et al, 1977 and Watada et al., 1986). Melons are an important commercial crop in many countries. They are usually treated 18-24 hours with ethylene to improve uniform ripening. The range of ethylene treatment from 40 to 1000 ppm has proved effective experimentally (McGlasson et al., 1963, Bianco et al., 1977, and Pratt et al., 1977).

Changes in several morphological and physiochemical characteristics during growth and ripening are important in determining melon quality. These characteristics include changes in external and flesh color, weight, length, diameter, flesh firmness, total soluble solid contents, and selected volatile compound concentrations (Miccolis et al., 1991). Consumer acceptability is largely attributed to sweetness and characteristic aroma (Lester et al., 1992). Measurement of the respiratory rate and ethylene concentration could provide the information of the changes during ripening (e.g. respiratory climacteric). The rise in respiratory rate may due to the general changes in metabolic organization of the tissues, and may reflect an increase in energy requirement during the early (synthetic) stages of ripening (Pratt et al., 1968).

Volatile compounds of honeydew melons (*Cucumis melo* var. Inodorus Naud.) have been reported in several studies (Yabumoto and Jennings et al., 1977; Buttery et al., 1982). Buttery et al. (1982) concluded that the typical honeydew melon aroma is due to

(Z)-6-noneyl acetate, (Z, Z)-3,6-nonadienyl acetate, (Z)-3-nonenyl acetate, 3-methyl-2-butenyl acetate, (Z)-3-nonenyl acetate, 3-methyl-2-butenyl acetate and ethyl-(methio)-acetate. Odor threshold determination indicated that (Z)-6-nonenyl acetate is an important contributor to the total aroma. The objective of this study was to determine by instrumental analysis whether the ethylene treatment can enhance the quality of honeydew melons.

MATERIALS AND METHODS

Test Samples

Honeydew melons were provided by Farming Technology (Huston, TX). One box of melons was received in May and two boxes were received in June. They were stored at 10°C until 24 hours prior to the experiment.

Ethylene Treatment

Melons were treated with 1000ppm ethylene for 24 hours. Melons were sealed in a 10-liter glass vacuum desiccator. A 5 mm glass tube was inserted in a rubber stopper of the desiccator. A 10ml aliquot of ethylene was injected into the desiccator through the sleeve stopper. After 24 h treatment, melons were removed from the desiccator and stored at the room temperature for 24 and 48 h (ethylene treatment 1 and ethylene treatment 2).

Gas Sampling

All samples for gas analyses were collected by using 1-ml gas-tight syringe. Each melon was sealed in the desiccator for 3 hours. Gas samples (1ml) were obtained using a gas-tight syringe after injecting the syringe into the desiccator through the sleeve stopper and pumping the syringe 10 times. Gas samples were assayed for ethylene using a gas chromatograph (Varian 1400 with a 1.5m x 3.2 mm column of activated alumina, 70-100 mesh, 100°C column temperature, with air, N_2 and H_2 at 400, 80, 60 ml/min, respectively) fitted with a flame ionization detector (Beaudry et al., 1987). A second gas sample was withdrawn from the sealed desiccator in a similar manner and assayed for CO_2 using a Fisher-Hamilton gas partitionar with a thermal conductivity detector (dual columns: a 2.0 m x 4.8 mm column of 42-60 mesh Molecular sieve 13 x and a 1.8 m x 6.4 mm column of DEHS on columnpak, 60-80 mesh; 70°C, He carrier at 40 ml/min) (Kays et al., 1983).

Color, TSS, L/D ratio and Moisture Content

The external color of the equatorial epidermal tissue (excluding the ground spot) was measured in four areas with a Minolta Chromameter model CR-2000 (Minolta Co., Japan) calibrated to a white tile under illuminant condition C and expressed in the L*a*b* mode (Lester et al., 1992). Each melon was cut in half along the equatorial plane and the internal color of mesocarp tissue (the edible tissue between the peel and the seed cavity tissue) and length/diameter (L/D) ratio was measured. A 200 g sample of melon flesh was blended for 20 sec and filtered with cheesecloth. The total soluble solids content (TSS) of melon juice was determined by a portable Palette refractometer model PR101 (Atago Co., Japan). Moisture determination was performed on mesocarp tissue cut

into cores and each core placed in a 50 ml beaker and inserted into a hot-air oven at 100°C for 24 hr. Changes in weight were measured.

Volatile Collection

The volatile collection procedure was adapted from Buttery et al. (1982). Each melon was sliced, seeds were removed, and the flesh was cut by a corer. A Tenax trapping system was used to collect volatile compounds by placing 550g mesocarp cores into the collection bottle. Airflow was generated by a lab vacuum line at a rate of 1000ml/min. Air was purified by passing it through an activated charcoal trap. Volatile compounds were collected on a trap using Tenax-TA (60/80 mesh, Scientific Instrument Services, Inc.) as the adsorbent for 20 min. The Tenax trap was prepared by packing about 50 mg of the adsorbent in Pyrex glass tube (3.5 mm inside diameter, 5 cm long). Desalted glass wool was used to contain the adsorbent on both end sides of the trap. Volatile compounds collected were desorbed from Tenax by rinsing with hexane (J. T. Baker, Phillipsburg, NJ), collecting 0.5 ml extract, adding 2.8µL of 3.75µL/ml phenyl acetate (Aldrich Chemical Co.) solution in n-hexane (J. T. Baker, Phillipsburg, NJ) as internal standard, concentrating the extract into 25µL and injecting 1µL into the GC.

Analysis of Collected Volatile Compounds

GC analysis was performed using HP 5890 series II gas chromatograph (Hewlett Packard, Avendale, PA) with a split-splitless injection port temperature of 225°C and flame ionization detector (FID) temperature of 250°C. The column used was DB-5

(Alltech Associates, Deerfield, IL). The oven temperature increased from 35°C to 70°C at a rate of 1.5°C/min followed by an increase to 235°C at a rate of 15°C/min.

For volatile-compound identification, the aroma extract was analyzed using a 5870 mass selective detector (MSD, quadrupole mass spectrometer) with a 5890 gas chromatograph (GC) both of which are manufactured by Hewlett Packard. The column used is a Econo-Cap EC-5 (Alltech Associates, Deerfield, IL), 30 m length, 0.25 mm ID, and 0.25 µm film. The GC head pressure was set at 12 psi. The mass spectrometer was set to scan the compounds with M.W from 50 to 550 using a thresh hold of 150 with a scanning speed of 1.2 scans/sec and the solvent delay was set for 2 min. The GC was programmed to start at 35 °C. The temperature was held at 35 °C for 1 min then ramped at 1.5 °C min to 70°C and held for 1 min. The temperature was again ramped at 15 °C/min to 235°C and held for 1 min at which time the run was terminated. Sample size injected was 1 µL, using splitless injection mode. After 1.75 min, the split valve was opened. The injector temperature was set to 225 °C and the transfer line (detector B) was at 250 °C.

The aroma extract was analyzed by gas chromatography-olfactometry (GCO) evaluation at the GC-thermal conductivity detector (TCD) exhaust port with the same column and condition as the FID analysis. The retention times were determined to be identical between TCD and FID techniques. The aroma of the individual components in the GC-TCD effluent were evaluated and given descriptors of the odor active compounds (Wang et al., 2000).

Statistical Analysis

All data were analyzed using SAS statistical package v. 8.1 (SAS Institute Inc., Cary, NC).

RESULTS AND DISCUSSION

Size, shape, total soluble solid and moisture contents

No significant differences were observed in size, shape, total soluble solids (TSS) or moisture content between ethylene-treated and control melons (Table 2.1 (a) and 1(b)). This result was expected since melons do not accumulate starch in the tissues, thus TSS value would not change once the melon was detached from the vine.

Table 2.1(a): size, shape, total soluble solid (TSS) and moisture content of the melon in May

May melon	Mass (kg)	L/D	TSS (%)	Moisture (%)
Control 1	1.30	1.11	8.51	91.6
Control 2	1.32	1.12	8.58	91.5
Ethylene 1	1.48	1.13	9.11	90.8
Ethylene 2	1.37	1.18	8.81	91.5

Table 2.1(b): size, shape, total soluble solid (TSS) and moisture content of the melon in June

June melon	Mass (kg)	L/D	TSS (%)	Moisture (%)
Control 1	1.39	1.18	9.53	90.63
Control 2	1.44	1.15	10.04	90.45
Ethylene 1	1.52	1.14	9.51	90.51
Ethylene 2	1.46	1.12	10.17	89.98

External Color

For the melons in June, the hue angle of ethylene-treated melons decreased dramatically on day 1(Figure 2.1) due to the larger percentage decrease in –a* readings than b* readings (Table 2.2). The b* readings of ethylene-treated melons increased on day 2, as the ethylene-treated melons became more yellow and less green than the control ones. These changes are attributed to the degradation of chlorophyll and the synthesis of carotenoids (Reid et al, 1970). The differences were also shown in a value on day 1 with no significant changes in L* value between ethylene treated melons and control groups. Melons in May had no significant changes in color after ethylene treatment.

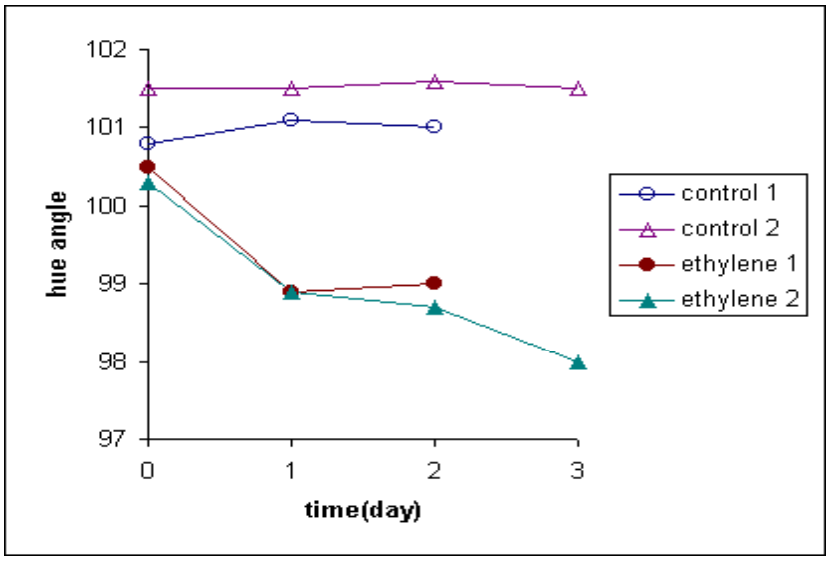

Figure 2.1: Changes in Hue angle of June Melon external color

Table 2.2: External color of June melons (Comparisons are between control and ethylene treatment. Values within a set for specific measurement followed by the same letter are not significantly different $p \leq 0.05$)

June Melon	Day 0	Day 1	Day 2	Day 3
L*				
Control 1	80.7	80.6	81.1	-
Ethylene 1	80.4	80.2	81.3	-
Control 2	80.6	80.6	80.1	81.0
Ethylene 2	80.9	81.2	81.5	77.8
a*				
Control 1	-4.8	-5.0a	-4.6	-
Ethylene 1	-4.9	-3.9b	-4.9	-
Control 2	-5.0	-5.0a	-4.9	-4.8
Ethylene 2	-4.4	-3.6b	-5.1	-4.4
b*				
Control 1	22.5	21.6	22.2a	-
Ethylene 1	22.1	24.4	29.9b	-
Control 2	22.9	22.9	22.9a	22.8
Ethylene 2	22.0	23.7	31.0b	29.7

Internal Color

The internal color of the melons was shown in table 2.2. There was no significant change in color between the control melons and ethylene treated melons in May (data not shown). The dramatic decrease in hue angle (Table 2.3) in ethylene-treated melons is attributed to the larger percentage decrease in –a* readings than b* readings. This change suggests a loss in chlorophyll in mesocarp tissues resulting in less green color.

Table 2.3: The internal color of melons in June. (Comparisons are between control and ethylene treatment. Values within a set for specific measurement followed by the same letter are not significantly different $p \leq 0.05$)

June melon	L*	a*	b*	Hue angle
Control 1	63.1 a	-10.5 a	22.0 ab	115.5 a
Control 2	60.1 a	-11.1 a	23.1 a	115.7 a
Ethylene 1	63.0 a	-5.3 b	15.2 c	109.2 b
Ethylene 2	64.9 a	-4.9 b	16.6 bc	106.4 b

Respiratory Rate and Ethylene Generation

The application of relatively low levels of ethylene on climacteric fruits can decrease the length of preclimacteric period without a substantial effect on respiratory rate at the climacteric peak (Kays, 1997). A respiratory climacteric peak was observed in June melons after ethylene treatment, while the treatment did not affect respiratory rate of May melons (Figure 2.2). The respiratory rate of treated melons reached 140 $mgCO_2$ $kg^{-1}hr^{-1}$ while the control melons' respiratory rate remained about 30 $mgCO_2kg^{-1}hr^{-1}$. The exposure of exogenous ethylene results in the increase of ethylene amount generated by melons. The ethylene generated by melons increased almost 300 fold after ethylene treatment, declining sharply within 48 hrs. These data suggest that melons received in May were past the climacteric peak and thus too ripe to benefit from ethylene treatment.

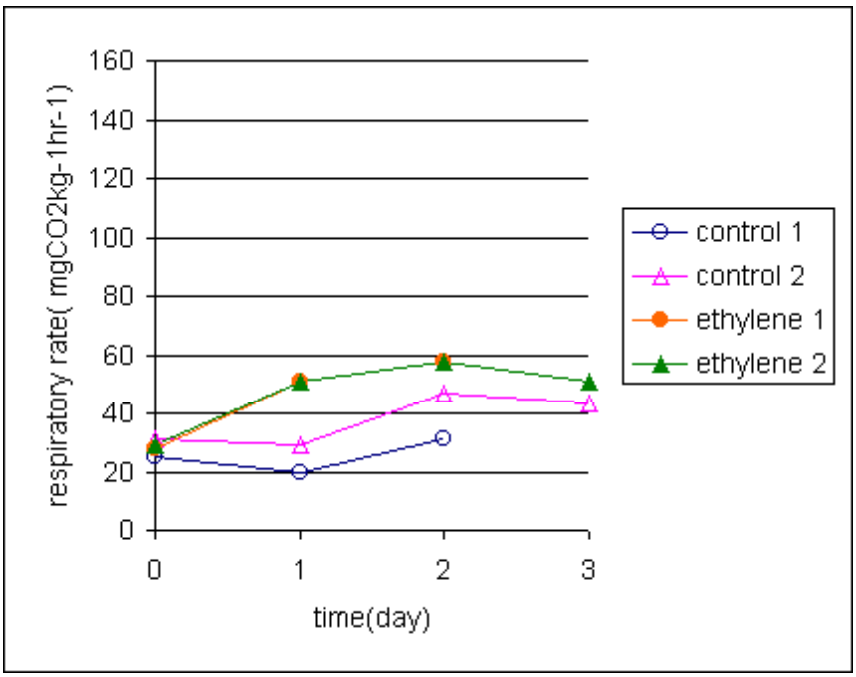

Figure 2.2(a): Changes in respiratory rate of May melons.

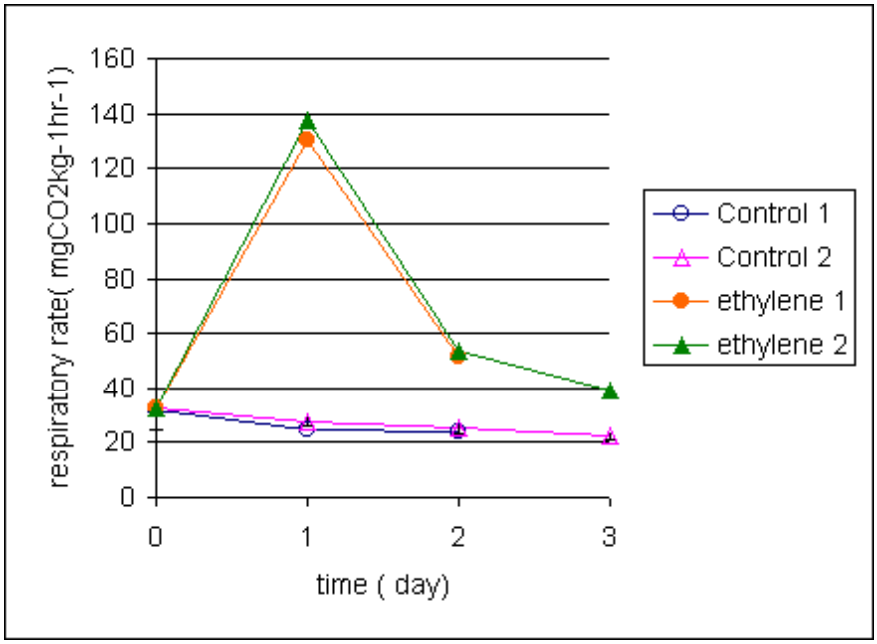

Figure2.2 (b): Changes in respiratory rate of June melons.

Volatile Compound Analysis

Volatile compounds, identified by GC/MS, are shown in Figure 2.3 and Table 2.4. Quantitative estimates for individual compounds were calculated from the ratio of the peak area to the internal standard (phenyl acetate) and related to the fresh weight of melon. Few changes were observed in generation of volatile compounds in May melons.

The generation of smaller molecular weight volatile compounds (compounds 1, 3-5, 7-14, and 16) were induced by ethylene treatment, while volatile compounds found in both control melons and ethylene treated melons included 2-methyl-methyl butanoate (2), 3-methyl butyl acetate (6), ethyl hexanoate (15), hexyl acetate (17), (E) 4-ethyl heptenoate (20), (Z)-6-nonenal (21), nonanal (22), 4-methyl cyclohexane (23), benzyl acetate (27), exo-4-methylbicyclo [3,2,1] octan-3-ene (31), (Z) 6-nonen-1-ol (32), and nonyl acetate (33). Total volatiles were higher in the May melons with little influence by ethylene treatment, while large increases were observed in ethylene-treated melons received in June (Figure 2.5).

Comparisons of individual volatile-compound between ethylene treatment and control groups are shown in Figure 2.6. The concentration of benzyl acetate and ethyl hexanoate in honeydew melons increased 5-10 fold after treatment with ethylene, while hexyl acetate and 3-methyl butyl acetate increased 25-100 fold.

Table 2.4: Honeydew melon volatile compounds

Number	Retention Time (Min.)	Compound	Concentration (μg/kg melon)
1	3.78	Methyl benzene	6.43×10^{-4}
2	4.10	2-Methyl-methylbutanoate	1.96×10^{-2}
3	4.75	Ethyl butanoate	8.79×10^{-3}
4	5.21	Butyl acetate	1.94×10^{-2}
5	6.46	2-Methylethyl butanoate	6.97×10^{-3}
6	8.04	3-Methylbutyl acetate	1.05×10^{-1}
7	8.73	Propyl butanoate	3.06×10^{-3}
8	9.12	Methyl 2-(methylthio) acetate	1.23×10^{-3}
9	9.76	Ethyl pentanoate	3.35×10^{-3}
10	10.16	Methyl hexanoate	1.63×10^{-3}
11	10.80	Pentyl acetate	7.82×10^{-3}
12	12.21	Benzaldehyde	1.55×10^{-4}
13	13.32	3-Methylbutyl propanoate*	3.06×10^{-4}
14	13.94	Ethyl (methylthio) acetate	2.29×10^{-3}
15	15.80	Ethyl hexanoate	1.34×10^{-2}
16	15.98	(Z) 3-hexenyl acetate	2.59×10^{-3}
17	16.71	Hexyl acetate	2.24×10^{-2}
18	17.13	1.8-Cineole	5.49×10^{-4}
19	20.74	2,3-Butanedioldiacetate	6.67×10^{-4}
20	23.14	(E) 4-Ethyl heptenoate*	7.22×10^{-4}
21	23.64	(Z)-6-nonenal	1.85×10^{-3}
22	23.85	Nonanal	1.25×10^{-3}
23	24.06	4-Methyl cyclohexane	2.53×10^{-3}
24	24.93	cis-1, 2-Dimethyl cyclopentane*	8.94×10^{-4}
25	25.76	Methyl octanoate*	1.33×10^{-4}
26	27.78	(Z) 3-Nonen-1-ol	1.97×10^{-4}
27	28.21	Benzyl acetate	1.58×10^{-2}
28	28.76	1-Nonanol	1.22×10^{-3}
29	29.73	Octyl acetate	5.23×10^{-4}
30	30.66	2-Phenylethyl acetate	8.66×10^{-4}
31	31.32	Exo-4-Methylbicyclo [3.2.1] octan-3-ene*	7.15×10^{-3}
32	31.50	(Z) 6-Nonen-1-ol	2.60×10^{-3}
33	31.56	Nonyl acetate	2.47×10^{-3}

* Not found in the literature

References: Kemp et al., 1972 and 1973; Wyllie et al., 1994 and 1995, and Buttery et al., 1982

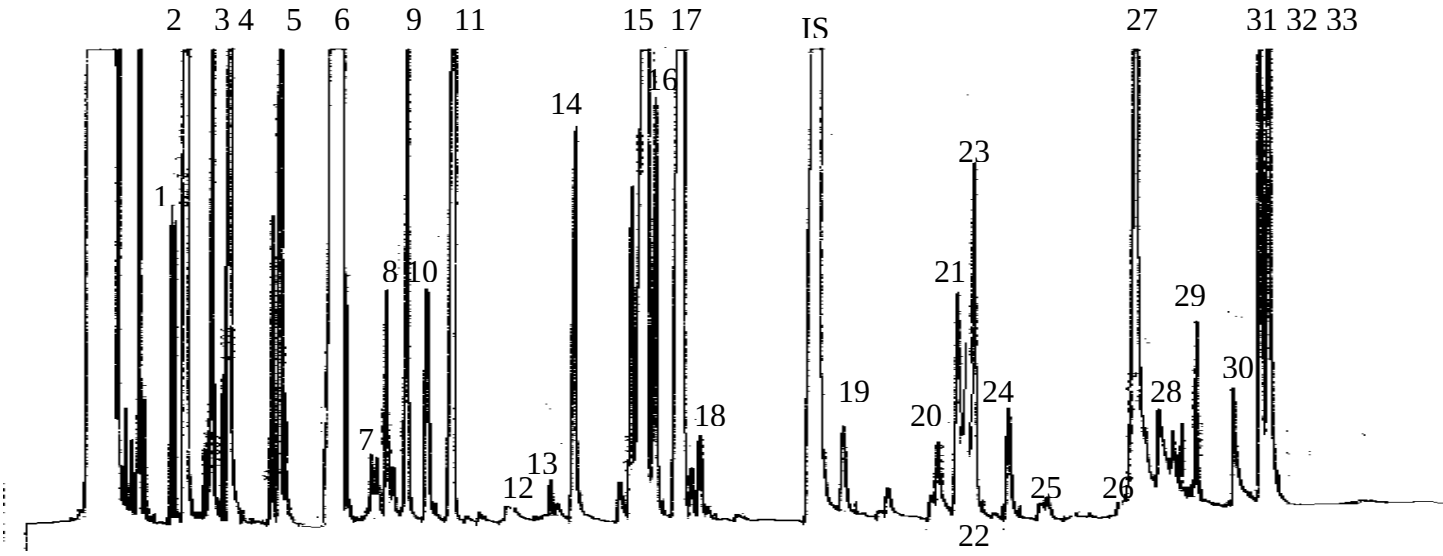

Figure 2.3: Gas chromatogram of honeydew melon volatile compounds. (I.S.: internal standard, phenyl acetate)

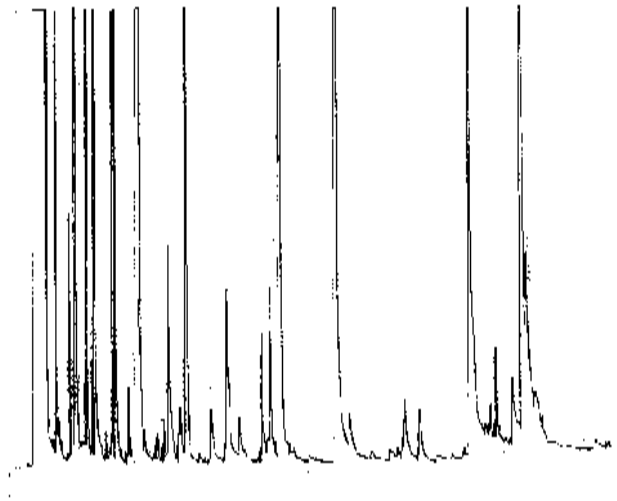

Figure 4a Gas chromatogram of control melon in May

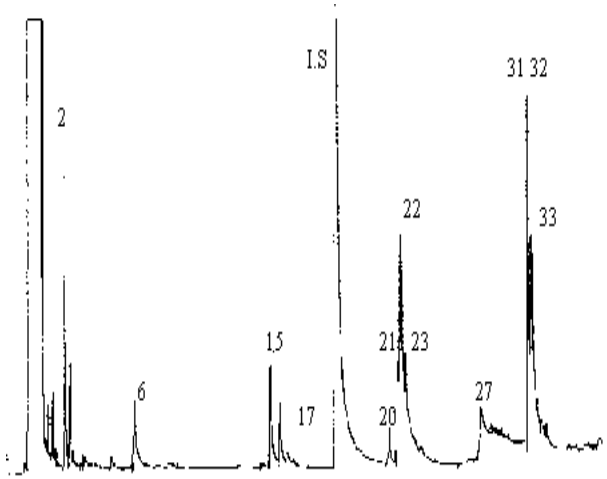

Figure 4.3 Gas chromatogram of control melon in June

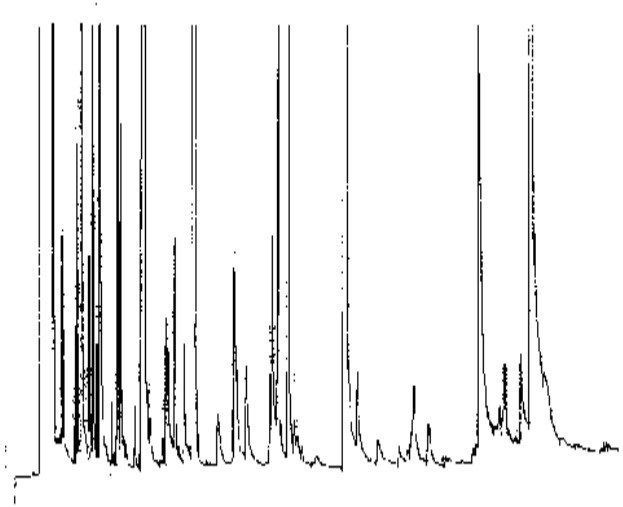

Figure 4.b Gas chromatogram of ethylene treated melon in May

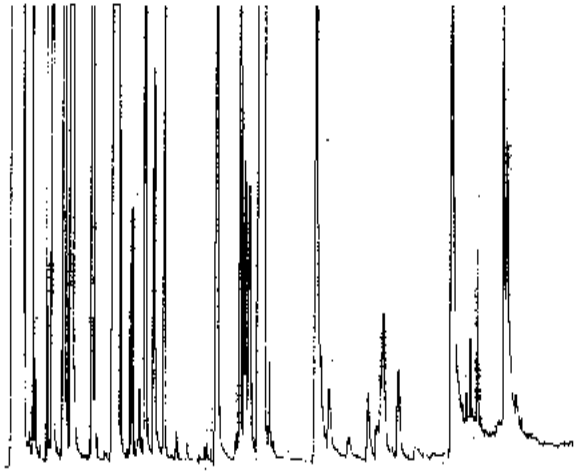

Figure 4.4 Gas chromatogram of ethylene treated melon in June.

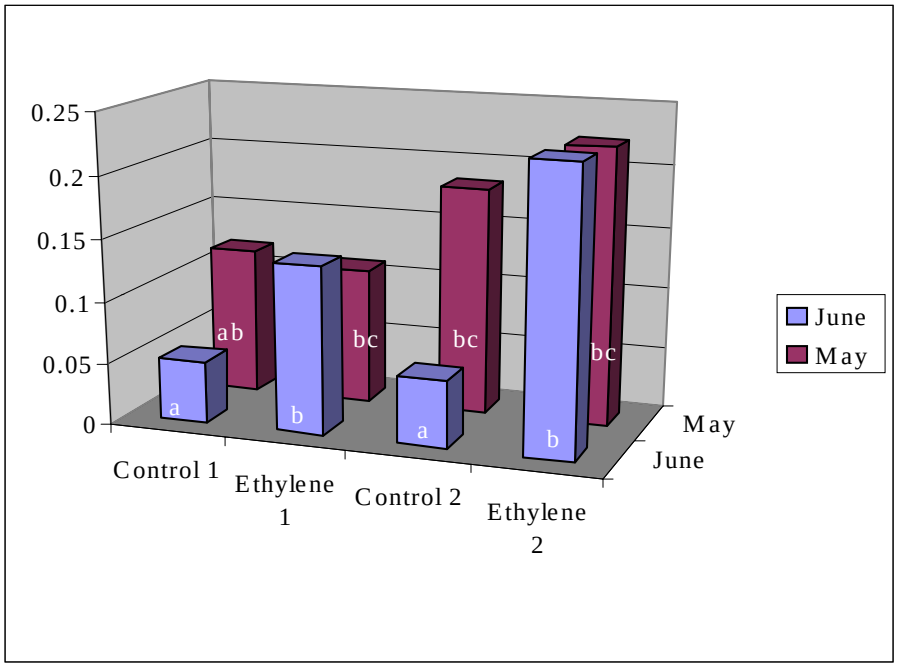

Figure 2.5: Changes in total volatile concentration (µg/kg melon) of melons in May and June(Comparisons are between control and ethylene treatment. Values within a set for specific measurement followed by the same letter are not significantly different $p \leq 0.05$)

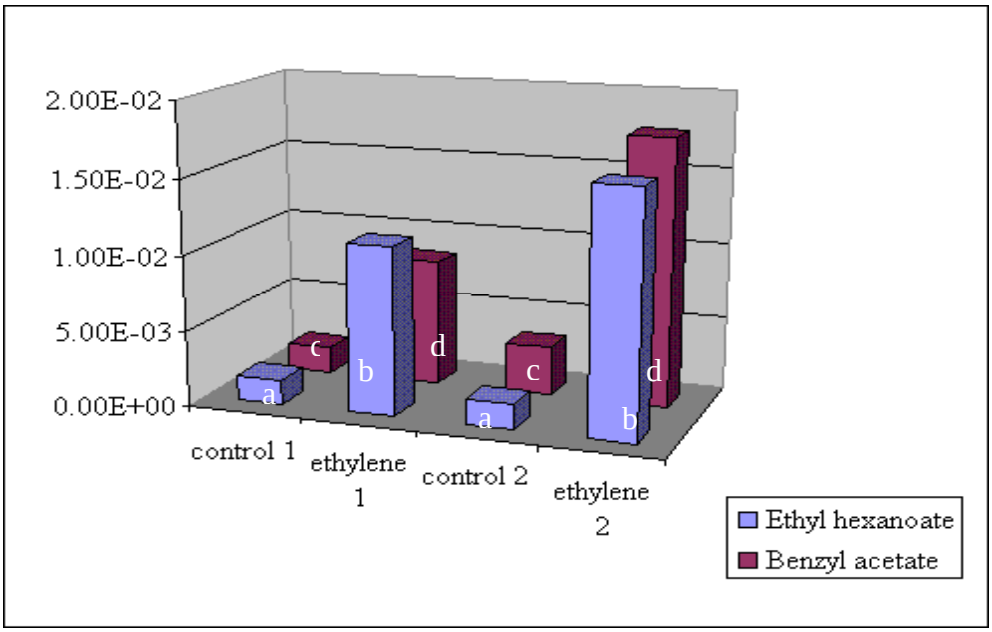

Figure 2.6(a): Volatile concentrations (µg/kg melon) of ethyl hexanoate and benzyl acetate in June melons (Comparisons are between control and ethylene treatment. Values within a set for specific measurement followed by the same letter are not significantly different $p \leq 0.05$)

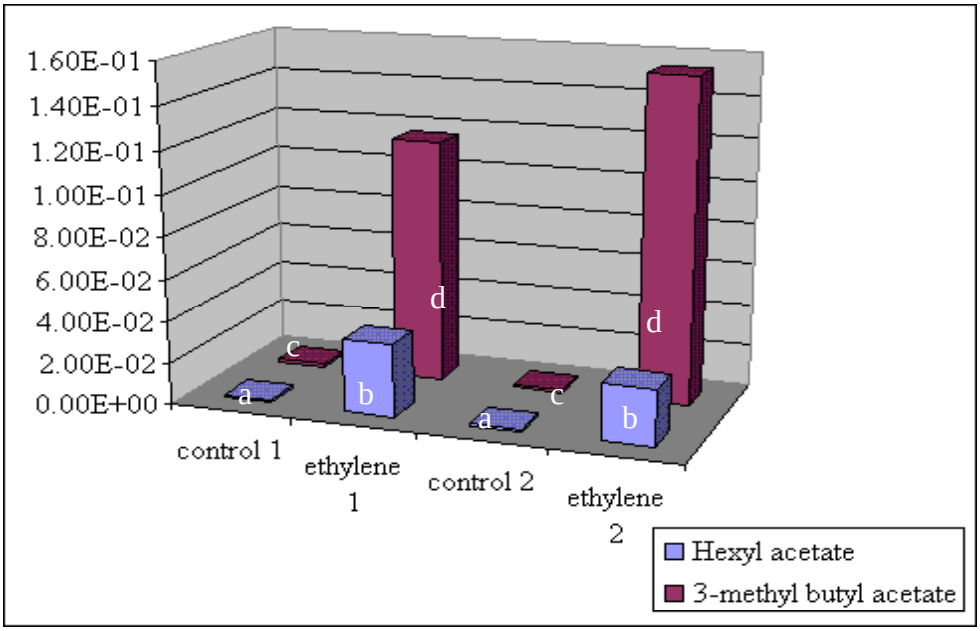

Figure 2.6(b): Volatile concentrations (µg/kg melon) of hexyl acetate and 3-methyl butyl acetate in June melons. (Comparisons are between control and ethylene treatment. Values within a set for specific measurement followed by the same letter are not significantly different $p \leq 0.05$)

Bliss et al. (1979) indicated that the application of high levels of ethylene on harvested melons accelerated the onset of production of the organic volatiles but do not significantly affect their ultimate concentration. Since the melons received in May were more advanced in ripeness than the melons received in June, the internal ethylene generated by May melons have reached the level that can trigger the volatile generation metabolic pathway. Therefore, the exposure of exogenous ethylene does not appear to influence generation of volatile compounds. The lack of upsurge in respiratory rate (Figure 2.2a) also provides an indication that melons had already ripened, thus exposure to ethylene did not affect the concentration of the volatile compounds. Harvestable maturity of honeydew melons is attained at 35 to 37 days after anthesis and the self-ripening stage is reached 47 days after anthesis (Pratt et al., 1977). Generally speaking, melons are harvested in the horticultural maturity stage, thus the ethylene treatment can contribute to uniform ripening and provide the consumer with high quality melons.

Six thioether esters, methyl (methylthio) acetate, ethyl (methylthio) acetate, 2(methylthio) ethyl acetate, methyl 3-(methylthio) propanoate, ethyl 3-(methylthio) propanoate, and 3-(methylthio) propyl acetate are considered to have the importance in the aroma profiles of a Galia-type of netted muskmelons (Wyllie et al, 1992). By using the tenax trap to collect the volatiles, only methyl-2- (methylthio) acetate and ethyl (methylthio) acetate were found in melon with higher degree of maturity. These esters may be derived from methionine due to their structure, and the synthesis is possibly via the biological pathway utilized the ripening hormone ethylene (Yang et al, 1984). Thus the production of those volatile compounds may dependent on fruit maturity and the harvest time (Wyllie et al, 1992).

Some compounds found in trace amounts were also identified by GC/MS, such as camphene, 1,2-diethyl benzene, benzene methanol, ethyl benzoate, decanal, 2,5-cyclohexadiene-1, 4-dione, 1-methoxy naphthalene, and cyclooctene.

Gas Chromatography-Olfactometry (GCO)

Five volatile compounds were identified as odor active compounds via GCO. (Z)-6-nonenal is a potent odorant and it is known to have a characteristic melon aroma (Buttery et al, 1982), but it was not found in detectable amounts in their work. However, instead of using diethyl ether, we used hexane to elute the volatile compounds from the Tenax trap. We found (Z) 6-nenenal in detectable amounts and it contributed to the typical melon aroma. Although (Z) 6-nenenal is considered the character impact compound of honeydew melon aroma, there was no significant change in the amount of (Z) 6-nonenal due to ethylene treatment (data not shown).

Table 2.5: Honeydew melon volatile compound descriptors.

Number	Compound	Descriptor	Descriptor from literature
2	2-methyl-methylbutanoate	Grassy	Fruity (Schieberle et al)
5	2-methyl-ethyl butanoate	Apple, fruity	Fruity (Kotseridis et al)
6	3-methylbutyl acetate	Green, grassy	-
21	(Z) 6-nonenal	Melon, fruity	Melon (Buttery et al)
22	Nonanal	Sweet, fruity	Fruity (Schlüter et al)

In conclusion, the results show that ethylene treatment has significant effects on the color, respiratory rate, ethylene concentration and total volatile concentration of the melons before they self-ripened. Once the melons have already self-ripened, the exposure of exogenous ethylene would no longer have effect on those characteristics. Thus, a honeydew melon that has reached its maximum sugar potential could be harvested prior to the climacteric peak, shipped and then treated just prior to distribution. This practice would provide a higher quality melon than one picked at a lower sugar concentration but with a longer shelf life than one harvested at or past its climacteric peak.

ACKNOWLEDGEMENTS

To Dr. Dennis R. Phillips, Department of Chemistry, The University of Georgia for facilitating the Mass Spectrometry. To Betty Schroeder and Yan Wang, Department of Horticulture, The University of Georgia, for their help in volatile analysis. To Farming Technology Inc. for funding this research.

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CHAPTER 3

GENERATION OF VOLATILE COMPOUNDS IN HONEYDEW MELONS (*Cucumis melo* L. Inodorus Naud.) AS AFFECTED BY MATURITY AT HARVEST

Liang, C-P, Shewfelt, R. L., Kays, S. J., to be submitted to Journal of Food Quality

ABSTRACT

Physicochemical characteristics of honeydew melons including size, shape, external and internal color, moisture contents, total soluble solids contents, and volatile compounds were measured to determine the best indicators of maturity as they relate to melon quality at purchase. The honeydew melon volatile compounds were collected by Tenax trapping, identified by gas chromatography-mass spectrometry, and quantified by gas chromatography. Six volatile compounds, 2-methyl methylbutanoate, ethyl butanoate, 2-methylethyl butanoate, pentyl acetate, benzyl acetate, and (Z) 6-nonen-ol were screened from thirty-three volatile compounds by stepwise regression analysis (R^2 = 0.43). Of these compounds benzyl acetate appears to be the only one that is a significant contributor to honeydew aroma. External hue angle and total soluble solids were the best indices of total volatile production.

INTRODUCTION

Changes in morphological and physicochemical characteristics during growth and ripening are important indicators of melon quality. These characteristics include external and internal color, weight, length, diameter, flesh firmness, total soluble solid contents, and concentration of specific volatile compounds (Miccolis et al., 1991)

Sucrose, glucose and fructose are the major contributors to the total sugar content in the ripe melon fruit (Burger et al., 2000). Since melons do not have starch reserve in the fruit (Pratt et al., 1971), the accumulation of sugar depends on the supply of photoassimilates from the leaf during the ripening stage (Hubbard et al., 1990). Thus, once a melon is detached from the vine, total soluble solids (TSS) will not increase. Because sweetness is only partially correlated with TSS, high TSS alone cannot adequately define good melon quality (Aulenbach et al., 1974). Absence of high TSS is an indicator of poor melon quality (Pratt et al., 1977).

The aroma of fruit is ordinarily composed of complex mixtures of volatile compounds present in the headspace (Ohliff et al., 1978). The key volatile contributors to characteristic aroma of melons include alcohols, aldehydes, and large quantities of esters (Kemp et al., 1972 and 1973; Yabumoto et al., 1977 and 1978; Buttery et al., 1982, and Wyllie et al., 1990). Shalit et al. (2001) indicated that the unique aroma of melons could not be related to any single compound, but the melon or fruity notes are provided by the interaction of many individual volatile compounds.

The aroma and sweetness of melons are the important factors in their overall quality and consumer acceptability (Yamaguchi et al., 1977, and Shalit et al., 2000). The

objective of this research was to determine the best indicators of honeydew melon maturity that relate to melon quality at purchase.

MATERIALS AND METHODS

Test Samples

Honeydew melons were provided by Farming Technology Inc. (Huston, TX). They were stored at 10°C until 24 hours prior to the experiment.

Color, TSS, L/D ratio and Moisture Content

The external color of the equatorial epidermal tissue (excluding the ground spot) was measured in four areas with a Minolta Chromameter model CR-2000 (Minolta Co., Japan) calibrated to a white tile under illuminant condition C and expressed in the L*a*b* mode (Lester et al., 1992). Each melon was cut in half along the equatorial plane and the internal color of mesocarp tissue (the edible tissue between the peel and the seed cavity tissue) and length/diameter (L/D) ratio was measured. A 200 g sample of melon flesh was blended for 20 sec and filtered with cheesecloth. The total soluble solids content (TSS) of melon juice was determined by a portable Palette refractometer model PR101 (Atago Co., Japan). Moisture determination was performed on mesocarp tissue cut into cores and each core placed in a 50 ml beaker and inserted into a hot-air oven at 100°C for 24 hr. Changes in weight were measured.

Volatile Collection

The volatile collection procedure was adapted from Buttery et al. (1982). Each melon was sliced, seeds were removed, and the flesh was cut by a corer. A Tenax trapping system was used to collect volatile compounds by placing 550g mesocarp cores into the collection bottle. Airflow was generated by a lab vacuum line at a rate of 1000ml/min. Air was purified by passing it through an activated charcoal trap. Volatile compounds were collected on a trap using Tenax-TA (60/80 mesh, Scientific Instrument Services, Inc.) as the adsorbent for 20 min. The Tenax trap was prepared by packing about 50 mg of the adsorbent in Pyrex glass tube (3.5 mm inside diameter, 5 cm long). Desalted glass wool was used to contain the adsorbent on both end sides of the trap. Volatile compounds collected were desorbed from Tenax by rinsing with n-hexane (J. T. Baker, Phillipsburg, NJ), collecting 0.5 ml extract, adding 2.8µL of 3.75µL/ml phenyl acetate (Aldrich Chemical Co.) solution in n-hexane (J. T. Baker, Phillipsburg, NJ) as internal standard, concentrating the extract into 25µL and injecting 1µL into the GC.

Analysis of Collected Volatile Compounds

GC analysis was performed using HP 5890 series II gas chromatograph (Hewlett Packard, Avendale, PA) with a split-splitless injection port temperature of 225°C and flame ionization detector (FID) temperature of 250°C. The column used was DB-5 (Alltech Associates, Deerfield, IL). The oven temperature increased from 35°C to 70°C at a rate of 1.5°C/min followed by an increase to 235°C at a rate of 15°C/min.

For volatile-compound identification, the aroma extract was analyzed using a 5870 mass selective detector (MSD, quadrupole mass spectrometer) with a 5890 gas

chromatograph (GC) both of which are manufactured by Hewlett Packard. The column used is a Econo-Cap EC-5 (Alltech Associates, Deerfield, IL), 30 m length, 0.25 mm ID, and 0.25 µm film. The GC head pressure was set at 12 psi. The mass spectrometer was set to scan the M.W. from 50 to 550 using a thresh hold of 150 with a scanning speed of 1.2 scans/sec and the solvent delay was set for 2 min. The GC was programmed to start at 35 °C. The temperature was held at 35 °C for 1 min then ramped at 1.5 °C min to 70°C and held for 1 min. The temperature was again ramped at 15 °C/min to 235°C and held for 1 min at which time the run was terminated. Sample size injected was 1 µL, using splitless injection mode. After 1.75 min, the split valve was opened. The injector temperature was set to 225 °C and the transfer line (detector B) was at 250 °C.

Statistical Analysis

All data were analyzed using SAS statistical package v. 8.1 (SAS Institute Inc., Cary, NC).

RESULTS AND DISCUSSION:

The correlation coefficients among the physicochemical characteristics of 50 melons are shown in the Table 3.1. TSS was negatively correlated with total volatile concentration, moisture content and external and internal hue angle of the honeydew melons. Moisture content and lightness (L*) of the mesocarp tissue correlate most significantly with the TSS. ($p \leq 0.0001$). The external color (hue angle) is highly and positively correlated with the hue angle of mesocarp tissue($R=0.84$).

Table 3.1: Correlation coefficients among total soluble solid contents (TSS), total volatile concentration, moisture (MST), external color, and internal color and of honeydew melons.

	TSS	Volatile	MST	Ext. Hue	Int.Hue	Int. L*
TSS	1.00	-0.38*	-0.90***	-0.51**	-0.48**	-0.53***
Volatile	-0.38*	1.00	0.30	-0.04	-0.02	0.33
MST	-0.90***	0.30	1.00	0.37*	0.33*	0.50**
Ext. Hue	-0.51**	-0.04	0.37*	1.00	0.84***	0.17
Int. Hue	-0.48**	-0.02	0.33*	0.84***	1.00	0.16
Int. L*	-0.53***	0.33	0.50**	0.17	0.16	1.00

* $p \leq 0.01$
** $p \leq 0.001$
*** $p \leq 0.0001$

Five variables (TSS, moisture, external hue angle, internal hue angle and internal L*) were used to predict the volatile concentration by stepwise regression analysis. Only TSS and external hue angle were significant indicators of ultimate volatile concentration. The equation was shown as follows:

Total volatile =0.743-0.024(TSS)-0.005(External hue angle) $R^2 = 0.22$

A total of 33 honeydew melon volatile compounds were identified by GC-MS analysis (as shown in chapter 2). Regression analysis was performed to screen the melon volatile compounds for their relationship to TSS. The six volatile compounds that emerged from this analysis were 2-methyl methylbutanoate(a), ethyl butanoate(b), 2-methylethyl butanoate(c), pentyl acetate(d), benzyl acetate(e), and (Z) 6-nonen-ol(f) (Figure 3.1). These compounds appear to be the best indicators of maturation of honeydew melons as they relate to sugar development. The following equation was derived:

TSS =10 +1377(methyl methylbutanoate)+608 (ethyl butanoate)

-453(2-methylethyl butanoate)-152(pentyl acetate)-14 (benzyl acetate)

-115 ((Z) 6-nonen-ol)

R^2=0.43

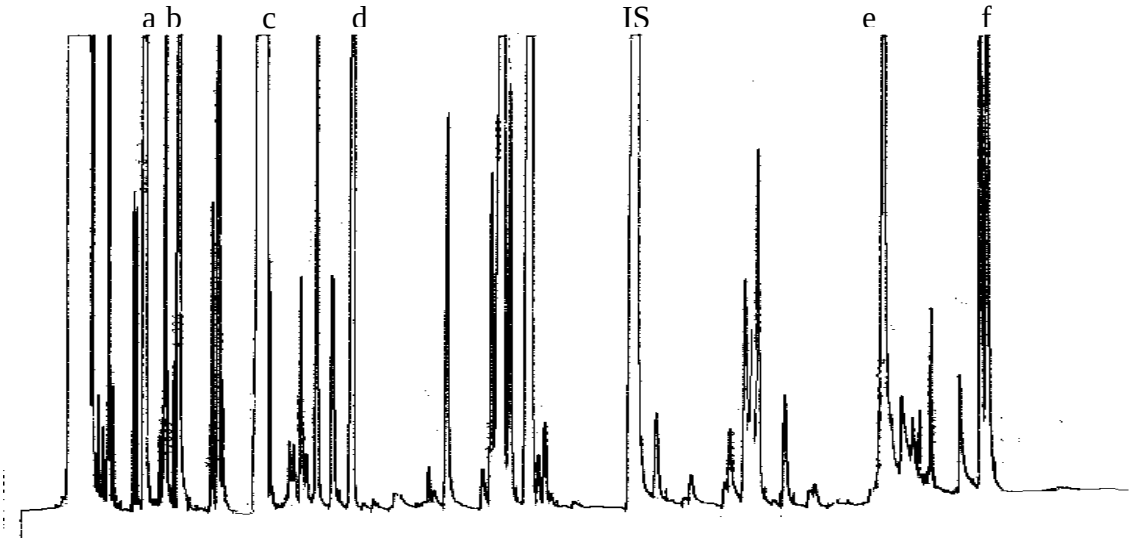

Figure 3.1: Honeydew melon volatiles gas chromatogram. (a. 2-methyl methylbutanoate, b. ethyl butanoate, c. 2-methylethyl butanoate, d. pentyl acetate, e. benzyl acetate, f. (Z) 6-nonen-ol, IS. Internal standard, phenyl acetate)

Of these six compounds, only 2-methyethyl butanoate significantly correlates with TSS(R=-0.33) (Table 3.2), but the interaction of the volatiles provided the model equation shown above. In addition, 2-methyethyl butanoate closely relates to the maturity indices of internal and external color of honeydew melons. Pentyl acetate and benzyl acetate are highly correlated with the total volatile concentration while benzyl acetate also significantly correlated with the color of melons.

Table 3.2: Correlation coefficients among melon volatile compounds, total soluble solid contents, total volatile concentration, moisture contents, external color, internal color.

	2-methyl-methylbutanoate	Ethyl butanoate	2-methylethyl butanoate	Pentyl acetate	Benzyl acetate	(Z) 6-Nonen-1-ol	Volatile
TSS	0.18	0.37	-0.33*	-0.27	-0.31	-0.23	-0.38*
Volatile	0.19	-0.15	0.29	0.73***	0.65***	-0.06	1.00
MST	-0.20	-0.38*	0.26	0.24	0.23	0.15	0.30
External Hue	-0.01	0.00	0.47**	-0.25	-0.01	0.43*	-0.04
Internal Hue	-0.05	-0.13	0.50**	-0.22	-0.11	0.40*	-0.02
Internal L*	-0.06	-0.47**	0.25	0.35*	0.30	-0.12	0.33

* $p \leq 0.01$
** $p \leq 0.001$
*** $p \leq 0.0001$

The major compounds that have been reported to attribute to of honeydew melon aroma include ethyl 2- methylbutyrate, ethyl butyrate, ethyl hexanoate, hexyl acetate, 3-methylbutyl acetate, benzyl acetate, and (Z)-6-nonenyl acetate. (Buttery et al., 1982). For those six compounds screened by stepwise regression analysis in our study, only benzyl acetate has been identified as a significant contributor to melon aroma.

ACKNOWLEDGEMENT

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CHAPTER 4

THE EFFECT OF ETHYLENE TREATMENT ON QUALITY FACTORS IN HONEYDEW MELONS (*Cucumis melo* L. inodorus Naud.)

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ABSTRACT

Honeydew melons were treated with 1000 ppm ethylene. Instrumental analysis and sensory evaluation were conducted to determine if the quality of honeydew melons can be enhanced by ethylene treatment. The intensity of five attributes: fruitiness, grassiness, honey, sweetness, crispiness were determined using 150-mm unstructured line scales by sensory descriptive analysis. The physiochemical properties of honeydew melons were measured by instrumental analysis. GC was used in order to determine the respiratory rate, exogenous ethylene concentration and total volatile concentration. Relationships between sensory and instrumental measures of quality were determined using Pearson correlation analysis. Ethylene treatment enhanced the fruitiness and decreased the crispiness of the melons. TSS, volatile concentration, internal color L*and the external b*were the best indicators of melon quality.

INTRODUCTION

The effects of ethylene on melon fruits have been widely reported (Bliss et al., 1979, McGlasson et al., 1964, Pratt et al., 1968, Bianco et al., 1977, and Pratt et al., 1977); it can initiate the ripening process of fruit. During the ripening process, physiochemical changes observed include increase in carbon dioxide and ethylene production, flesh softening, color changes, formation of wax on the fruit surface, and the production of a characteristic aroma. Harvested melons can be treated with ethylene, usually 18-24 hours, to provide uniform ripening. The ethylene concentrations in the range of 40 to 1000 ppm have proved effective experimentally (McGlasson et al., 1963, Bianco et al., 1977, Pratt et al., 1977), but the melons with insufficient maturity will not respond to the ethylene treatment (Pratt et al., 1977).

Melon research has focused on the relationship between the physicochemical characteristics and their corresponding sensory attributes to predict the eating quality (Yamaguchi et al., 1977, Mutton et al., 1981, Lester et al., 1992, Wang et al., 1996, and Pardo et al., 2000). Consumer acceptability is primarily based on sweetness and characteristic aroma (Lester et al., 1992). Textural characteristics also play a role in melon acceptability (Yamaguchi et al., 1977; Mutton et al., 1981).

Identification of a nondestructive fruit maturity index would be very useful for

growers and distributors in assessing optimal harvest dates for high quality. Thus the objective of this study was two fold: to determine if the quality of honeydew melon flavor can be enhanced by ethylene treatment and to identify a physicochemical index of melon maturity.

MATERIAL AND METHODS

Test Samples

Honeydew melons were provided by Farming Technology. One box of melons was received in July (set 1) and two boxes were received in August (set 2 and set 3). They were stored at 10°C until 24 hours prior to the experiment.

Ethylene Treatment

Melons were treated with 1000ppm ethylene for 24 hours. Melons were sealed in a 10-liter glass vacuum desiccator. A 5 mm glass tube was inserted in a rubber stopper of the desiccator. A 10ml aliquot of ethylene was injected into the desiccator through the sleeve stopper. After 24 h treatment, melons were removed from the desiccator and stored at the room temperature (23°C) for 24 h.

Gas Sampling

Each melon was sealed in the desiccator for 3 hours. Gas samples (1ml) were obtained using a gas-tight syringe after injecting the syringe into the desiccator through

the sleeve stopper and pumping the syringe 10 times. Gas samples were assayed for ethylene using a gas chromatograph (Varian 1400 with a 1.5m x 3.2 mm column of activated alumina, 70-100 mesh, 100 º C column temperature, with air, N_2 and H_2 at 400, 80, 60 ml/min, respectively) fitted with a flame ionization detector (Beaudry et al., 1987). A second gas sample was withdrawn from the sealed desiccator in a similar manner and assayed for CO_2 using a Fisher-Hamilton gas partitionar with a thermal conductivity detector (dual columns: a 2.0 m x 4.8 mm column of 42-60 mesh Molecular sieve 13 x and a 1.8 m x 6.4 mm column of DEHS on columnpak, 60-80 mesh; 70 ºC, He carrier at 40 ml/min). (Kays et al., 1983)

Color, TSS, L/D ratio and Moisture Content

The external color of the equatorial epidermal tissue (excluding the ground spot) was measured in four areas with a Minolta Chromameter model CR-2000 (Minolta Co., Japan) calibrated to a white tile under illuminant condition C and expressed in the L*a*b* mode (Lester et al., 1992). Chroma $[(a^{*2} + b^{*2})^{1/2}]$ was also calculated (Clydesdale et al., 1978). Each melon was cut in half along the equatorial plane and the internal color of mesocarp tissue (the edible tissue between the peel and the seed cavity tissue) and length/diameter (L/D) ratio was measured. A 200 g sample of melon flesh was blended for 20 sec and filtered with cheesecloth. The total soluble solids content (TSS) of

melon juice was determined by a portable Palette refractometer model PR101 (Atago Co., Japan). Moisture determination was performed on mesocarp tissue cut into cores and each core placed in a 50 ml beaker and inserted into a hot-air oven at 100°C for 24 hr. Changes in weight were measured.

Volatile Collection

The volatile collection procedure was adapted from Buttery et al. (1982). Each melon was sliced, seeds were removed, and the flesh was cut by a corer. A Tenax trapping system was used to collect volatile compounds by placing 550g mesocarp cores into the collection bottle. Airflow was generated by a lab vacuum line at a rate of 1000ml/min. Air was purified by passing it through an activated charcoal trap. Volatile compounds were collected on a trap using Tenax-TA (60/80 mesh, Scientific Instrument Services, Inc.) as the adsorbent for 20 min. The Tenax trap was prepared by packing about 50 mg of the adsorbent in Pyrex glass tube (3.5 mm inside diameter, 5 cm long). Desalted glass wool was used to contain the adsorbent on both end sides of the trap. Volatile compounds collected were desorbed from Tenax by rinsing with n-hexane (J. T. Baker, Phillipsburg, NJ), collecting 0.5 ml extract, adding 2.8µL of 3.75µL/ml phenyl acetate (Aldrich Chemical Co.) solution in n-hexane (J. T. Baker, Phillipsburg, NJ) as internal standard, concentrating the extract into 25µL and injecting 1µL into the GC.

Analysis of Collected Volatile Compounds

GC analysis was performed using HP 5890 series II gas chromatograph (Hewlett Packard, Avendale, PA) with a split-splitless injection port temperature of 225°C and flame ionization detector (FID) temperature of 250°C. The column used was DB-5 (Alltech Associates, Deerfield, IL). The oven temperature increased from 35°C to 70°C at a rate of 1.5°C/min followed by an increase to 235°C at a rate of 15°C/min.

Sensory Evaluation:

The ethylene-treated honeydew melons were stored at the room temperature for 24 h before sensory evaluation. The non-ethylene-treated honeydew melons were stored at room temperature for 48 h before sensory evaluation. The honeydew melons were evaluated using a modified Spectrum® method for descriptive analysis (Meilgaard, et al., 1991). The 150 mm unstructured line scales were used to determine the intensity of each attributes based on the reference standards. Eight judges in the age range of 22-51 were chosen in the evaluation. None of the panelists had any negative reaction towards honeydew melons. Both the training session and evaluations were conducted at the Food Processing Research and Development Laboratory in the Department of Food Science and Technology at the University of Georgia, Athens. The panelists were calibrated using reference standards established for Spectrum® analysis (Meilgaards, et al., 1991).

Intensity rating based on 150-mm unstructured line scales anchored with the descriptors weak = 12.5 and strong = 137.5.

Panelists used unsalted crackers and water to clean their palates between each samples. Panelists rated the honeydew melons for all the flavor descriptors listed in Table 3b based on the ratings of reference standards. For sample preparation, ca. 500gram of each honeydew melon was used, the rest of the honeydew melons were used for instrumental analysis. The honeydew melon chunks (ca. 2.5 cm x 3 cm x 4 cm) were placed in 3-oz. plastic soufflé cups, which were immediately capped. The samples were prepared 1 hr before evaluations and were coded with 3 digits random numbers.

Statistical Analysis

All data were analyzed using SAS statistical package v. 8.1 (SAS Institute Inc., Cary, NC)

RESULTS AND DISCUSSION

The physicochemical characteristics of melons are shown in Table 4.1. Ethylene-treatment of melons resulted in dramatic increases in the volatile concentration for treatment sets 2 and 3, but showed had no effect for set 1. The level of total volatile concentration in set1 is similar to the control melons in set2 and 3, suggesting that the application of exogenous ethylene in set1 failed to initiate the generation of volatile.

Table 4.1: Physiochemical characteristics of melons. (Comparisons are between control and ethylene treatment. Values within a set for specific measurement followed by the same letter are not significantly different $p \leq 0.05$)

	Total Volatiles		Mass		TSS		Moisture	
	control	ethylene	control	ethylene	control	ethylene	control	ethylene
Set1	0.043a	0.060a	2.17a	2.23a	10.2a	9.1b	90.4a	91.3a
Set2	0.060a	0.465b	1.88a	1.76a	7.6 a	11.1b	92.0a	89.3a
Set3	0.084a	0.640b	2.15a	2.21a	10.5b	11.4b	89.4a	89.3a

External Color

Treatment with ethylene led to increased yellowness in the melons. Ethylene treatment resulted in a lower hue angle and higher chroma, attributed to an increase in b*(Figure 4.1). No significant changes were observed in L* or a*. These results suggest a synthesis of yellow pigments triggered by ethylene treatment. The increase in chroma (brightness) due to ethylene treatment was observed only on the second day after treatment in sets 2 and 3 but not set1 (Table 4.2).

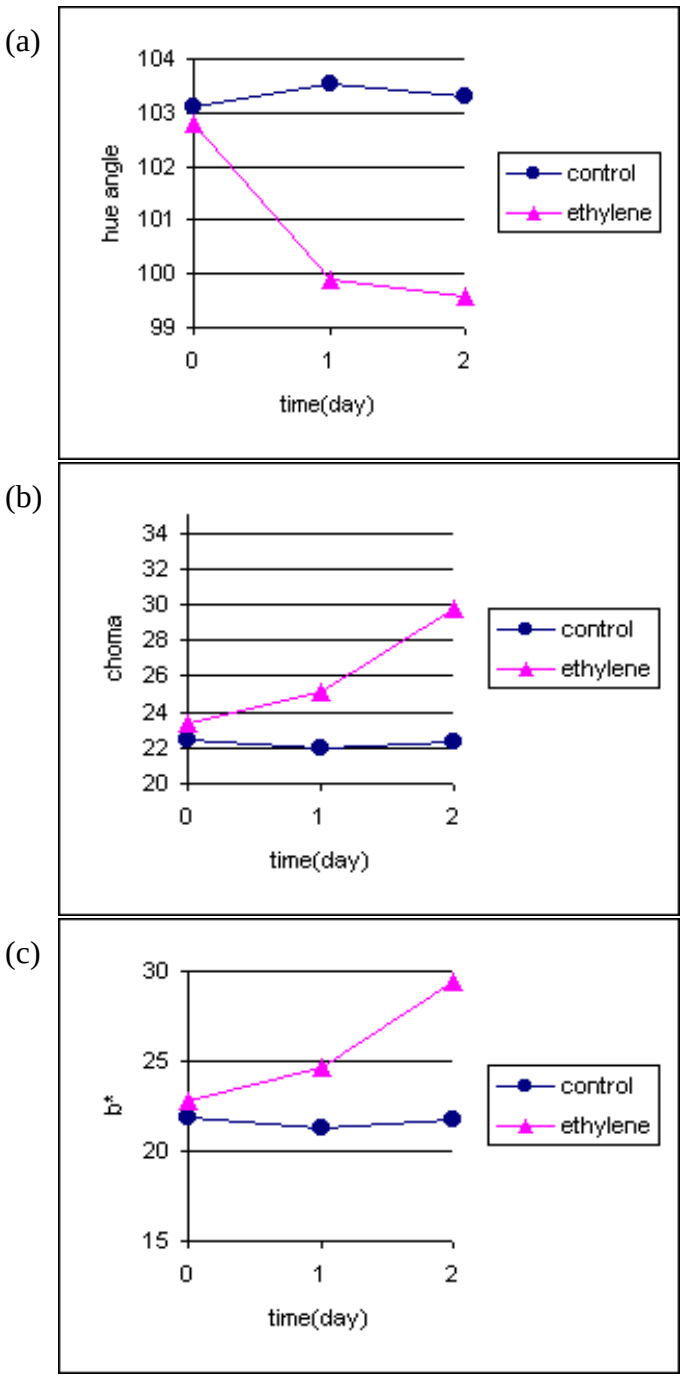


Figure 4.1. External color of honeydew melons. (a) Hue angle, (b) Chroma and (c) b*.

Table 4.2. The external color (Chroma) changes of the melons. (Comparisons are between control and ethylene treatment. Values within a set for specific measurement followed by the same letter are not significantly different p≤0.05)

	Day 0		Day 1		Day 2	
	control	ethylene	control	ethylene	control	ethylene
Set1	21.4 a	21.2 a	21.7 a	23.5 a	22.4 a	24.9 a
Set2	20.0 a	21.5 a	19.6 a	23.5 a	19.6 a	29.8 b
Set3	26.2 a	27.3 a	24.5 a	28.2 a	25.0 a	34.7 b

Internal Color

Internal color changes of the honeydew melons are shown in Table 4.3. The only significant differences between the ethylene-treated melons and control melons were observed for a* and b* in set3. The lower a* and higher b* depicted that internal color of ethylene-treated melons is less green than control melon in set3. These results indicate that ethylene treatment accelerates loss of chlorophyll in honeydew flesh.

Table 4.3: Internal color of melons. (Comparisons are between control and ethylene treatment. Values within a set for specific measurement followed by the same letter are not significantly different p≤0.05)

	L*		a*		b*		Hue angle		Chroma	
	control	ethylene	control	ethylene	control	ethylene	control	ethylene	control	ethylene
Set1	58.9 a	63.0 a	-9.7 a	-10.0 a	20.5 a	21.6 a	115.3 a	114.8 a	22.7 a	23.8 a
Set2	66.4 a	59.2 a	-12.0 a	-9.6 a	25.1 a	22.8 a	115.6 a	110.5 a	27.8 a	24.7 a
Set3	57.4 a	59.8 a	-11.7 a	-8.0 b	24.6 a	20.6 b	115.4 a	111.2 a	27.3 a	22.1 a

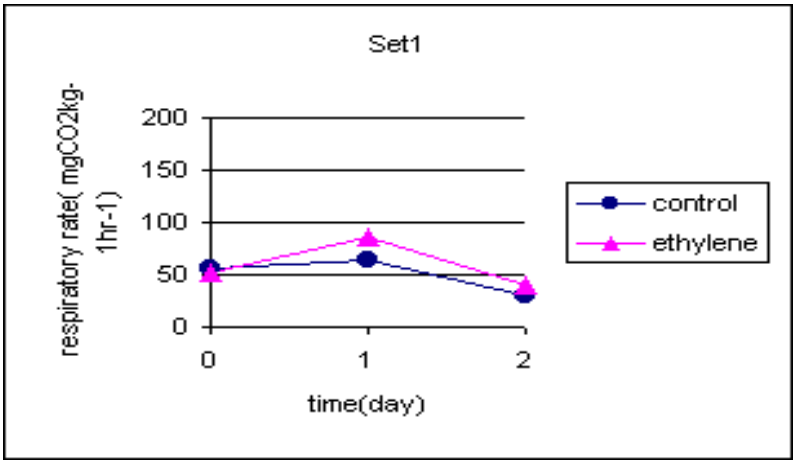
Respiratory Rate and Ethylene Production

The respiratory rates of honeydew melons are shown in Figure 4.2. Ethylene treatment increased respiratory rate and exogenous ethylene concentration rapidly soon after treatment. The respiratory climacteric was induced by ethylene treatment in set2 and 3(Figure 4.2b and c) and the respiratory rate of melons had increased 4-6 fold after ethylene treatment. There is no significant difference in respiratory rate between control melons and ethylene-treated melons in set1. The rise in respiratory rate may reflect an increase in energy requirement during the early (synthetic) stages of ripening (Pratt et al, 1968). The high level of ethylene concentration in day1 is due to the residues of ethylene from ethylene treatment (data not shown).

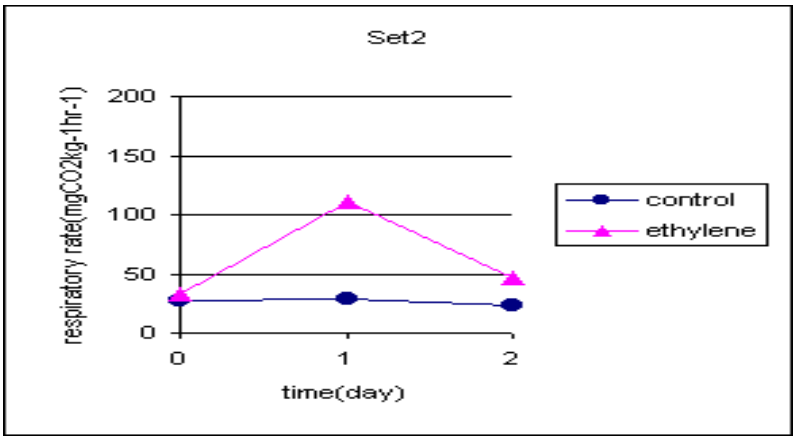
Sensory Evaluation:

The attributes evaluated include sweetness, honey, fruity, crispy and grassy. The definition of each attributes are described in Table 4.4. For the attributes honey and crispy, the intensity of reference standards were determined during the training session and the ratings are shown in Table 4.5. For the attributes of sweet, grassy and fruity, the intensity of reference standards was obtained from previous studies (Meilgaard, et al., 1991, and Abegaz, 2000)

(a)



(b)



(c)

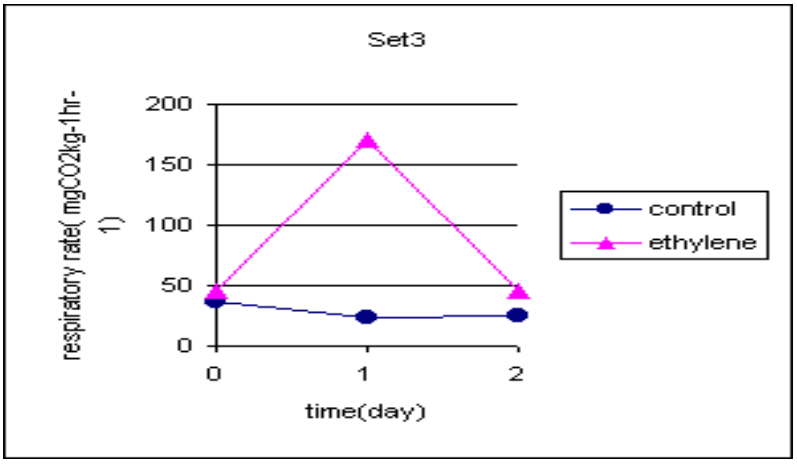


Figure 4.2: The respiratory rate of melons.

Table 4.4: Flavor descriptor used to evaluate the honeydew melon

Descriptor	Definition
Taste	
Sweet	The taste simulated by sucrose or other sugars, such as fructose, glucose, etc. and by other sweet substances such as saccharin and aspartame
Honey	The taste associate with honey
Aromatics	
Fruity	The aromatic with a mixture on non-specific fruits: berries, apples/pears, tropical melons; usually not citrus fruits.
Grassy	The aroma associate with fresh vegetation and green vegetables
Texture	
Crispy	The sound sensation received while tasting.

The intensity of each attribute of melon samples are shown in Table 4.6. No significant differences were observed between the control melons and ethylene-treated melons in grassiness. The ethylene treatment had no effect on any sensory attribute in set 1.Ethylene treatment significantly increased intensity of fruitiness while decreasing crispiness of melons in sets 2 and 3. Ethylene treatment increased perception of honey flavor and sweetness in set 2 but not set3.

Table 4.5: Reference standards and intensity ratings used to evaluate honeydew melon flavor. Intensity rating based on 150-mm unstructured line scales anchored with the descriptors weak = 12.5 and strong = 137.5.

Attribute	Reference Standard	Rating
Taste		
Sweet	2% solution of sucrose in deionized water	20
	5% solution of sucrose in deionized water	50
	10% solution of sucrose in deionized water	100
	16% solution of sucrose in deionized water	150
Honey	5% solution of honey in deionized water	20
	10% solution of honey in deionized water	60
	15% solution of honey in deionized water	100
	20% solution of honey in deionized water	140
Aroma		
Fruity	Libby's Juicy Juice 100% juice	55
Grassy	Green bean (2.5 cm x 1 cm)	70
	Parsley (4 leaves)	110
Texture		
Crispy	Peach (DelMonte Light Sliced Peaches)	30
	Pickle (Mt. Olive Kosher Baby Dills)	90
	Baby carrot (Kroger)	130

Table 4.6: The intensity of sensory attributes in honeydew melons. (Comparisons are between control and ethylene treatment. Values within a set for specific measurement followed by the same letter are not significantly different $p \leq 0.05$)

	Fruitiness		Grassiness		Honey		Sweetness		Crispiness	
	control	ethylene	control	ethylene	control	ethylene	control	ethylene	control	ethylene
Set1	29.5 a	31.5 a	32.4 a	31.7 a	46.8 a	45.1 a	67.7 a	63.6 a	54.8 a	63.7 a
Set2	20.5 a	44.7 b	31.3 a	32.1 a	31.1 a	56.7 b	38.7 a	78.2 b	76.8 a	27.8 b
Set3	32.8 a	50.5 b	38.3 a	30.5 a	35.8 a	50.5 a	47.6 a	74.3 a	65.8 a	28.0 b

Based on the intensity of crispiness, fruitiness, and the volatile concentration we concluded that ethylene treatment had no effect on ripening of set1 melons but did lead to ripening of sets 2 and 3. These results suggest that set 1 melons were harvested too immature stage to permit ripening by ethylene.

Correlation coefficients relating the instrumental analysis to sensory characteristics are shown in Table 4.7. As expected the total soluble solid content significantly and positively correlates with fruitiness, honey and sweetness but negatively correlates with crispiness. The high correlation coefficient between TSS and sweetness supported that the panelists had good performance on judging the sweetness of honeydew melons. For the aromatic sensory attributes, fruity correlated well with the total volatile concentration($R>0.84$). Increases of volatile concentrations of treated fruit supported the

sensory data. There was no significant correlation between grassiness and the instrumental data.

Table 4.7: Correlation of instrumental analysis data with sensory attributes

	Fruitiness	*Grassiness*	*Honey*	*Sweetness*	*Crispiness*
TSS	0.81*	-0.23	0.70**	0.77**	-0.69**
Volatile	0.84*	-0.26	0.55	0.59	-0.80*
Moisture	-0.83*	0.08	-0.72	-0.74**	0.68
Weight	0.25	0.02	0.12	0.37	-0.11
L/D	0.01	0.43	-0.30	-0.32	0.13
External color					
L*	0.24	-0.08	0.05	-0.11	-0.46
a*	-0.02	-0.15	0.13	0.06	-0.13
b*	0.82*	0.02	0.53	0.55	-0.73**
Hue	-0.50	-0.10	-0.32	-0.39	0.34
Internal color					
L*	-0.74**	0.07	-0.70	-0.61	0.84*
a*	0.52	-0.17	0.41	0.56	-0.62
b*	-0.36	0.15	-0.37	-0.56	0.45
Hue	-0.42	-0.04	-0.19	-0.32	0.33

*significant at $p < 0.0001$

** significant at $p < 0.001$

Color of the melons is also an indicator of the melon quality, L* of internal color and the b* of external color significantly correlate with the fruitiness and the crispiness. L* (lightness) of internal color was highly and positively correlated with crispiness ($R>0.90$) in all the melons. L* of internal color were highly and negatively correlated with the intensity of fruitiness, honey ($R<-0.90$) and sweetness ($R<-0.85$) in mature fruit but not immature fruit. From our findings, L* of internal color appears to be an indicator of melon quality. Although we did not use the instrument to measure the texture of the melon, the crispiness of melons have high and negative correlation coefficients with other physiochemical characteristics, such as total soluble solid content, total volatile concentration, b* of external color. For set1 melons, which had failed to benefit from ethylene treatment, external b* was less than 21. We conclude that the melon with b* less that 21 is too immature to respond to ethylene treatment (data not shown).

From our findings, TSS, volatile concentration L* of internal color and the b* of external color can be considered the best indicators of melon quality. The relationship between b* and fruitiness, crispiness are shown in Figure 4.3.

Comparison of immature (set1) with more mature (sets 2 and 3) honeydew melons reveal opportunities for enhanced quality available in the supermarket. Use of external color reading b* as an index of maturity shows promise in sorting out fruit that are too

immature to benefit from postharvest treatment with ethylene, specific guidelines for maturity assessment and levels ethylene need to be determined.

From the comments of our sensory panelists, melons had become overripe with mealy texture after ethylene treatment. This may due to the acceleration of senescence by ethylene treatment. Thus catching the right degree of maturity and apply the suitable amount of ethylene are two important factors for the ethylene treatment. According to our data, the concentration of ethylene treatment we used (1000ppm) might be too high for honeydew melons.

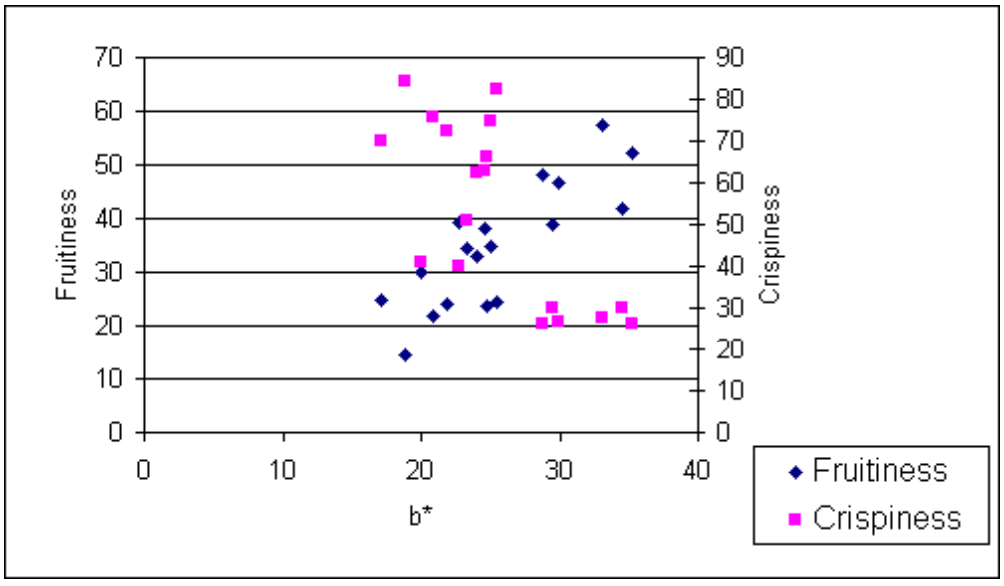


Figure 4.3: Relationship between fruitiness and b*, crispiness and b*.

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CHAPTER 5

SUMMARY AND CONCLUSIONS

Honeydew melon belongs to the *Cucumis melo L. Inodorus* group and has important commercial significance in U.S. This thesis investigated the quality of honeydew melons by measuring the physicochemical characteristics and discussed the effects of ethylene treatment on melon quality.

Thirty-three volatile compounds associated with honeydew aroma were identified by GC-MS. Significant odor active compounds included 2-methyl-methylbutanoate, 2-methyl-ethyl butanoate 3-methylbutyl acetate, (Z) 6-nonenal, and nonanal. Treatment with 1000ppm ethylene for 24 hr could induce the respiratory climacteric, accelerate the volatile compounds production and lead to a loss of green color. Once the melon reaches the self-ripening stage, the endogenous ethylene is enough to trigger the ripening process further treatment with ethylene will not improve melon quality.

Linear regression models relating total soluble solid contents (TSS) and volatile compounds were developed for honeydew melons at a wide range of harvest maturity. TSS was negatively correlated with total volatile concentration, moisture content, external and internal hue angle of the honeydew melons. Moisture content and lightness of the mesocarp tissue correlate most significantly with the TSS. ($p \leq 0.0001$).Six volatile compounds, 2-methyl methylbutanoate, ethyl butanoate, 2-methylethyl butanoate, pentyl acetate, benzyl acetate, and (Z) 6-nonen-ol were screened by stepwise regression from 33 volatile compounds are most closely related to sugar development as an indicator of maturation of honeydew melons ($R^2=0.43$).

Sensory characterization of honeydew melons demonstrated that ethylene treatment increased the intensity of fruitiness and decreased crispiness. Instrumental results supported the sensory data with total soluble solid content significantly and

positively correlated with fruitiness, honey and sweetness as expected. The volatile concentrations of ethylene-treated melons were higher than the controlled melons. The melons with low maturity did not respond to the ethylene treatment. Use of external color reading b* as an index of maturity showed promise in sorting out fruit that were too immature to benefit from postharvest treatment with ethylene.

The results suggest that ethylene treatment can improve the quality of honeydew melons but only within a small range maturity. If the melon is too immature, it won't respond to the ethylene treatment. On the contrary, if the melon has already reached the self-ripening stage, it could not benefit from the application of exogenous ethylene and it might accelerate the fruit senescence. This narrow range may not be sufficient to be useful in commercial operations, particularly without a clear index of melon maturity at harvest. In addition, a lower level of ethylene treatment than 1000ppm should be used to enhance melon quality as delivered to the retail outlet.